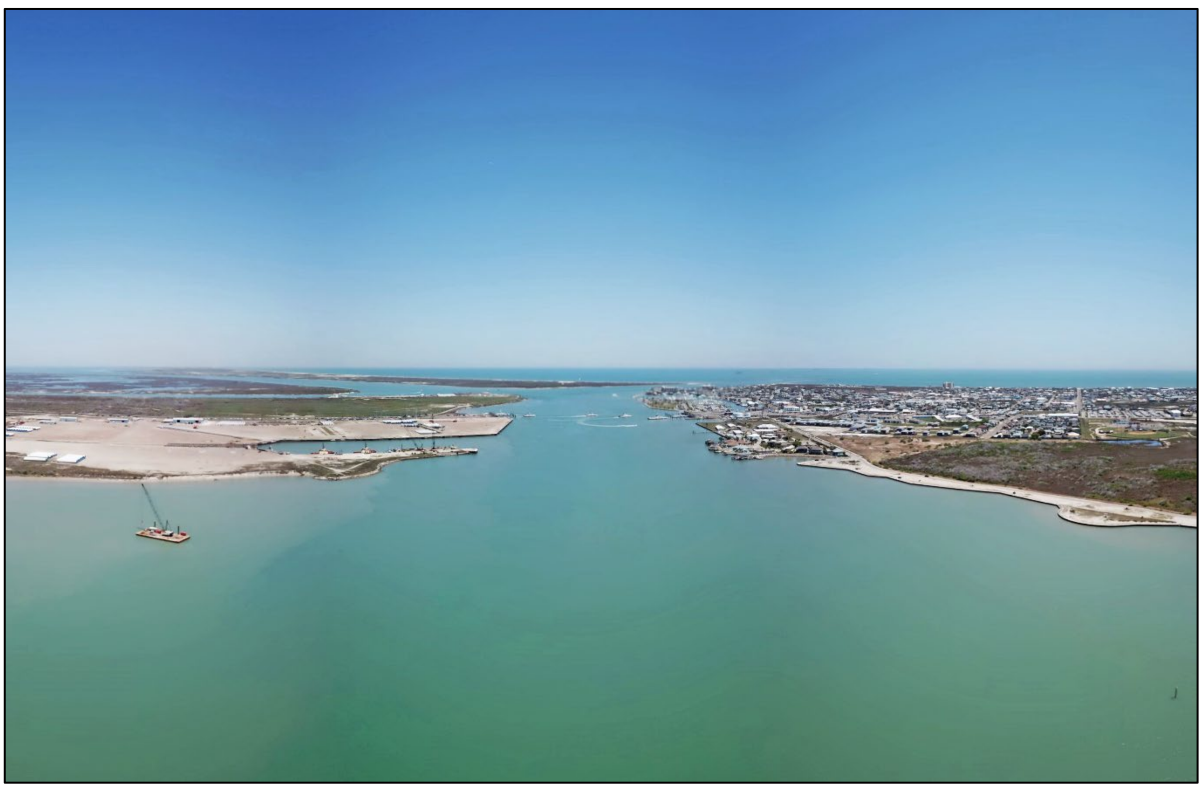
U.S. Army Corps of Engineers

Galveston District
Southwestern Division

Draft

Environmental Impact Statement for the Proposed Corpus Christi Ship Channel Deepening Project

Volume III – Appendices D-P



June 2022

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Appendix D

Endangered Species Act Biological Assessment

Note: The Section 508 amendment of the Rehabilitation Act of 1973 requires that the information in Federal documents be accessible to individuals with disabilities. The USACE has made every effort to ensure that the information in this appendix is accessible. However, this appendix is not fully compliant with Section 508, and readers with disabilities are encouraged to contact Mr. Jayson Hudson at the USACE at (409) 766-3108 or at SWG201900067@usace.army.mil if they would like access to the information.

Job No. PCA20166

APPENDIX D

DRAFT
BIOLOGICAL ASSESSMENT
FOR THE
PROPOSED CORPUS CHRISTI SHIP CHANNEL DEEPENING PROJECT

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U.S. Army Corps of Engineers

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Acronyms and Abbreviations

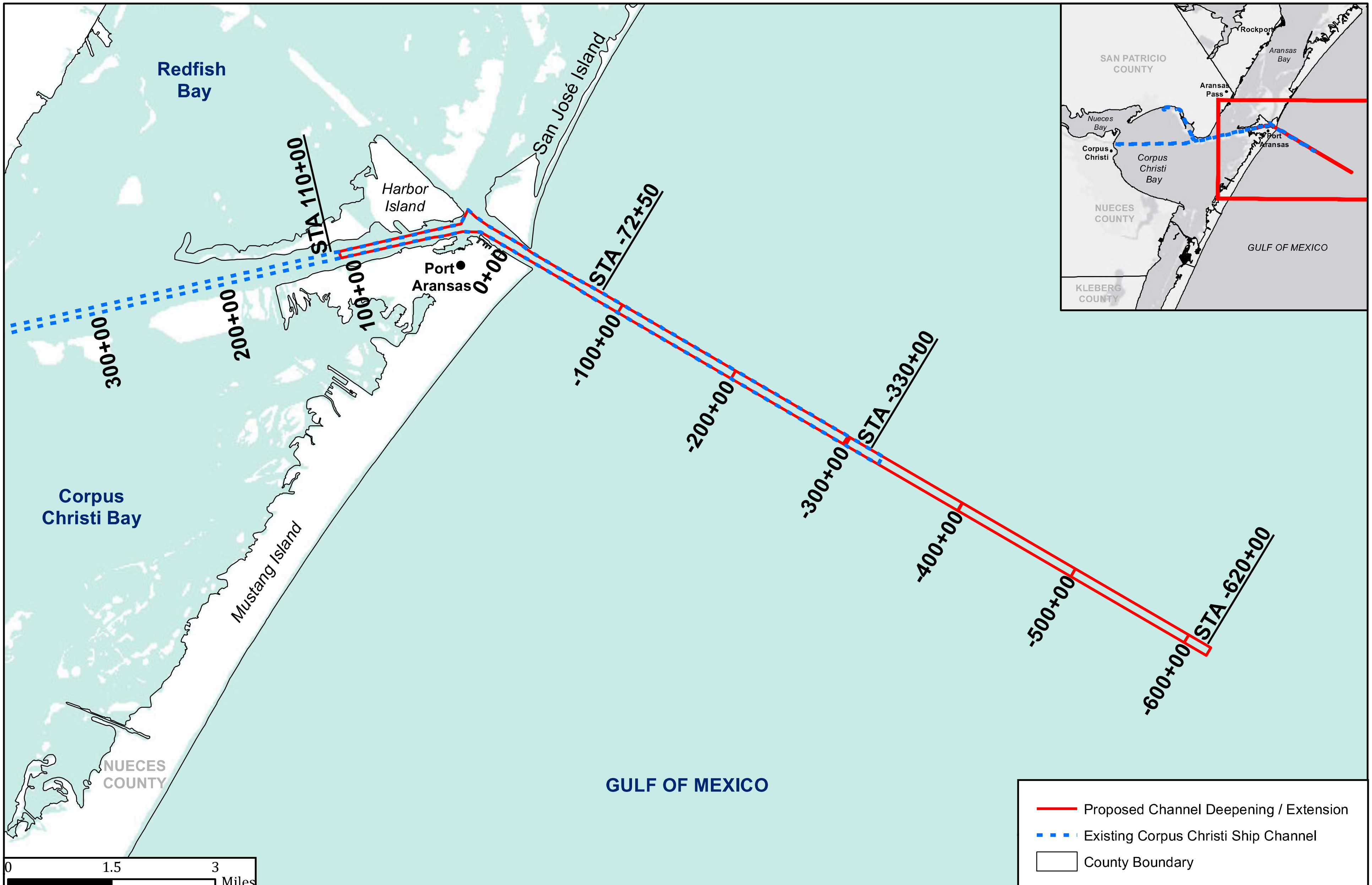
°F	Degrees Fahrenheit
BA	Biological Assessment
CCSC	Corpus Christi Ship Channel
CDP	Channel Deepening Project
CEA	Cumulative Effect Analysis
CFR	Code of Federal Regulations
CWS	Canadian Wildlife Service
EIS	Environmental Impact Statement
ESA	Endangered Species Act
FR	Federal Register
Gulf	Gulf of Mexico
MLLW	Mean Lower Low Water
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
NWR	National Wildlife Refuge
PCCA	Port of Corpus Christi Authority
STSSN	Sea Turtle Stranding and Salvage Network
TPWD	Texas Parks and Wildlife Department
USACE	U.S. Army Corp of Engineers
USFWS	U.S. Fish and Wildlife Service
VLCC	Very Large Crude Carrier

1.0 INTRODUCTION

1.1 PURPOSE OF THE BIOLOGICAL ASSESSMENT

This biological assessment (BA) was prepared to fulfill the U.S. Army Corp of Engineers (USACE), Galveston District requirements as outlined under Section 7(c) of the Endangered Species Act of 1973, as amended, for activities related to the proposed channel improvements to the Corpus Christi Ship Channel (CCSC). The proposed Port of Corpus Christi Authority (PCCA) Channel Deepening Project (CDP) is located in Port Aransas, Nueces County, Texas within the existing channel bottom of the CCSC near the southeast side of Harbor Island, and traversing easterly through Aransas Pass and extending an additional 5.5 miles beyond the existing terminus of the channel (Figure 1). The proposed Federal action consists of a channel deepening alternative. This BA evaluates the potential impacts the CDP may have on Federally listed threatened and endangered species listed by the National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USFWS).

The NMFS and USFWS Information for Planning and Consultation websites were referenced to determine species protected under the Endangered Species Act (ESA) with the potential to occur within the counties of the study area that should be included in this BA. The NMFS website identified six species: Blue Whale (*Balaenoptera musculus*), Fin Whale (*Balaenoptera physalus*), Humpback Whale (*Megaptera novaeangliae*), Sei Whale (*Balaenoptera borealis*), Sperm Whale (*Physeter macrocephalus*), and Giant Manta Ray (*Manta birostris*). The five species of whales receive additional protection under the Marine Mammal Protection Act of 1972 (National Oceanic and Atmospheric Administration [NOAA], 2019). The USFWS website identified the following 17 species as endangered or threatened: Ocelot (*Leopardus pardalis*), West Indian Manatee (*Trichechus manatus*), Northern Aplomado Falcon (*Falco femoralis septentrionalis*), Piping Plover (*Charadrius melodus*), Rufa Red Knot (*Calidris canutus rufa*), Whooping Crane (*Grus americana*), Eastern Black Rail (*Laterallus jamaicensis jamaicensis*), Attwater's Greater Prairie Chicken (*Tympanuchus cupido attwateri*), Green Sea Turtle (*Chelonia mydas*), Hawksbill Sea Turtle (*Eretmochelys imbricata*), Kemp's Ridley Sea Turtle (*Lepidochelys kempii*), Leatherback Sea Turtle (*Dermochelys coriacea*), Loggerhead Sea Turtle (*Caretta caretta*), Slender Rush-pea (*Hoffmannseggia tenella*), South Texas Ambrosia (*Ambrosia cheiranthifolia*), and Black Lace Cactus (*Echinocereus reichenbachii var. albertii*). There are two mussel species with proposed federal listing as endangered and one insect as a candidate, the False Spike (*Fusconaia mitchelli*) and Guadalupe Orb (*Cyclonaias necki*) are proposed endangered. The Monarch Butterfly (*Danaus plexippus*) is a candidate species for listing. Federally designated Critical Habitat for Piping Plover is also addressed. Table 1 presents a list of threatened and endangered species addressed in this BA (USFWS, 2022a).



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Port of Corpus Christi Authority
Corpus Christi Ship Channel Deepening Project

Project Location Map

FIGURE 1

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Table 1
Federally Listed Endangered and Threatened Species within Nueces, San Patricio, Refugio, and Aransas Counties[1]

Common Name	Scientific Name[2]	Status[3]	
		USFWS	NMFS
MAMMALS			
Ocelot	*Leopardus pardalis*	E	N/A
Blue Whale	*Balaenoptera musculus*	N/A	E
Fin Whale	*Balaenoptera physalus*	N/A	E
Humpback Whale	*Megaptera novaeangliae*	N/A	E
Sei Whale	*Balaenoptera borealis*	N/A	E
Sperm Whale	*Physeter macrocephalus*	N/A	E
West Indian Manatee	*Trichechus manatus*	T	N/A
FISH			
Giant Manta Ray	*Manta birostris*	N/A	T
BIRDS			
Northern Aplomado Falcon	*Falco femoralis septentrionalis*	E	N/A
Piping Plover	*Charadrius melodus*	T w/CH	N/A
Red Knot (Rufa)	*Calidris canutus rufa*	T w/proposed CH	N/A
Whooping Crane	*Grus americana*	E w/CH	N/A
Eastern Black Rail	*Laterallus jamaicensis jamaicensis*	T	N/A
Attwater's Greater Prairie Chicken	*Tympanuchus cupido attwateri*	E	N/A
REPTILES			
Green Sea Turtle	*Chelonia mydas*	T	T
Hawksbill Sea Turtle	*Eretmochelys imbricata*	E	E
Kemp's Ridley Sea Turtle	*Lepidochelys kempii*	E	E
Leatherback Sea Turtle	*Dermochelys coriacea*	E	E
Loggerhead Sea Turtle	*Caretta caretta*	T	T
CLAMS			
False Spike	*Fusconaia mitchelli*	PE	N/A
Guadalupe Orb	*Cyclonaias necki*	PE	N/A
INSECT			
Monarch Butterfly	*Danaus plexippus*	C	N/A
PLANTS			
Slender Rush-pea	*Hoffmannseggia tenella*	E	N/A
South Texas Ambrosia	*Ambrosia cheiranthifolia*	E	N/A
Black Lace Cactus	*Echinocereus reichenbachii var. albertii*	E	N/A

[1] According to the USFWS (2022a) and NOAA (2022a).
[2] Nomenclature follows American Ornithological Society (2020), USFWS (2022a), and NOAA (2022a).
[3] E – Endangered; T – Threatened; PE– Potentially Threatened; C– Candidate; w/CH – with designated Critical Habitat.

The American Peregrine Falcon (*Falco peregrinus anatum*), Arctic Peregrine Falcon (*Falco peregrinus tundrius*), Brown Pelican (*Pelecanus occidentalis*), Interior Least Tern (*Sterna antillarum*), and Bald Eagle (*Haliaeetus leucocephalus*) have been removed from the ESA but continue to receive protection under the Migratory Bird Treaty Act and Bald and Golden Eagle Protection Act and therefore, not referenced in this BA.

This BA also describes the avoidance, minimization, and conservation measures proposed for this project relative to habitat and species referenced in the BA. The BA is offered to assist the NMFS and USFWS in fulfilling their obligations under the ESA. An Environmental Impact Statement (EIS) has also been prepared to further address the potential effects resulting from the proposed CDP.

For the BA, the study area encompasses a larger area for which environmental effects of the proposed CDP have been analyzed (Figure 2). The study area includes Nueces, San Patricio, Refugio, and Aransas counties. The project area provides spatial boundaries for evaluation of species that may be more-directly impacted by the construction and operation of the proposed project in Nueces and Aransas counties. Therefore, the project area is a smaller area, more immediate to the proposed project features (Figure 3).

1.2 PROJECT AREA HABITAT DESCRIPTION

The project area is located within the Tamaulipan biotic provinces (Blair, 1950). The project area is in the Western Gulf Coastal Plains region and includes Mid-Coast Barrier Islands and Coastal Marshes. The project area habitat includes barrier islands, coastal dunes, coastal grasslands, tidal flats, estuaries, fresh to saline marshes, bays, and open water habitats (Griffith et al., 2007).

The project area is located within the Corpus Christi Bay, a 96,000-acre bay on the Texas central coast. The average depth is 11 feet (Texas Parks and Wildlife Department [TPWD], 2021a). The Corpus Christi Bay estuary habitat types include uplands, wetlands, open-bay water, open-bay bottom, sea grass meadows, and intertidal mud flats. Existing habitat within the proposed project footprint includes developed and urbanized land, armored and natural shorelines, beaches, tidal flats, open water, brackish to saltwater wetlands, submerged aquatic vegetation, oyster reefs, uplands, sand dunes, coastal prairie and mud flats (USFWS, 2017a).

1.3 ALTERNATIVES CONSIDERED

1.3.1 No-Action Alternative

The No-Action Alternative provides a means to evaluate the environmental impacts that would occur if the proposed CDP were not constructed. The characterization of the No-Action Alternative provides a baseline for comparison of performance and impacts of the Proposed Action Alternative. Under the No-Action Alternative, the CCSC would not be deepened and would remain at –54 Mean Lower Low Water (MLLW). The CCSC will continue to be maintained and dredged to the approved depth. Very Large

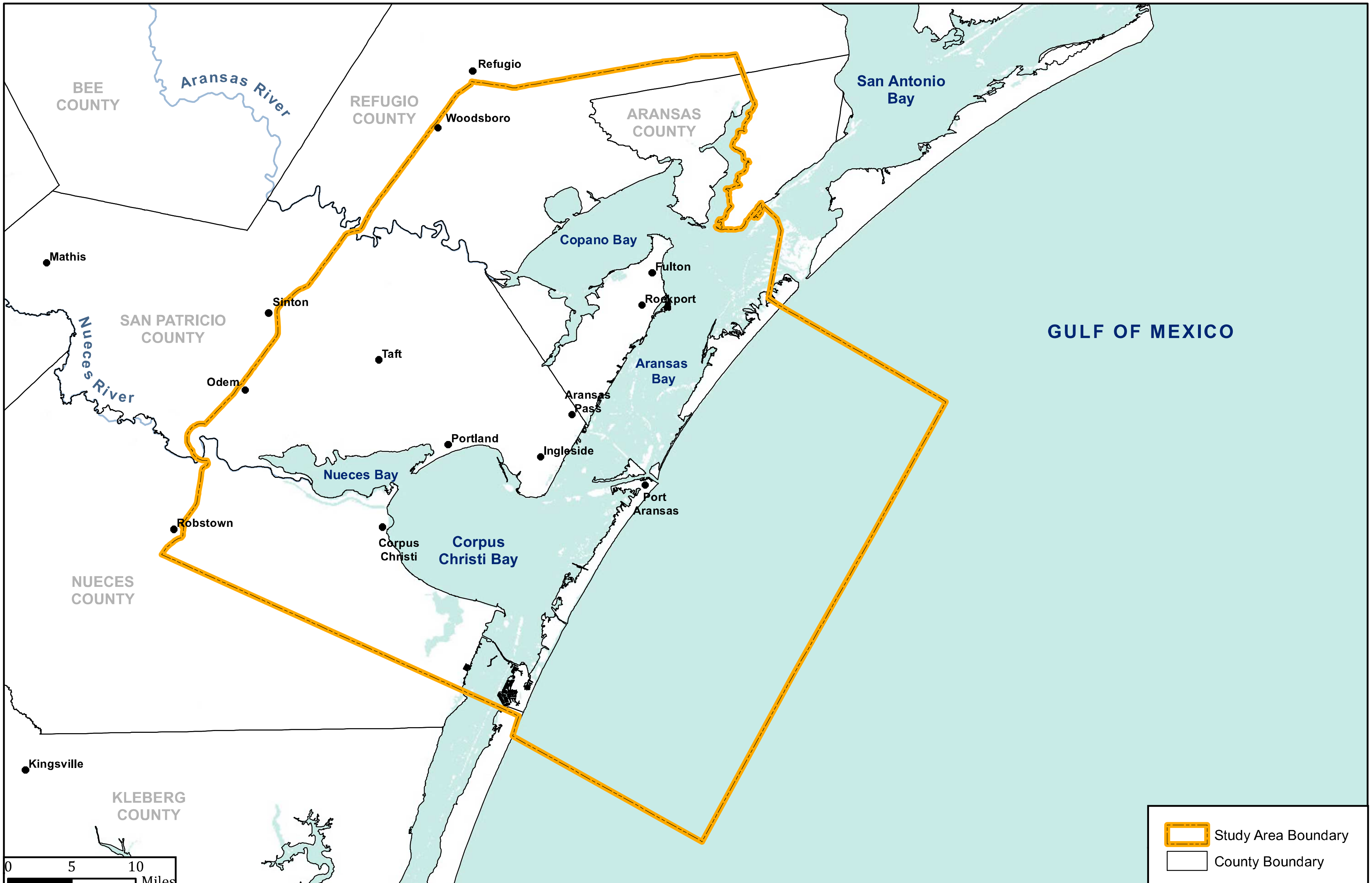

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FIGURE 2

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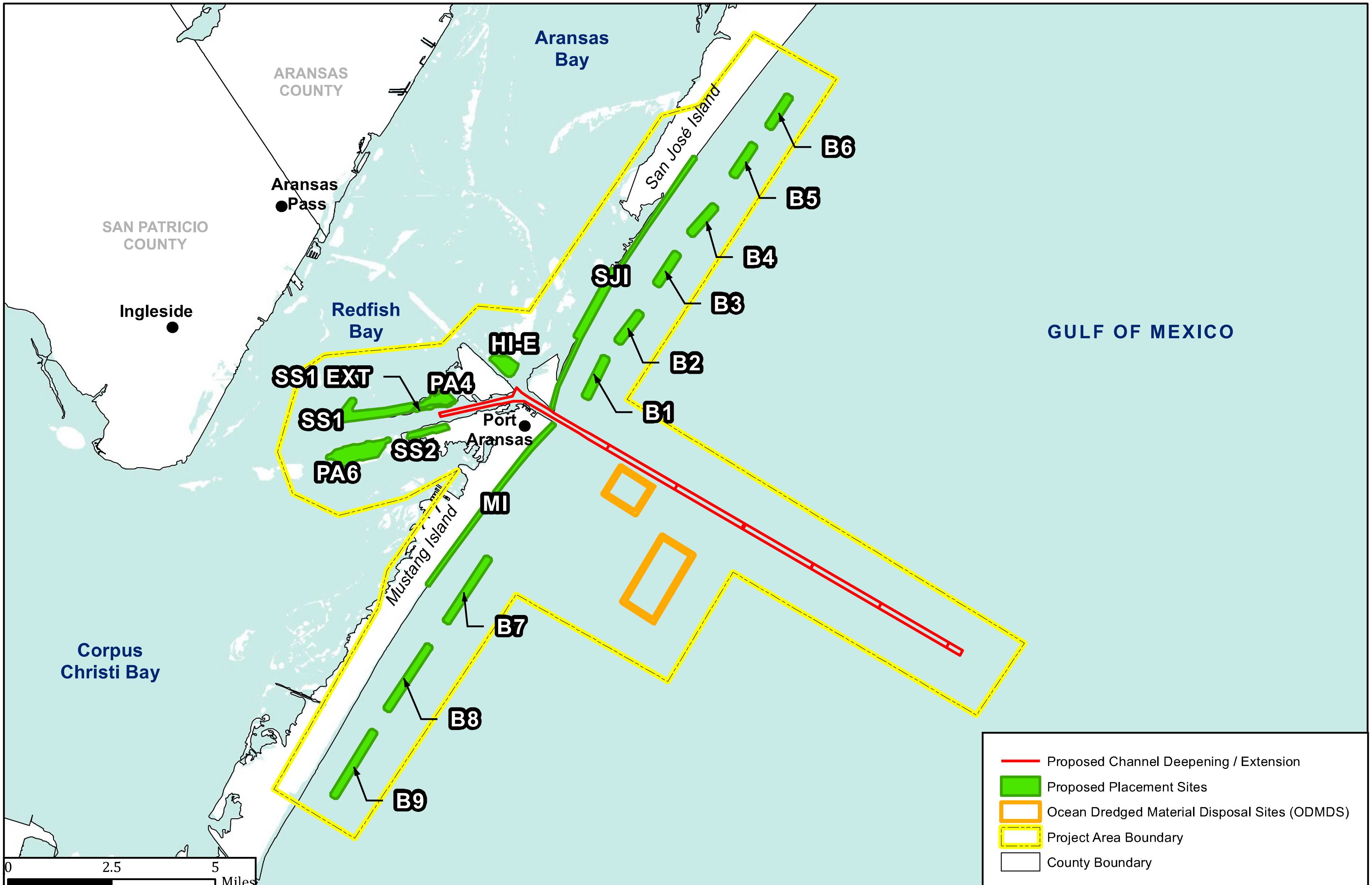

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Port of Corpus Christi Authority
Corpus Christi Ship Channel Deepening Project

Project Area Boundary

FIGURE 3

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Crude Carriers (VLCCs) would continue to be partially loaded and reverse-lightered offshore. The No-Action Alternative does not meet the project purpose and need but is carried forward for detailed analysis in this EIS for comparison purposes.

1.3.2 Alternative 1: Proposed Action Alternative – Channel Deepening

Alternative 1 consists of deepening the CCSC to –75 MLLW from the Gulf of Mexico (Gulf) to station 110+00 near Harbor Island, including the approximate 10-mile extension to the Entrance Channel necessary to reach sufficiently deep waters. Deepening would take place largely within the footprint of the currently authorized –54-foot MLLW channel. Dredging approximately 46.3 million cubic yards would be required with inshore and offshore placement of the material. Under this alternative, only berths at Harbor Island would be capable of fully loading VLCCs. Partially loaded VLCCs at Ingleside could top off at Harbor Island thereby reducing or eliminating reverse lightering. All dredged material would be placed in inshore and offshore actions targeting BU.

1.3.3 Alternative 2: Offshore Single Point Mooring

Under Alternative 2, the CCSC would not be deepened to a –75 MLLW and would remain at –54 MLLW. To meet the project purpose, multiple deep-water port facilities (Single Point Moorings) capable of sustaining all projected oil exportation would be constructed. VLCCs would be fully loaded offshore eliminating the need to traverse the channel and reverse-lighter. This alternative would also eliminate dredging of the channel and the impacts associated with dredged material placement.

1.3.4 Alternative 3: Inshore/Offshore Combination

Under Alternative 3, the CCSC would not be deepened to a –75 MLLW and would remain at –54 MLLW. To meet the project purpose, VLCC vessels would be partially loaded at inshore facilities in Ingleside and Harbor Island then traverse the channel to the offshore facility to be fully loaded. This alternative would eliminate the need to reverse-lighter and would also eliminate dredging of the channel and the impacts associated with dredge material placement.

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2.0 STATUS OF THE LISTED SPECIES

Species identified by USFWS (2022a) and NMFS (NOAA, 2022a) for this BA are listed in Table 1. The following section present the natural history of each species relevant to its potential occurrence in the counties of the study area. Section 3.0 presents the potential of the proposed actions to affect these species.

2.1 OCELOT

The Ocelot is a small, spotted, feline found within a wide range of habitat from South America to isolated populations in Arizona and south Texas. The Ocelot was Federally listed as endangered by the USFWS in July 1982 (47 *FR* 31670–31672, USFWS, 1982). Ocelots are nocturnal hunters, about twice the size of an average house cat. Threats to the ocelots include habitat loss and fragmentation, loss of genetic diversity, and illegal hunting. Ocelots are nocturnal predators, and their diet consists of small mammals, reptiles, birds, and rodents (USFWS, 2016).

2.1.1 Habitat

Ocelots inhabit a wide range of habitat from thorn scrub woodlands, coastal grasslands in Texas, and tropical forests, rainforests, and cloud forests in its range in South America. Ocelots in Texas require dense vegetation (greater than 75 percent canopy cover) with 95 percent shrub cover. Typical vegetation includes brasil, honey mesquite, granjeno (*Celtis pallida*), and elbowbush (*Forestiera angustifolia*) (USFWS, 2016).

2.1.2 Range and Distribution

Ocelot range extends from southern Texas and southern Arizona through Central America, Ecuador, and Argentina. There are historical records of ocelots in Florida and California. In Texas, recent live trapping and camera surveys found populations of ocelots on the Yturria Ranch and East El Sauz Ranch in Willacy County, the Laguna Atascosa National Wildlife Refuge in Cameron County, and in Jim Wells, Kleberg, and Kenedy counties. In the U.S., they are primarily found in Cameron County, Texas. There are an estimated 19 individual ocelots within the Laguna Atascosa National Wildlife Refuge and 38 total individuals within Cameron County. The USFWS has not designated any Critical Habitat for the Ocelot. Habitat fragmentation and lack of range connectivity is a large concern for populations of ocelots. Many dispersing ocelots are victims of vehicle collisions (USFWS, 2016).

2.1.3 Presence Within the Study Area

Ocelots and their associated habitat are not found within the study area counties (TPWD, 2022). It is highly unlikely that Ocelots occur within the study area.

2.2 BLUE WHALE

The Blue Whale is the largest whale species in the world and can weigh over 330,000 pounds. Blue Whales have long, slender bodies with variable mottling pattern. They are found worldwide and migrate thousands of miles between foraging areas where they feed primarily on krill (NOAA, 2021b).

2.2.1 Habitat

Blue Whales are found in all oceans except for the Arctic Ocean. They primarily occur in waters where krill is concentrated (NOAA, 2021a).

2.2.2 Range and Distribution

Blue Whales migrate seasonally between their summer feeding ground in the polar waters to winter breeding grounds in the equatorial waters. In the North Atlantic, their range extends from the subtropics to Greenland. They occur infrequently in the Gulf and Caribbean Ocean (NOAA, 2021a).

2.2.3 Presence Within the Study Area

There are only two documented records of Blue Whales in the Gulf. The only documented Texas record was an individual stranding between Freeport and San Luis Pass in 1940 (Schmidly, 2004). It is unlikely that the species would be found within the study area.

2.3 FIN WHALE

The Federally listed Fin Whale is the second largest whale in the world. Fin Whales are long and sleek with a V-shaped head and hooked dorsal fin. They were historically hunted but more recently face threats from vehicle collision, habitat degradation, and reduced prey abundance of krill, herring (Clupeidae), cod (Gadidae) and other schooling fishes from overfishing (Schmidly, 2004; NOAA, 2021b).

2.3.1 Habitat

Fin Whales are found in deep offshore waters, away from the coast, in all major oceans (NOAA, 2021b).

2.3.2 Range and Distribution

Fin Whales occur within a wide range of latitude. Most migrate from the feeding areas around the poles during the summer to the warmer waters of the tropics for breeding and calving (NOAA, 2021b).

2.3.3 Presence Within the Study Area

Fin Whales can be found year-round in the Gulf although there has only been one recorded observation near Texas in 1951 (Schmidly, 2004). It is unlikely that the species would be found within the study area.

2.4 HUMPBACK WHALE

The Humpback Whale has one of the longest migration routes of any whale species, travelling as much as 3,000 miles in the span of 36 days. Humpback Whales are primarily black with white markings on their fins, tail, and underbellies. Since the ban on commercial whaling the population of humpbacks have been steadily increasing. They face threats from ship strikes and entanglement in fishing gear (NOAA, 2021c).

2.4.1 Habitat

Humpback Whales are found in all the major oceans. They can be found in deep oceans and close to shore (NOAA, 2021c).

2.4.2 Range and Distribution

Humpback Whales are typically found in high latitude feeding grounds during the warmer months and migrate to tropical waters in the winter. The North Atlantic population of Humpback Whales are found from the Gulf of Maine to Norway during the summers. Humpbacks migrate to the West Indies and Cape Verde in the winter (NOAA, 2021c).

2.4.3 Presence Within the Study Area

The only documented observation of a Humpback Whale in Texas waters was in 1992 near the Bolivar Jetty in Galveston. The species is rare in the Gulf (Schmidly, 2004). This species is unlikely to occur in the study area.

2.5 SEI WHALE

This migratory species can commonly be found in higher latitudes during the summer and equatorial waters in the winter and fall. Individuals are long, sleek with dark blue-gray coloration and mottling. Sei Whales also have a hooked dorsal fin and grooves that extend from their mouth to their bellies. They currently face threats from ship collisions, entanglement with fishing gear, and habitat degradation (NOAA, 2021d).

2.5.1 Habitat

Sei Whales inhabit deeper waters away from the coastline (NOAA, 2021d).

2.5.2 Range and Distribution

Sei Whales are distributed in subtropical, tropical, and subpolar waters of the Atlantic, Indian, and Pacific Ocean. Their migration pattern and breeding grounds are not known (NOAA, 2021d).

2.5.3 Presence Within the Study Area

Sei Whales can be found in the Gulf and Caribbean Sea but no records exist for Texas (Schmidly, 2004). It is unlikely for Sei Whales to occur within the study area.

2.6 SPERM WHALE

Sperm Whales are the largest tooth whales in the world. Sperm Whales are mostly dark gray with a large head and single blowhole. They are proficient divers and often spend most of their time in deep waters feeding. The average dive can last for 35 minutes and can reach depths of over 1,312 feet. Sperm Whales currently face threats from vessel strikes, entanglement on fishing gear, ocean noise, marine debris, and oil spills (NOAA, 2021e).

2.6.1 Habitat

Sperm Whales inhabit deep ocean waters where they dive and feed on squid, sharks, and fish (NOAA, 2021e).

2.6.2 Range and Distribution

Sperm Whales are the most common species of whale in the Gulf. Sightings and stranding have been known to occur along the Texas Gulf (NOAA, 2021e).

2.6.3 Presence Within the Study Area

Although Sperm Whales are known to occur in the Gulf, they typically inhabit deep offshore waters (Schmidly, 2004). The species is common with in the Gulf but would be rare within the study area.

2.7 WEST INDIAN MANATEE

The West Indian Manatee was Federally listed as endangered in 1967 (USFWS, 1967), the manatee was reclassified as a threatened in May 2017 (82 *FR* 16668, USFWS, 2017b). Adult manatees are typically 9.8 feet long and can weigh around 2,200 pounds. They have two front flippers and a wide tail. Human threats to the manatee include collisions with boats and ships, entrapment in gillnets and floodgates, poaching, and ingesting marine debris. Natural mortality of manatees is caused by cold stress and outbreaks of red tide caused by algal blooms (USFWS, 2001).

2.7.1 Habitat

West Indian Manatee are found in bays, estuaries, lakes, rivers, and shallow coastal waters. They are intolerant of prolonged exposure to waters cooler than 68 degrees Fahrenheit (°F). During the winter, they seek out and congregate in warmer waters at spring-fed rivers and power plant outfalls. They tend to avoid areas with strong currents. Manatees are herbivores and feed on a variety of submerged, floating, and emergent vegetation (USFWS, 2001). Critical Habitat is designated in Florida, but none have been designated in Texas (USFWS, 2022b).

2.7.2 Range and Distribution

The United States is believed to have the largest population of manatees. Most of the United States population of manatees reside in Florida. During the warm summer months, manatees have been known to migrate towards Rhode Island or Texas. Historically, manatees have been found in the Laguna Madre area. Outside of the United States, West Indian Manatees occur in the Greater Antilles, Trinidad, on the east coast of Mexico and Central America, and along the northern coast of South America (USFWS, 2001).

2.7.3 Presence Within the Study Area

Manatees have historically been an uncommon visitor along the Texas Gulf coast. Although extremely rare, recent records of manatees in Texas exists for Cow Bayou, Copano Bay, Bolivar Peninsula, near Sabine Lake, and at the mouth of the Rio Grande (Schmidly, 2004). Manatee sightings were observed near Rockport as recently as 2004, West Galveston Bay in 2012, and Trinity Bay in 2014 (TPWD, 2004; Rice, 2012; Hooper, 2014). Within the Corpus Christi area, manatees were observed near Shoreline Boulevard in the Corpus Christi Bay in 2009, 2014, and 2019 (Ren, 2019; Dawson, 2019). In 2021, manatees were observed in Laguna Madre and South Padre Island (Aguirre, 2021; Von Preysing, 2021). The USFWS has not designated Critical Habitat for the West Indian Manatee along the Texas coastline (USFWS, 2022b). The occurrence of West Indian Manatees in the study area is possible, but not likely.

2.8 GIANT MANTA RAY

Giant Manta Rays are Federally listed threatened species and are known as the world's largest species of rays. Manta Rays have a large diamond shaped body with black backs, mostly white bellies, elongated pectoral fins and two long lobes which extends from their mouth. Adult Manta Rays can have a wingspan of 29 feet and weigh up to 5,300 pounds. The main threat to Giant Manta Rays is commercial fishing, bycatch, and habitat loss (NOAA, 2021f).

2.8.1 Habitat

Giant Manta Rays are filter feeders and can often be found foraging in shallow coastal waters or open oceans where they feed on zooplankton within the water column. Manta Rays can dive to depths of 3,280 feet (NOAA, 2021f). Nearshore, Manta Rays have been observed along sandy bottom areas, reefs, and seagrass beds (USFWS, 2020a).

2.8.2 Range and Distribution

Giant Manta Rays are migratory and found worldwide in tropical, subtropical, and temperate waters and commonly found offshore and inshore near coastlines. Within U.S. waters, Giant Manta Rays can be found as far north as Long Island, New York, the Gulf, and the Caribbean Islands (NOAA, 2021f). The Flower

Garden Banks National Marine Sanctuary, located approximately 100 miles from the Texas coastline, is habitat and nursery for juvenile Manta Rays (Stewart et al., 2018).

2.8.3 Presence Within the Study Area

Manta Rays are common within the Gulf and around the Corpus Christi area. The Flower Garden Banks National Marine Sanctuary is located approximately 190 miles from the study area. Barring a catastrophic incident, the proposed project would not have any effect on the marine sanctuary or the Manta Ray nursery habitat.

2.9 NORTHERN APLOMADO FALCON

The Northern Aplomado Falcon was Federally listed as endangered in 1986 (51 *FR* 6686, USFWS, 1986). The Northern Aplomado Falcon subspecies is generally larger with a darker cummerbund than other Aplomado Falcons (USFWS, 1990). The number of Aplomado Falcons began to decline through the 1900s. The cause of the Northern Aplomado Falcon decline has been linked to the use of pesticides such as the earlier use of DDT (dichloro-diphenyl-trichloroethane) causing thinning egg shells, habitat loss, the effects of climate change on prey populations, and the increased presence of Great-horned Owls (*Bubo virginianus*), which predate on the falcons (USFWS, 2014a).

2.9.1 Habitat

Habitat for the Northern Aplomado Falcon is typically coastal prairie and desert grasslands. In Texas, the falcons can be found in open honey mesquite, oak (*Quercus* sp.), acacia (*Acacia* sp.) and yucca (*Yucca* sp.) woodlands, grassland savannahs, and coastal prairie dunes. The falcons hunt in pairs over grasslands with low cover and an abundance of small mammals and insects. The Northern Aplomado Falcon pairs prefer nesting on stick platforms abandoned by other raptors and corvids. Breeding pairs have also been known to nest on the ground, and on powerlines, trees, and yucca (USFWS, 2014a). No Critical Habitat has been designated for the Northern Aplomado Falcon (USFWS, 2022b).

2.9.2 Range and Distribution

Historically, the Northern Aplomado Falcon was found from Trans-Pecos and south Texas, southern New Mexico, and southeastern Arizona. In Mexico, the Aplomado Falcons can be found along the Atlantic region of Mexico from northern Veracruz to the Yucatan Peninsula (USFWS, 2014a). Since their listing, there have been reintroduction efforts of Northern Aplomado Falcon in west Texas, the King Ranch in Kleberg County, Matagorda Island, and Laguna Atascosa National Wildlife Refuge (NWR) (TPWD, 2021b). There are established nesting populations in Brownsville and on Matagorda Island in Texas (USFWS, 2014a).

2.9.3 Presence Within the Study Area

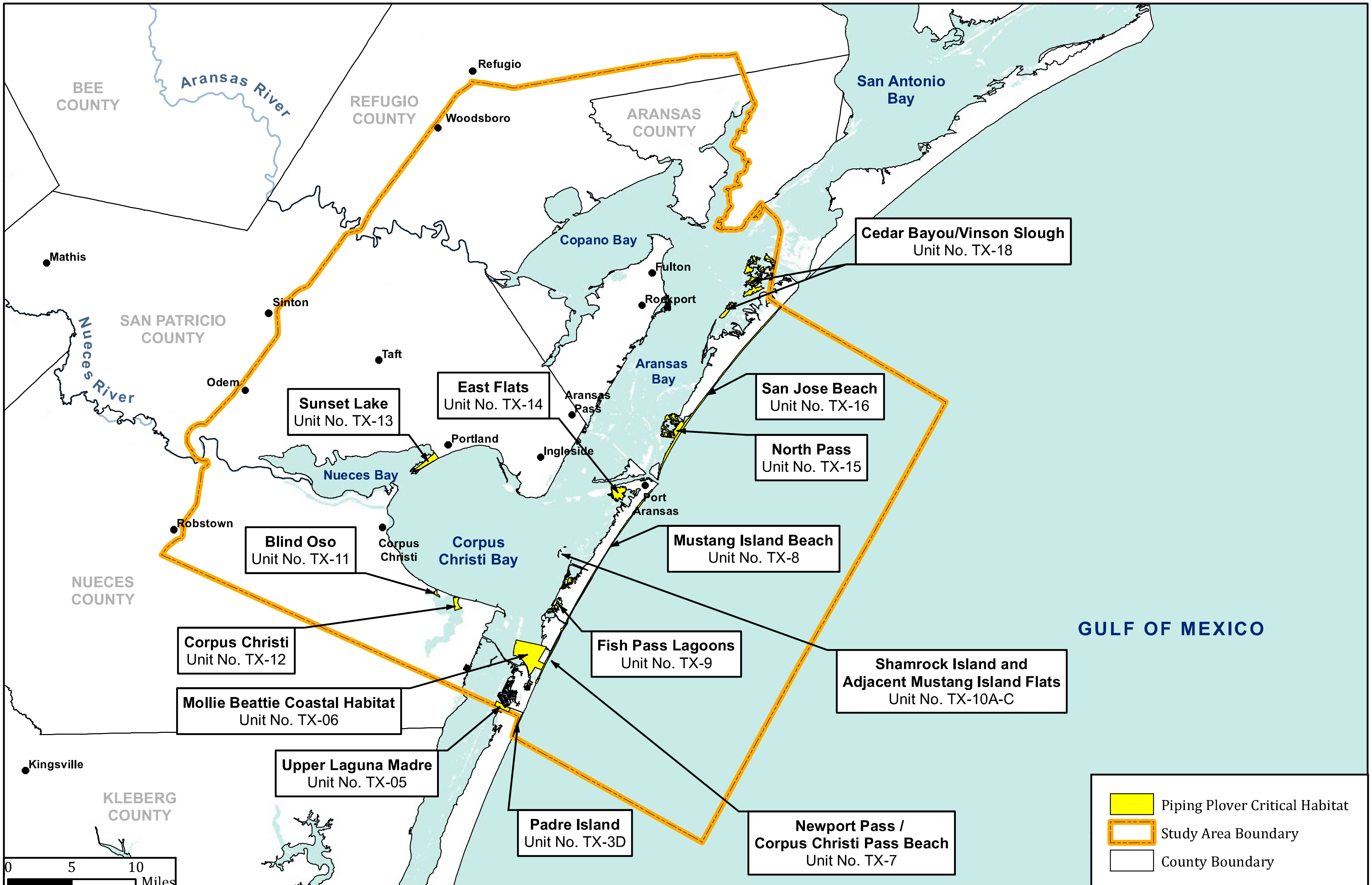
The Northern Aplomado Falcon have been observed within the study area (eBird, 2022a). It is likely populations of Aplomado Falcons occur throughout the study area including Mustang Island, Port Aransas, and San Jose Island. Since the falcons are known to nest on San José Island and hunt along upland areas along coastal barrier islands and coast, it is likely that the dredging or material placement activities along the shoreline will affect the falcons (eBird, 2022a; pers. comm., M.K. Skoruppa [USFWS], 2022).

2.10 PIPING PLOVER

Piping Plovers are small, white to gray-colored shorebirds with a thin, solid black neck band. The Atlantic Coast/Northern Great Plains population was Federally listed as threatened in 1985 (50 *FR* 50726–50734, USFWS, 1985b). Piping Plovers that winter in Texas and Louisiana are from both the Northern Great Plains and Great Lakes populations. Approximately 35 percent of the global population of Piping Plovers winter along the Texas Gulf coast (USFWS, 2003). Piping Plover populations are threatened due to habitat loss and degradation from commercial, residential, and recreational development on the coast. In addition, they are also impacted by wetland drainage, damming and channelization of rivers, and egg depredation by predators (USFWS, 1996).

2.10.1 Habitat

From September to March, Piping Plovers are typically found along the Gulf coast shoreline using beaches, sandflats, tidal mudflats, dunes, and dredge islands as loafing and foraging areas (Haig and Elliott-Smith, 2004). Along their summer range in the Great Lakes, populations were found utilizing sparsely vegetated beaches, sandy substrates, unvegetated dunes, and inter-dune wetlands. The Northern Great Plains Piping Plover population prefer gravelly substrates, alkali lakes, rivers, and reservoirs (USFWS, 2009a). Although all populations winter along the Gulf coast, their summer ranges include the Great Lakes, Northern Great Plains, and Atlantic Coast (USFWS, 1996). There are fourteen USFWS-designated Critical Habitats for Piping Plover within the study area (Figure 4). Piping Plover Critical Habitat within the study area include TX-3D: Padre Island, TX-5: Upper Laguna Madre, TX-6: Mollie Beattie Coastal Habitat, TX-7: Newport Pass/Corpus Christi Pass Beach, TX-8: Mustang Island Beach, TX-9: Fish Pass Lagoons, TX-10A-C: Shamrock Island and Adjacent Mustang Island Flats, TX-11: Blind Oso, TX-12: Corpus Christi, TX-13: Sunset Lake, TX-14: East Flats, TX-15: North Pass, TX-16: San José Beach, and TX-18: Cedar Bayou/Vinson Slough (USFWS, 2022b). However, not all designated Critical Habitat listed would be directly affected by project construction or beneficial use.



PROJECT NO. PCA20166	Port of Corpus Christi Authority Corpus Christi Ship Channel Deepening Project
DATE CREATED Date: 9/7/2021	
DATUM & COORDINATE SYSTEM NAD83 State Plane (feet) Texas South Central	**Piping Plover Critical Habitat**
FILE NAME Name: Fig_4_Piping Plover	
PREPARED BY KLC	

N W E S

FIGURE 4

Date Saved: 9/7/2021 12:09:33 PM Path: H:\ENVIRONMENTAL\Final_Exhibits\BA Figures\Fig_4_Piping Plover.mxd

2.10.2 Range and Distribution

Piping Plovers breed on the northern Great Plains (Iowa, Minnesota, Montana, Nebraska, North and South Dakota, Alberta, Manitoba, and Saskatchewan), the Great Lakes (Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania, Wisconsin, and Ontario), and the Atlantic Coast from Newfoundland to Virginia. Wintering grounds are found along the Southern Atlantic and Gulf Coast from North Carolina to Mexico (USFWS, 1986b).

2.10.3 Presence Within the Study Area

There are wintering populations of Piping Plovers that occur within the designated Critical Habitats and study area (eBird, 2022b). Construction activities related to the project could temporarily disturb Piping Plovers during construction. Placement of dredge material could potentially disturb the shorebird along their foraging and roosting habitat. However, beneficial use of dredged material will eventually benefit Piping Plovers by increasing wintering habitat and stabilizing the shoreline.

2.11 RUFA RED KNOT

Red Knots of the *rufa* subspecies (*Calidris canutus rufa*) are medium-sized sandpiper known for their red plumage, bold eye stripe, and long migration route from the arctic to the southern tip of South America, a migratory route of approximately 18,500 miles. The Rufa Red Knot was Federally listed as a threatened species in 2014 (79 *FR* 73705–73748, USFWS, 2014b). Threats to the Rufa Red Knot include habitat loss in wintering and breeding areas, reduction of food sources such as Horseshoe Crab eggs, and climate change (USFWS, 2013a).

2.11.1 Habitat

Along the Texas coast, Rufa Red Knots use coastal marine and estuarine habitats such as large exposed intertidal flats on the bay sides of barrier islands, beaches, and oyster reefs (NatureServe, 2021). Red Knots forage for bivalves, gastropods, and crustaceans on beaches, oyster reefs, exposed bay bottoms (Baker et al., 2013). In the evening, they roost on high sand flats and reefs protected from high winds and tides (NatureServe, 2021). Their nesting grounds in northern Canada are in dry, slightly elevated tundra locations. Nests are scraped patches on low vegetation containing lichen, moss, and leaves (USFWS, 2013a). The USFWS does not have any designated Critical Habitat for the Rufa Red Knot. However, USFWS is considering Critical Habitat designation of coastal habitats along the Atlantic and Gulf. Along the Gulf, this includes Gulf beaches, back bays, flats, and intermittently exposed seagrasses in Texas (USFWS, 2021a).

2.11.2 Range and Distribution

Worldwide, there are six distinct subspecies of Red Knot, each with various morphological differences and distinct migration routes. The migratory route for the Rufa Red Knot ranges from its breeding grounds in northern Canada to Tierra del Fuego on the tip of South America. Rufa Red Knots are found in Texas during the wintering period, arriving in late July and staying on the coast until mid-May (USFWS, 2020b). The wintering population in Texas occurs near Bolivar Flats in Galveston County, Mustang Island, and South Padre Island (USFWS, 2007, 2015a). Estimates for the wintering population of Red Knots in Texas are about 2,000 individuals (USFWS, 2013a, 2015a).

Delaware Bay is the largest and most important spring stopover site. It corresponds with the timing of horseshoe crab (*Limulus polyphemus*) spawning which provides an important diet before their migration to breeding ground in the Arctic. The population of Horseshoe Crabs in Delaware are also declining due to harvesting of eggs for bait and adults for biomedical research. With low prey resources and lower body masses, Red Knots could have difficulty completing their migration to the arctic for nesting (USFWS, 2013a).

2.11.3 Presence Within the Study Area

According to eBird (2022c), wintering populations of red knots are regularly observed within the study area. Populations of Rufa Red Knots could be temporarily disturbed by construction activities related to the project. However, beneficial use of dredged material placement areas is expected to improve roosting and foraging habitats near the study area.

2.12 WHOOPING CRANE

Whooping Crane are the tallest birds in North America and are known for their call, size, and white plumage. They were Federally listed as endangered on March 11, 1967 (32 *FR* 4001, USFWS, 1967). Threats to whooping cranes include habitat loss, powerline collision, illegal hunting, and human disturbances (Canadian Wildlife Service [CWS] and USFWS, 2007). Whooping Cranes have responded positively to recovery efforts since their listing. The Aransas-Wood Buffalo population, which migrates between Canada's Wood Buffalo National Park and Aransas NWR, has increased from less than 50 individuals in 1941 to 506 individuals in 2020 (USFWS, 2020c).

2.12.1 Habitat

The wintering habitat in Texas within the Aransas NWR near Rockport and adjacent areas on the Gulf coast are comprised of salt flats, marshes, and grasslands. Typical vegetation of these habitats includes salt grass (*Distichlis spicata*), smooth cordgrass (*Spartina alterniflora*), Gulf cordgrass (*Spartina spartinae*), and sea ox-eye (*Borrichia frutescens*). The refuge also maintains oak savannahs which contains live oak (*Quercus virginiana*), redbay (*Persea borbonia*), and bluestem (*Andropogon* sp.) as habitat. Whooping Crane winter diet consists of Carolina wolfberry (*Lycium carolinianum*), Blue Crab (*Callinectes sapidus*), and clams (*Tagelus plebeius, Ensis minor, Rangia cuneate, Cyrtopleura costada, Phacoides pectinate, Macoma constricta*) (Allen, 1952; Chavez-Ramirez, 1996). During the summer and migration period, they feed primarily on frogs, crayfish, insects, berries, and fish (USFWS, 2012). The USFWS designated Aransas

NWR and adjacent lands including San Antonio Bay, Mesquite Bay, portions of Matagorda Island, and Espiritu Santo Bay as Critical Habitat (43 *FR* 20942, USFWS, 1978a).

2.12.2 Range and Distribution

Historically, the Whooping Crane was once thought to number 10,000 individuals with a historical range extending from central Mexico to the Arctic coast, and from Utah to New Jersey (CWS and USFWS, 2007). More recently, the population rebounded from an all-time low of 15 individuals in 1941 to 442 wild individuals in 2015 (USFWS, 2012, 2017a). There were several migration routes across the United States from the Central Plains to Louisiana, Hudson Bay in Canada to the Atlantic Coast, and a route alongside Sandhill Cranes through west Texas and into Mexico (CWS and USFWS, 2007). Currently there are several populations of Whooping Cranes in Canada and the United States. There are non-migratory populations in Louisiana and Florida and two migratory populations that winters in central Florida and Texas. The migratory Texas population breeds and nests in Wood Buffalo National Park in northern Alberta, Canada during the summer and flies south to Aransas NWR where they spend the winter (USFWS, 2012).

2.12.3 Presence Within the Study Area

According to eBird (2022d) data, Whooping Cranes have been observed within the study area. Populations of Whooping Cranes could be temporarily disturbed by construction related activities near the shoreline. However, beneficial use of dredged material is expected to stabilize shoreline and protect foraging habitat for the cranes.

2.13 EASTERN BLACK RAIL

The Eastern Black Rail are small black birds with white speckling on their back and wings with long dark legs and red eyes. The species was listed by the USFWS in 2020. Black Rails are threatened by habitat loss, invasive species, changes to hydrology, mangrove encroachment, and habitat fragmentation. Due to its small and cryptic nature, little is known about the species (USFWS, 2020d).

2.13.1 Habitat

Black Rails occupy salt, brackish, and freshwater marshes. The Gulf coast subspecies can be found in higher elevation wetland areas with shrubby vegetation and dense cover. Their habitats included high elevation zones dominated by Gulf cordgrass (*Spartina spartinae*), salt meadow cordgrass (*S. patens*), eastern baccharis (*Baccharis halimifolia*), salt grass (*Distichlis spicata*), and sea oxeye *(Borrichia frutescens*) (USFWS, 2020d).

2.13.2 Range and Distribution

Black Rails are partially migratory and are found within the U.S., Caribbean, and South America. Within the United States, they were historically found in inland states such as Colorado, Arkansas, Nebraska, Oklahoma, and Ohio. Black Rails are found year-round in Texas, Florida, South Carolina, and North

Carolina from March to August (USFWS, 2020d). No Critical Habitat was designated for the species (USFWS, 2022b).

2.13.3 Presence Within the Study Area

It is likely that Eastern Black Rails are found within the study area. There are no planned actions that would directly impact coastal marshes where black rails inhabit. Black rails could be temporarily disturbed by construction activities related to the project. However, beneficial use of dredged material is expected to stabilize shorelines and increase marsh habitats.

2.14 ATTWATER'S GREATER PRAIRIE CHICKEN

The Attwater's Greater Prairie Chicken is a subspecies of the Greater Prairie Chicken (*Tympanuchus cupido*). The Attwater's Greater Prairie Chicken was Federally listed as an endangered in 1967 (32 *FR* 4001, USFWS, 1967). The birds are well known for their unique mating display where the males congregate at breeding grounds called leks in the springtime. Their mating behavior includes inflating their air sacs and producing low 'booming' calls to attract females. The main threats to the Attwater's Greater Prairie Chicken are loss of grassland prairie habitat, depredation, invasive fire ants, and poor brood survival (USFWS, 2010a).

2.14.1 Habitat

The Attwater's Greater Prairie Chicken require unfragmented tallgrass prairie habitat maintained by periodic wildfires. Common plant species associated in suitable habitat include little bluestem (*Schizachyrium scoparium*), big bluestem (*Andropogon gerardi*), and switchgrass (*Panicum virgatum*). Optimal habitat contains abundant open spaces and little to no woody cover or artificial structures (USFWS, 2010a). No Critical Habitat has been designated by the USFWS (2022b).

2.14.2 Range and Distribution

Historical accounts of the Attwater's Greater Prairie Chicken suggested a population of more than 1 million individuals on approximately 6 million acres of native coastal prairie from south Texas to Louisiana. Historically found in all counties along the Texas-Louisiana Gulf coast, the prairie chickens were extirpated from Louisiana in 1919. The population of the prairie chickens has steadily decreased from 8,000 individuals in 1937 to approximately 90 individuals in 2009. A small population was introduced to the Texas City Prairie Preserve in 2008, but subsequent reintroduction efforts were discontinued. There are presently only two populations of the Attwater's Greater Prairie Chicken in Texas: Attwaters Prairie Chicken NWR in Colorado County and at release sites in Goliad, Refugio, and Victoria counties (Williams and Harrell, 2009).

2.14.3 Presence Within the Study Area

The prairie chicken current range exist further inland within upland habitats. They are extremely rare outside of their known areas. It is highly unlikely that the Attwater's Prairie Chicken occur within the study area. There is no preferred habitat within the study area.

2.15 GREEN SEA TURTLE

The Green Sea Turtle was Federally listed as threatened in 1978, except for the Florida and the Pacific Coast of Mexico (including the Gulf of California) where it is listed as endangered (43 *FR* 32800–32811, USFWS, 1978b). In 2015, the USFWS identified 11 distinct population segments worldwide (80 *FR* 15272–15337, USFWS, 2015b). The proposed distinct population segments rule would continue to list the North Atlantic Population (which includes Texas) as threatened. Primary threats to worldwide populations of Green Sea Turtle includes harvesting of adults and eggs, capture in fishing gear, and incidental take from dredging activities (NOAA, 2021g).

2.15.1 Habitat

Green Sea Turtle utilize shallow habitats such as lagoons, bays, inlets, coral reefs, shoals, estuaries, and other areas with an abundance of marine algae and sea grasses. Female Green Sea Turtles prefer nesting on high energy beaches with deep sand. Green Sea Turtle nests are common in Texas. National Park Service (NPS) biologists located 28 Green Sea Turtle nests on the Padre Island National Seashore, one on Mustang Island in 2020, and one on South Padre in 2021 (NPS, 2021). Green Sea Turtles are omnivores and consume seagrasses, algae, jellyfish, crustaceans, and mollusks (USFWS, 1991).

2.15.2 Range and Distribution

Green Sea Turtles are found worldwide in tropical and subtropical waters. The North Atlantic population includes species within the U.S. Virgin Islands, Puerto Rico, and the continental United States from Massachusetts to Texas. Many Green Sea Turtles nest on the east coast of Florida while relatively small numbers nest in Georgia, North Carolina, and Texas (USFWS, 1991). The USFWS has not designated any Critical Habitat in Texas (USFWS, 2022b).

2.15.3 Presence Within the Study Area

Green Sea Turtles are common within the Corpus Christi Bay and the study area. Dredging for channel widening and maintenance, overnight lighting, and the increase in turbidity from construction operations could have a negative effect on the species. After the project is complete, vessel traffic is expected to decrease within the CCSC which may result in lower collision rates. Sea turtles may also benefit from having additional beach nesting habitat from beneficial use of dredged materials (beach nourishment), compared to beaches that do not receive nourishment (Gallaher, 2009).

2.16 HAWKSBILL SEA TURTLE

The Hawksbill Sea Turtle was Federally listed as endangered by the USFWS in 1970 (35 *FR* 8491–8498, USFWS, 1970a). The species is named after its distinctive sharp, curved beak and decorative shell. The primary global threat to the species is loss of coral reef habitat and associated communities, recreational use of nesting beaches, capture from fishing nets, and vessel strikes. Because of their unique sunburst carapace, individuals are harvested for their shells as well as for leather, oils, and other goods (NOAA, 2021h).

2.16.1 Habitat

Hawksbill Sea Turtles occupy a variety of different habitat at different life stages. Post-hatchling sea turtles are commonly found in pelagic waters among *Sargassum* rafts in convergence zones. Juvenile and adult hawksbills are more commonly found in coastal waters, estuaries, and mangrove bays where the turtles feed primarily on sponges (USFWS, 1993). The USFWS designated Critical Habitat near Mona Island and Isla Monito in Puerto Rico, no Critical Habitat has been designated in Texas (USFWS, 2022b).

2.16.2 Range and Distribution

Hawksbill Sea Turtles are circum-tropical and found within the Indian, Pacific, and Atlantic oceans. Nesting locations are widely distributed, scattered, low in number, and poorly documented (USFWS, 1998). Along the continental United States, the Hawksbill Sea Turtles can be regularly found in Florida and Texas (USFWS, 1993). Primary nesting areas in the United States are in Puerto Rico, U.S. Virgin Islands, southeast coast of Florida, and the Florida Keys. The first and only Hawksbill Sea Turtle nest in Texas was discovered in 1998 on the Padre Island National Seashore (NPS, 2021).

2.16.3 Presence Within the Study Area

The likelihood of encountering a Hawksbill Sea Turtle within the study area would be uncommon but possible. Dredging for channel widening and maintenance, overnight lighting, and the increase in turbidity from construction operations could have a temporary negative effect on the species. The turtles may benefit from having improved beach nesting habitat from beneficial use of dredged materials (beach nourishment), compared to beaches that do not receive nourishment (Gallaher, 2009). Vessel traffic is expected to decrease after completion of the project which may result in lower vehicle collision with sea turtles.

2.17 KEMP’S RIDLEY SEA TURTLE

The Kemp’s Ridley Sea Turtle was Federally listed as endangered in 1970 (35 *FR* 18319–18322, USFWS, 1970b). They are the smallest known species of sea turtle. Adults are usually 2 feet in length and weigh up to 100 pounds. Threats to the Kemp’s Ridley Sea Turtle include collection of eggs and adults for meat and other products, habitat loss, incidental take from shrimp trawlers and dredge hoppers, ship collision, and use of explosives to clear debris (NOAA, 2021i). Populations of nesting Kemp’s Ridley Sea Turtles in

Texas have steadily increased due to nest protection and the use of Turtle Excluder Devices on fishing trawlers and dredging ships (USFWS, 2011a).

2.17.1 Habitat

Kemp's Ridley Sea Turtles occupy a variety of habitat at different life stages. Post-hatch sea turtles occupy the oceanic zone, foraging around *Sargassum* rafts, and are passive migrants in the Gulf Loop Current. Juvenile and adult sea turtles are more commonly found in shallow coastal and estuarine waters feeding on crabs, bivalves, jellyfish, and other crustaceans (Campbell, 2003; USFWS, 2011a). The USFWS has not designated any Critical Habitat in Texas (USFWS, 2022b).

2.17.2 Range and Distribution

Kemp's Ridley Sea Turtles are found throughout the Gulf and western Atlantic from New England to eastern Mexico. They gather for nesting in large groups called an "arribada." Kemp's Ridley Sea Turtle nest areas are primarily found on the beaches near Tamaulipas, Veracruz, and Campeche, Mexico (Campbell, 2003). In the United States, nesting occurs throughout Texas with the greatest numbers on the Padre Island National Seashore, and occasionally in Florida, Alabama, Georgia, South Carolina, and North Carolina (USFWS, 2011a). In 2021, 198 Kemp's Ridley Sea Turtle nests were recorded in Texas (NPS, 2021).

2.17.3 Presence Within the Study Area

The likelihood of encountering a Kemp's Ridley Sea Turtle within study area is common. Dredging for channel widening and maintenance, overnight lighting, and the increase in turbidity from construction operations could have a temporary negative effect on the species. Vessel traffic is expected to decrease after completion of the project, which may result in lower vehicle collision with sea turtles. The turtles may benefit from having improved beach nesting habitat from beneficial use of dredged materials (beach nourishment), compared to beaches that do not receive nourishment (Gallaher, 2009).

2.18 LEATHERBACK SEA TURTLE

The Leatherback Sea Turtle was Federally listed as an endangered in 1970 (35 *FR* 8491–8498, USFWS, 1970a) by the USFWS and NMFS. They are the largest turtle species in the world, reaching up to 6 feet in length and 650 to 1,200 pounds, and the only sea turtle without a bony shell. Major threats to the species include egg collection, fishing bycatch, and nesting habitat loss (NOAA, 2021j).

2.18.1 Habitat

Leatherback Sea Turtles are pelagic and spend most of their time in open oceans, but forage in coastal waters during nesting season. The turtles feed primarily on jellyfish and tunicates. In the Gulf they commonly feed on cabbagehead (*Stomolophus* sp.) and moon jellyfish (*Aurelia* sp.). Due to their large body mass and insulating fat layer, Leatherback Sea Turtles can be found in colder waters as far north as

Newfoundland and the Pacific northwest and can dive as deep as 4,200 feet (NOAA, 2021j; NPS, 2020a). The USFWS has not designated Critical Habitat for the Leatherback Sea Turtle in Texas (USFWS, 2022b).

2.18.2 Range and Distribution

Leatherbacks have one of the largest migratory distributions of any reptile. They are found in tropical and temperate waters in the Atlantic, Pacific, and Indian oceans. Leatherback Sea Turtles can be found in the Gulf, Puerto Rico, U.S. Virgin Islands, and along the Atlantic coast to Maine. In the United States, leatherbacks nest on Puerto Rico, U.S. Virgin Islands, and southeast Florida (USFWS, 1992). Leatherback nesting in Texas is extremely rare. Leatherback Sea Turtle nests were recorded on Padre Island in the 1930's and 40's. Most recently, a Leatherback Sea Turtle nest was located at Padre Island National Seashore in 2008 (NPS, 2021). No Leatherback Sea Turtle nests have been known to occur anywhere in Texas since then (NPS, 2020a).

2.18.3 Presence Within the Study Area

The likelihood of encountering a Leatherback Sea Turtle within the study area is very rare. Two Leatherback Sea Turtles were stranded in 2020 off the Texas coast and reported in the Sea Turtle Stranding and Salvage Network (STSSN, 2020). There have been documented Leatherback Sea Turtle nests in Texas in 2008 and 2021 (Shaver et al., 2019; pers. comm., Donna Shaver [NPS], 2021). Dredging for channel widening and maintenance, overnight lighting, and the increase in turbidity from construction operations could have a temporary negative effect on sea turtle species. Sea turtles may benefit from having improved beach nesting habitat from beneficial use of dredged materials (beach nourishment), compared to beaches that do not receive nourishment (Gallaher, 2009).

2.19 LOGGERHEAD SEA TURTLE

In 2011, the NMFS and USFWS determined that Loggerhead Sea Turtles were composed of nine distinct population segments. The Northwest Atlantic population segment, which includes Texas, was Federally listed as threatened (76 *FR* 58868–58952, USFWS, 2011b). The Loggerhead Sea Turtle is known for their large head and powerful jaw, which they use to break coral and shellfish. Threats to Loggerhead Sea Turtles include bycatch from shrimp trawling, incidental take from dredging activities, nesting habitat loss, direct harvest, and pollution (NMFS, 2008; NOAA, 2021k).

2.19.1 Habitat

Female Loggerhead Sea Turtles typically nest on high energy, steeply sloped, coarse-grained subtropical beaches in the summer. Post-hatchlings are typically found associated with *Sargassum* rafts in convergence zones within the Gulf and North Atlantic. Juvenile and adult Loggerhead Sea Turtles occupy the neritic zone where they feed primarily on mollusks and benthic crabs (USFWS, 2011b). In 2013, NMFS and USFWS finalized Critical Habitat for the Loggerhead Sea Turtle. The proposed Critical Habitat is located along coastal areas in North Carolina, South Carolina, Georgia, Florida, Alabama, and Mississippi

(USFWS, 2013b). The USFWS has not designated Critical Habitat for loggerheads in Texas (USFWS, 2022b).

2.19.2 Range and Distribution

Loggerhead Sea Turtles are circumglobal and inhabit temperate and tropical waters of the Atlantic, Pacific, and Indian oceans. In the Atlantic, they can be found as far north as Newfoundland and as south as Argentina (NOAA, 2021k). Two Loggerhead nests were discovered along the Padre Island National Seashore in 2020 and two nests were discovered in 2021 (NPS, 2020b, 2021).

2.19.3 Presence Within the Study Area

The likelihood of encountering a Loggerhead Sea Turtle within the study area is uncommon but possible. According to STSSN (2020), 77 Loggerhead Sea Turtles were stranded or incidentally captured in Texas in 2020. Dredging for channel widening and maintenance, overnight lighting, and the increase in turbidity from construction operations could have a temporary negative effect on the species. The turtles may benefit from having improved beach nesting habitat from beneficial use of dredged materials (beach nourishment), compared to beaches that do not receive nourishment (Gallaher, 2009). Vessel traffic is expected to decrease after completion of the project which may result in lower vehicle collisions with sea turtles.

2.20 FALSE SPIKE

The False Spike is a medium-sized freshwater mussel species proposed by the USFWS for listing as an endangered species (86 *FR* 47916-48011). The exterior shell shape is elongate-oval; color is olive, brown to black sometimes with greenish rays (Howells, 2014). Host fish include Blacktail Shiners (*Cyprinella venusta*), Red Shiners (*C. lutrensis*), and other minnow species (86 *FR* 47916-48011).

2.20.1 Habitat

The False Spike occurs in larger creeks and rivers with sand, gravel, or cobble substrates with slow to moderate flows. The species is not found in impoundments or deep waters (Howells, 2014).

2.20.2 Range and Distribution

Currently, the False Spike is known to occur in four populations: the Little River and some tributaries within the Brazos River basin, lower San Saba and Llano Rivers within the Colorado River basin, and lower Guadalupe River (Howells, 2014).

2.20.3 Presence Within the Study Area

False Spikes are found further inland and beyond any construction activities or impacts. The mussel species are intolerant of brackish or saline waters. It is unlikely that the False Spike would be found within the study area.

2.21 GUADALUPE ORB

The Guadalupe Orb is a small-sized freshwater mussel species proposed by the USFWS for listing as endangered (86 *FR* 47916-48011). The species was recently separated from the Texas Pimpleback (*C. petrina*). The exterior shell shape is round or suboval and can reach up to 2.5 inches in length. Shell color is yellow to tan, brown to black sometimes with greenish rays or concentric blotches (Howells, 2014). Guadalupe Orb shell is generally thinner and more compressed than Texas Pimpleback. Host fish include Channel Catfish (*Ictalurus punctatus*), Flathead Catfish (*Pylodictis olivaris*), and Tadpole Madtom (*Noturus gyrinus*) (86 *FR* 47916-48011).

2.21.1 Habitat

Guadalupe Orbs occur in moderate to larger creeks and rivers with mud, sand, or gravel substrates at depths less than 2 meters. The species is not found in impoundments (Howells, 2014).

2.21.2 Range and Distribution

The Guadalupe Orb only occurs within the Guadalupe River basin (Howells, 2014).

2.21.3 Presence Within the Study Area

Guadalupe Orbs are found further inland and beyond any construction activities or impacts. The mussel species are intolerant of brackish or saline waters. It is unlikely that the Guadalupe Orb would be found within the study area.

2.22 MONARCH BUTTERFLY

The Monarch Butterfly is a candidate species for federal listing. USFWS has determined that listing the species was warranted, but a timeline on when listing is undetermined (85 *FR* 81813-81822). Adult Monarch Butterflies are large with bright orange wings with black borders and white spots. During the breeding season, monarch butterflies lay their eggs on milkweed (*Asclepias sp*.) plants. Larval caterpillars feed on the milkweed for a few weeks before pupating into a chrysalis and emerging 6-14 days later as an adult butterfly. Due to their short lifespan, there are multiple generations of Monarch Butterflies within a breeding season and along their 3,000-mile migratory route. Monarch migration begins in early spring from February to March (USFWS, 2019).

2.22.1 Habitat

Due to their long migratory routes, monarch butterflies can be found in a variety of habitats. During their breeding season, Monarchs are typically found in open grass areas and plains. Important nectar sources include *Coreopsis* sp., goldenrods (*Solidago* sp.), Asters (*Carlquistia* sp.), gayfeathers (*Latris* sp.), coneflowers (*Echinacea* sp.), and milkweeds (*Asclepias* sp.). Monarchs also utilize deciduous and evergreen trees to roost overnight. Monarch butterflies migrate to Mexico where they overwinter from

August to November. At their overwintering sites, they may roost on eucalyptus trees (*Eucalyptus globulus*), Monterey pines (*Pinus radiata*), and Monterey cypress (*Cupressus macrocarpa*) or narrow-leaved trees such as willows (*Salix* sp.) and pines (*Pinus* sp.) (USFWS, 2019).

2.22.2 Range and Distribution

Monarch butterflies are found throughout North America and in various locations around the globe. The eastern population (east of the Rocky Mountains) in North America migrates north from central Mexico to the US and Canada. The western population migrates from Baja California to northern California (USFWS, 2021b).

2.22.3 Presence Within the Study Area

The eastern population of monarch butterflies can be found throughout Texas during its migratory season. Individuals have been observed along the coast and within the study area. The project is not expected to impact monarch butterfly habitat. The monarch butterfly host plant, milkweed is not commonly found along the shoreline. It is unlikely that the project will affect populations of monarch butterfly.

2.23 SLENDER RUSH-PEA

The slender rush-pea was Federally listed as endangered in 1985 (50 *FR* 45614–45618, USFWS, 1985c). Slender rush-pea is a small, perennial legume with compound leaves and delicate yellow-orange flowers (TPWD, 2021c). Much of its historical range has been converted to croplands and individuals must compete with non-native grasses such as the Kleberg and King Ranch bluestem (USFWS, 2008). Additional threats to the plant include cattle grazing, herbicide use, habitat loss, and climate change.

2.23.1 Habitat

Slender rush-pea is commonly found in patches of native short- and mid-grass prairie adjacent to permanent or intermittent creeks (USFWS, 2008). There is no Federally designated Critical Habitat for the slender rush-pea.

2.23.2 Range and Distribution

The slender rush-pea is found in two Texas counties, Kleberg and Nueces in coastal prairie habitat. The largest population can be found at the St. James cemetery in Bishop, Texas. There have been no other populations reported outside of the two counties (USFWS, 2008).

2.23.3 Presence Within the Study Area

The slender rush-pea is found in a few well-documented locations within Nueces County, farther inland than any construction related activities. It is unlikely that the project impacts would affect the plant.

2.24 SOUTH TEXAS AMBROSIA

The South Texas ambrosia was Federally listed as endangered in 1994 (59 *FR* 43648–43652, USFWS, 1994). The South Texas ambrosia is a perennial herbaceous plant with gray-green leaves and yellow inflorescence flowers. The primary threat to the south Texas ambrosia is habitat loss, agricultural conversion of prairie, competition with non-native grasses, and urban development (USFWS, 2010b).

2.24.1 Habitat

The South Texas ambrosia is commonly found in lower elevations in well-drained, heavy soils in association with subtropical woodlands with coastal prairies and savannahs. Extant populations are found in sites with native grasses such as Texas grama (*Bouteloua rigidiseta*) and buffalograss (*Buchloe dactyloides*) and maintained with regular mowing and minimal tilling. There is no Federally designated Critical Habitat for the South Texas ambrosia (USFWS, 2010b).

2.24.2 Range and Distribution

Historically, populations of the South Texas ambrosia have been found within Cameron, Jim Wells, Kleberg, and Nueces counties in South Texas, and the state of Tamaulipas in Mexico. More recently, there are six documented sites with the species in fragmented habitats within Kleberg and Nueces counties (USFWS, 2010b).

2.24.3 Presence Within the Study Area

The South Texas ambrosia is presently located inland in Nueces County, away from the coast. Outside of their known sites, the presence of other populations is unknown due to private property restrictions and lack of historical documentation. It is unlikely that South Texas ambrosia is found within the study area.

2.25 BLACK LACE CACTUS

The black lace cactus was Federally listed as endangered in 1979. The black lace cactus is a small columnar-shaped cactus with pink flowers. Individuals can be found with single stem or with multiple branches. The primary threat to the cactus species is habitat loss from brush clearing, collection, and encroachment of non-native grasses (USFWS, 1987)

2.25.1 Habitat

The black lace cactus is found in sandy-loam brush tracts in saline soils (USFWS, 1987). Habitat for the cacti can be found in mesquite brush openings along streams within the coastal plains at low elevation (USFWS, 2009b). The black lace cactus is associated with thorn scrub species such as honey mesquite, huisache (*Acacia farnesiana*) and Texas pricklypear (*Opuntia* sp.). There is no Federally designated critical habitat for the black lace cactus (USFWS, 2022b).

2.25.2 Range and Distribution

The population of black lace cacti are known in only three Texas counties: Jim Wells, Kleberg, and Refugio. All the known populations are found on private lands.

2.25.3 Presence Within the Study Area

The black lace cactus is found in a few well-documented locations within Refugio County, farther inland than any construction related activities. No suitable habitat for the cactus exists within the study area, it is unlikely that the black lace cactus would be affected by the project.

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3.0 DIRECT, INDIRECT, AND CUMULATIVE EFFECTS FROM THE PROPOSED PROJECT

This section details the direct, indirect, and cumulative effects of the Proposed Action Alternative described in Section 1.3. Proposed CDP activity includes dredging and fill placement and maintenance dredging. The effects of the proposed CDP on listed species and their habitat include noise, water quality, and habitat modification. Noise, turbidity, and water quality impacts would be short-term and limited to the duration of dredging and construction activities. Conservation measures would be applied to minimize these effects.

3.1 NOISE

Sound waves can be used by fish, sea turtles, and marine mammals to interpret their surrounding environments, detect predators and prey, orient themselves during migration, attract mates, aggregate, engage in territorial behavior, and for acoustic communication. Excessive underwater noise could lead to communication impairment, disturbance, and potentially increase predation, disease, starvation, and death (Peng et al., 2015). Behavioral changes could cause marine species to alter their movements and foraging patterns. On land, noise from construction activity can potentially disturb birds, mammals, and other wildlife. There are a variety of noise from underwater activities associated with the project including from dredging, pile driving, and general construction. Dredge-related noise are produced from the rotating cutterhead, pumps, generators, ship propulsion, and from the sound of the sediment slurry moving through the pipe. Noise from dredging activities is dependent on the type of dredge used. A cutter suction dredge can produce noise from 168 to 175 decibels. A trailing suction hopper dredge can produce noise ranging from 172 to 190 dB (McQueen et al., 2018). Vibratory or impact hammers used to drive piles into the sediment can produce noise up to 180 to 200 dB (NRC, 2012).

Anthropogenic noise can cause auditory masking and changes in individual and social behaviors. Noise impact is expected to be temporary. Disturbed wildlife would be able to move to adjacent habitats and recolonize the project area once construction is completed. Construction noise can be reduced by utilizing air bubble curtains, temporary noise attenuation piles, filled fabric barriers, or cofferdams (NRC, 2012). Since the deepening of the channel is expected to decrease vessel traffic throughout the ship channel and Corpus Christi Bay, it is expected that the level of ocean noise within the area will decrease after the completion of the channel deepening project. Offshore vessel traffic and noise is expected to remain generally the same.

3.2 ENTRAINMENT IN DREDGING EQUIPMENT

Operation of hopper dredges, suction dragheads, and relocation trawlers are potential sources of mortality and injury to sea turtles and manatees. Impacts may also include avoidance of the project area from dredging activities for beach nourishment material and marsh fill. To reduce the potential for incidental take, the USACE would adhere to the proposed avoidance and minimization measures provided by NMFS (2007). The avoidance, minimalization, and conservation measures that would be implemented include onboard observers, physical screening, sea turtle deflecting dragheads and pumps, Sea Turtle Stranding and Salvage Network notification and relocation trawling (more detail in Section 4.8 below) (NMFS, 2007). Stranded or injured marine mammals should be reported to the Texas Marine Mammal Stranding Network. Any harm to individuals would be reported as take. Should incidental take occur because of the proposed CDP, the USACE and the PCCA has an incidental take allotment.

3.3 TURBIDITY AND RESUSPENDED SEDIMENTS

Dredging, dredge material placement, and construction activity on the water can affect water quality by increasing turbidity within the water column. Generally, the amount of suspended sediments would be highest next to dredging and placement areas. The amount and extent of resuspension is a result of sediment properties, site conditions, obstructions, and operational considerations of the dredging equipment and operator.

Increased turbidity can affect fish, sea turtles, manatees, and shorebirds by interfering with foraging activities, gill tissue or respiratory damage, physical stress, and behavioral changes (Wilber and Clarke, 2001) (see Section 4.2.2 [Aquatic Resources] of the Draft Environmental Impact Statement). The level of impact would be limited to the exposure time and the concentration of suspended sediments. An increase in suspended sediments from dredging may cause sea turtles and marine mammals to alter their movements. Fish, sea turtles, manatees, and other marine mammals are mobile and can relocate to adjacent undisturbed areas (Johnson, 2018). Increases in turbidity would be temporary, lasting only a few days after dredging and placement operations and would not extend far beyond the area of disturbance. Control measures, such as silt curtains, could be used if turbidity levels are excessive. Regular maintenance dredging to maintain the depth of the channel is also expected to cause temporary and localized turbidity.

3.4 DISSOLVED OXYGEN, SALINITY, AND WATER TEMPERATURE

Water quality in the Corpus Christi Bay and along the Texas Gulf coast is highly variable depending on the season, weather, and water depth. Construction activities associated with the project are expected to cause temporary changes to the water quality. Based on hydrodynamic and salinity modeling analysis by W.F. Baird and Associates (2022), minor increases in salinity are anticipated because of Alternative 1 compared to the No-Action. Average salinity levels are anticipated to increase less than 1 parts per thousand in the Corpus, Nueces, Redfish, and Aransas Bays with up to a 3 ppt change at the outlet of Nueces Bay and in the vicinity of the deepened channel. Some localized changes in salinity of less than ±3 ppt in the proposed dredge area and connected navigation channels may occur (W.F. Baird and Associates, 2022). Activities associated with offshore placement and placement actions targeting BU of dredged material are not anticipated to impact salinity levels in the project area. Average salinities in the study area range from 30 to 36 ppt, with dry years having salinity levels above 32 ppt and wet years around 25.5 ppt (Montagna et al., 2021). This salinity increase is not expected to alter fauna. This minor increase in salinity is not expected to impact fauna as most organisms occupying these environments are ubiquitous along the Gulf coast and can tolerate a wide range of salinities (Pattillo et al., 1997). Temporary decreases in dissolved oxygen associated with dredging activity is anticipated to be localized to the project area and last a couple of days.

3.5 CUMULATIVE EFFECTS

A cumulative impacts assessment takes into consideration the impact on the environment, which results from the incremental impact of the proposed action when added to other past, present, and reasonably foreseeable actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a given period of time. Impacts include both direct and indirect effects. Direct effects are caused by an action and occur at the same time and place as the proposed action. Indirect effects are caused by the action, occur later in time, and are farther removed in distance; however, they are still reasonably foreseeable. Ecological effects refer to effects on natural resources and the components (including listed species), structures, and functioning of affected ecosystems, whether direct, indirect, or cumulative.

The Proposed Action Alternative would have several effects on listed species. The proposed action would result in temporary and localized increases in turbidity which can reduce sea turtle and shorebirds feeding efficiency. Dredging can also impact sea turtles and manatees with direct impacts. Associated construction noise and light could also affect listed species. By utilizing biological observers or other best management practices, harm to threatened and endangered species can be avoided or minimized. Other methods such as using turtle deflector, turtle excluder devices, relocation trawling, or limiting the use of hopper dredging from December to March can avoid and minimize impacts. Noise related to construction activities such as dredging and pile driving can interfere with acoustic communication and harm auditory organs in wildlife species such as marine mammals, sea turtles and fish. Noise impact is expected to be temporary and localized. Construction noise can be reduced by utilizing air bubble curtains, temporary noise attenuation piles, filled fabric barriers, or cofferdams (NRC, 2012). Any spills can impact several Federally listed species. If it is uncontained, an oil spill can harm wildlife and aquatic species. If not immediately contained, the spill can spread to nearby shorelines and impact sea turtles, shorebirds, and wildlife. Dredging and placement actions may disturb shorebirds such as Piping Plover and Red Knots. Triton Environmental Solutions (2021, 2022) observed Piping Plovers and Red Knots utilizing PAs and BU sites within the project area. Placement actions would temporarily impact foraging grounds and construction activities may disturb shorebirds via lights, turbidity, and noise. Scheduling dredge and placement actions targeting BU outside of the wintering period of listed shorebirds and nesting period for sea turtles can avoid and minimize these disturbances. Additional beneficial use placement actions could potentially benefit Federally listed species such as Piping Plovers and Red Knots by nourishing or restoring habitats. Designated Piping Plover Critical Habitat can be found throughout the project area on Mustang Island, San José Island, Port Aransas, and along Corpus Christi Bay. Placement actions could potentially increase shoreline habitat within designated Critical Habitat on San José Island and Mustang Island. These beach nourishment actions may also benefit nesting sea turtles. Whooping Crane habitat may benefit from placement actions targeting BU as well.

Past, present, and reasonably foreseeable actions with dredging or construction activities, and resultant ship traffic, can potentially impact listed shorebirds, marine mammals, and sea turtles. Noise and light during construction can also result in impacts these species, although these effects would be minor and temporary. If any of these projects undergo construction in timeframes that overlap with the Proposed Action Alternative, there could be minor, temporary, and localized cumulative effects to listed species. Various infrastructure can convert potential habitats for listed species, and any habitat conversions associated with placement actions may contribute to cumulative impacts of habitat loss. Ecosystem restoration initiatives typically yield beneficial effects on listed species, and in conjunction with the proposed actions, PAs could result in beneficial cumulative effects.

Most actions were identified primarily through a comprehensive review of the USACE regulatory permit database for permits within the four counties within the study area (Nueces, San Patricio, Refugio, and Aransas counties). Individual project documents, such as public notices, draft and final Environmental Assessments and EIS's, Records of Decision, newspaper articles, planning documents, and project websites or fact sheets, were also reviewed for impacts to the resource areas. Some of the projects are undergoing revisions that may alter their eventual environmental impact, but it has relied upon the best available information in existing published documents. Table 2 includes the projects included within the Cumulative Effect Analysis (CEA).

Table 2
Past, Present, and Reasonably Foreseeable Projects

Project ID	Project Name	CEA Project Group*	Action Type
1	Bluewater Texas Terminal/Midway Tank Terminal	1	Deepwater Port/ Storage Terminal/Pipeline
2	Texas Gulf Terminals Inc./Laguna Madre and Gulf of Mexico	1	Deepwater Port/Storage Terminal/Pipeline
3	Ingleside Ethylene LLC/La Quinta Channel	2	Ethylene Pipeline Installation
4	Corpus Christi LNG, LLC/Terminal Project	2	Liquid Natural Gas Terminal
5	Cheniere Liquids Terminal LLC/La Quinta Channel	2	Dredging/Boat Slip/Bank Stabilization/Dock
6	Flint Hills Resources/Corpus Christi Ship Channel	2	Maintenance Dredging
7	Moda Midstream/Corpus Christi Ship Channel	2	Dredging/Boat Slip
8	Corpus Christi Liquefaction, LLC/La Quinta Channel	2	Private Navigation Dredging
9	Port of Corpus Christi/La Quinta Channel	2	Container Terminal
10	Oxy Ingleside Energy Center (Moda)/Corpus Christi Bay	2	Commercial Development
11	Plains All American LP/Corpus Christi Terminal	2	Liquid Petroleum Storage Terminal
12	Gulf Coast Growth Venture	2	Petrochemical Complex
13	Newfield Exploration Company/Gas Pipeline	3	Gas Pipeline/Abandonment

Project ID	Project Name	CEA Project Group*	Action Type
14	Infinity Engineering & Consulting/Trilogy Midstream	3	Direction Drill Pipeline
15	Epic Y-Grade Pipeline LP/Robstown to Ingleside	3	Pipeline
16	Corpus Christi Infrastructure LLC/Nueces Bay)	3	Pipeline
17	Enterprise Products Operating LLC/Dean Expansion	3	Pipeline
18	Harvest Midstream/Kinney Bayou	3	Utility Line
19	Flint Hills Resources, LLC/Corpus Christi Ship Channel	3	Pipeline
20	Kiewit Offshore/La Quinta Channel	4	Dredging/Bulkhead
21	AccuTRANS Inc./Corpus Christi Ship Channel	4	Bulkhead/Dredging
22	Corpus Christi Ship Channel Deepening and Widening Project	4	Dredging
23	Corpus Christi Ship Channel Project	4, 5	Dredging/Breakwaters
24	City of Aransas Pass/Conn Brown Harbor	5	Boat Ramp/Dredging/ Pier/Docking Structures
25	PA Waterfront/Corpus Christi Bay	5	Residential Development/ Marina
26	City of Port Aransas/Corpus Christi Ship Channel	5	Rock Revetment
27	City of Port Aransas/Corpus Christi Ship Channel	5	Marina
28	TxDOT Port Aransas Ferry	6	Transportation Project
29	TxDOT/Harbor Bridge/Corpus Christi Ship Channel	6	Transportation/Bridge
30	De Ayala Properties/Redfish Bay	7	Residential Development
31	Pelican Cove Development, LLC	7	Residential Development/Commercial
32	Seven Seas Water Corporation/Harbor Island	8	Desalination Plant
33	Port of Corpus Christi/Corpus Christi Ship Channel	8	Desalinization Plant
34	City of Corpus Christi/Inner Harbor Desal Project	8	Desalinization Plant
35	Texas Parks and Wildlife Department/Dagger Island	9	Breakwater/Bank Stabilization
36	Texas General Land Office/Texas Coastal Resiliency Masterplan	9	various restoration projects and actions
37	Coastal Bays Bend and Estuaries/Various Restoration Projects	9	various restoration projects and actions
38	Axis Midstream/Midway to Harbor Island	2, 3	Storage Terminal/Pipeline
39	South Texas Gateway Terminal LLC/Redfish Bay	2, 4	Dredging/Industrial Development
40	Subsea 7 (US) LLC/Loadout Facility	2, 4	Facilities and Maintenance Dredging

Project ID	Project Name	CEA Project Group*	Action Type
41	Port of Corpus Christi/Harbor Island Terminal	2, 4	Dock/Turning Basin/Terminal
42	City of Corpus Christi/Packery Channel Dredging	4, 9	Maintenance Dredging/ Beach Nourishment

* 1 = Offshore Oil and Gas Terminals; 2 = Onshore Storage and Fabrication Terminals; 3 = Utility, Gas, and Petroleum Pipelines; 4 = Maintenance and Navigation Dredging; 5 = Bulkheads, Breakwaters, Boat Ramps, and Marinas; 6 = Transportation Projects; 7 = Commercial and Recreational Development; 8 = Desalination Facilities; 9 = Ecosystem Restoration

To organize discussions on the cumulative analysis, projects have been compiled into the nine CEA project groups below:

1. Offshore Oil and Gas Terminals
2. Onshore Storage and Fabrication Terminals
3. Utility, Gas, and Petroleum Pipelines
4. Maintenance and Navigation Dredging
5. Bulkheads, Breakwaters, Boat Ramps, and Marinas
6. Transportation Projects
7. Commercial and Recreational Development
8. Desalination Facilities
9. Ecosystem Restoration

Despite the potential for cumulative effects on listed species, most effects from projects are assumed to occur primarily during construction or during routine maintenance activities, and those impacts are typically localized, temporary, and minor. Construction impacts of other projects could contribute to cumulative impacts if actions occur concurrently. If these projects are temporally staggered or spatially distant from one another, cumulative impacts to federally listed species can be lessened. Some projects are also assumed to have permanent impacts associated with their physical footprint, such as noise, air emissions, or induced traffic and growth. Examples of these would include offshore and oil and gas terminals, pipelines, marinas, and fabrication terminals. Technologies or BMPs such as horizonal directional drilling, secondary containment, and chemical spill prevention plans can avoid or minimize these impacts. The cumulative effects of extreme drought conditions, deepened channel and desalinization facilities within the bay can contribute to hydrosalinity gradient impacts.

Beneficial cumulative impacts may be expected when considering the proposed action’s placement areas in combination with restoration actions that are planned within the study area by State and Federal agencies, non-governmental organizations, and private entities. These include actions outlined in the Texas Coastal Resilience Master Plan, Coastal Bay Bends and Estuaries Program, and TPWD Dagger Island restoration projects. Bird islands, beach nourishment, and DMPA will provide additional loafing and nesting habitat for federally listed species such as Piping Plover, Red Knot, and Eastern Black Rail. Restoration actions can result in long term improvements and decrease adverse cumulative impacts.

The Proposed Action Alternative's impacts could contribute to cumulative effects where they overlap with impacts of past, present, and reasonably foreseeable actions. Even though potential temporary and permanent impacts may be associated with past, present, and reasonably foreseeable actions, it is also assumed that these projects were, or would be, implemented in compliance with applicable laws and regulations that exist to avoid and minimize project impacts, particularly Endangered Species Act, Marine Mammals Protection Act, and the Magnuson-Steven's Act.

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4.0 CONSERVATION MEASURES

The following conservation measures would be implemented to reduce potential impacts to marine and terrestrial wildlife during construction activities.

4.1 CHANNEL DREDGING

As part of the Proposed Action Alternative, the following conservation measures would be implemented by the PCCA and their contractors to minimize impacts to Federally listed species during beach nourishment activities.

Avoidance measures have been developed to avoid and minimize adverse impacts to Sperm Whales, West Indian Manatees, Giant Manta Rays, and sea turtles from dredging and disposal of dredged material in the ODMDS during construction of the CDP. These avoidances include reasonable and prudent measures that have largely been incorporated in USACE regulatory and civil works projects throughout the Gulf for more than a decade. These measures are:

- Training: All contracted personnel involved in operating dredges must receive thorough training (as specified by NMFS or USFWS) on measures of dredge operation that will minimize impacts to Sperm Whales, West Indian Manatees, and sea turtle takes.
- Observers: The PCCA will arrange for NMFS-approved protected species observers to be aboard the hopper dredges to monitor the hopper bin, screening, and dragheads for sea turtles and their remains. Observer coverage sufficient for 100 percent monitoring (i.e., two observers) of hopper dredging operations will be implemented. If a manatee is sighted, project observers should contact the Texas Coastal Ecological Services Field Office at (361) 533-6765 and the Texas Marine Mammal Stranding Network at 800-962-6625 (800-9MAMMAL).
- Staff and crew should not feed or water manatees. All in-water operations, including vessels, must be shut down if a manatee comes within 50-feet (15 meters) of the operation. Activities will not resume until the manatee has moved beyond the 50-foot radius of the project operation, or until 30 minutes elapses if the manatee has not reappeared within 50-feet of the operation. Animals must not be herded away or harassed into leaving the area.
- Dredge Take Reporting: Observer reports of incidental take by hopper dredges will be submitted by e-mail (takereport.nmfsser@noaa.gov) to NMFS Southeast Regional Office by onboard protected species observers within 24 hours of any observed sea turtle take. Reports shall contain information on location, start-up and completion dates, cubic yards of material dredged, problems encountered, incidental takes, and sightings of protected species, mitigative actions taken, screening type, and daily water temperatures. An end-of-project summary report of the hopper dredging results and any documented sea turtle takes will be submitted to NMFS Southeast Regional Office within 30 working days of completion of the dredging project.
- Seasonal Hopper Dredging Window: Hopper dredging activities shall be completed between December 1st and March 31st, when sea turtle abundance is lowest throughout Gulf coastal waters.

- Sea Turtle Deflecting Draghead and Dredging Pumps: A state-of-the-art rigid deflector draghead will be used on all hopper dredges at all times of the year. Dredging pumps will be disengaged by the operator when the dragheads are not firmly on the bottom, to prevent impingement or entrainment of sea turtles within the water column (especially important during dredging cleanup).
- Non-hopper Type Dredging: Pipeline or hydraulic dredges, which are not known to take turtles, must be used whenever possible between April 1st and November 30th.
- Dredge Lighting: From March 15th through September 30th, sea turtle nesting and emergence season, all lighting aboard hopper dredges and support vessels operating within three nautical miles of sea turtle nesting beaches shall be limited to the minimal lighting necessary to comply with U.S. Coast Guard and Occupational Safety and Health Administration requirements. Non-essential lighting shall be minimized through reduction, shielding, lowering, and appropriate placement.
- STSSN Notification: PCCA or its representative will notify the STSSN state representative of start-up and completion of dredging and relocation trawling operations. The STSSN will be notified of any turtle strandings in the project area that may bear the signs of interaction with a dredge. Dredge relevant stranding information will be reported in the end-of-project summary report and end of year annual report.
- Relocation Trawling: Relocation trawling will be undertaken by a NMFS-approved protected species observer retained by the PCCA where any of the following conditions are met: (a) two or more turtles are taken in a 24-hour period in the project or (b) four or more turtles are taken in the project. The purpose of the trawling would be to capture sea turtles that may be in the dredge path and relocate them away from the action area. An end-of-project report would be generated upon completion and incorporated into the dredging annual summary report.
- Sperm Whales and Giant Manta Rays: Observers shall report Giant Manta Ray and Sperm Whale sightings to the NMFS Southeast Region Protected Resources Division. Observations should be photographed and include the latitude/longitude, date, and environmental conditions at the time of the sighting.

4.2 PLACEMENT OF DREDGED MATERIAL

Avoidance measures have been developed to avoid and minimize adverse impacts to Piping Plovers, Red Knots, Eastern Black Rail, Whooping Crane, and nesting sea turtles from placement of dredged material during construction of the CDP. These avoidances include reasonable and prudent measures that have largely been incorporated in USACE regulatory and civil works projects throughout the Gulf for more than a decade. These measures are:

- Species Training and Monitoring – The following measures apply to species training and on-site monitoring during placement of dredged material for beneficial use in beach nourishment and in-water placement and construction activities:
    - The PCCA will ensure all crew members (contractors, work crews, drivers, wildlife monitors, etc.) attend a half-day training session training prior to the initiation of, or their participation in, project work activities. Qualified biologist will conduct training and the

scope of training will include: 1) recognition of sea turtles, Eastern Black Rail, Piping Plovers, Whooping Cranes, and Red Knots, their habitats, and tracks; 2) avoidance and minimization measures; 3) reporting criteria; and 4) contact information for different rescue agencies in the area. Documentation of this training, including a list of attendees, will be submitted to the USACE and USFWS prior to the start of placement of dredged materials, including beach nourishment, and as new members are trained.

- A minimum of one qualified wildlife monitor, separate from the equipment operator, will be assigned to each active work area. The wildlife monitor will inspect the active work areas prior to the start of work and continuously throughout the workday. Wildlife monitor qualifications will be submitted to the USACE and USFWS prior to the start of each beach nourishment project.
- The PCCA will provide the USACE with the name of a single point of contact responsible for communicating with the crew and wildlife monitors and reporting on endangered species issues during the life of the project. The wildlife monitors will be on-site to ensure listed species are not affected by placement of dredged materials, including beach nourishment activities.
- Prior to the start of work each day, the PCCA will ensure that the wildlife monitors inspect the work area and surrounding areas before construction begins each morning. Wildlife monitors will communicate all activities to the point of contact and the point of contact will coordinate that information with the USACE and USFWS as required.
- Prior to the start of work each day, all contractors, work crews, drivers, etc., will attend a brief training on the recognition of sea turtles, , Piping Plovers, and Red Knots, Whooping Cranes, Eastern Black Rail (and their habitats) and updated on any previous day encounters, if any, with nesting or injured wildlife.

4.2.1 Piping Plovers and Red Knots

The Piping Plovers and Red Knots wintering season begins July 15th, extending through May 15th. To minimize potential impacts to Piping Plovers, Red Knots, and other migratory birds during beach nourishment activities, the PCCA and their contractors will implement the following measures:

- Wildlife monitors will be on-site to ensure Piping Plovers and Red Knots are not affected during beach nourishment activities. The wildlife monitors will ensure that beach nourishment activities will not begin until Piping Plovers and Red Knots leave the project area.
- Wildlife monitors will escort equipment operating on to the beach. No equipment will be powered on or working until the wildlife monitors is present and the equipment inspections are complete.
- Wildlife monitors will check under and around vehicles and heavy equipment before they are moved. Wildlife monitors should be aware that Piping Plovers and Red Knots are especially vulnerable during periods of cold temperature, inclement weather, and when roosting. Birds are more susceptible to injury or disease during inclement winter weather. Careful consideration of construction activities and monitoring should be considered when winter winds exceed 20 mph and temperature drops below 40 degrees. These conditions can cause the birds to roost to conserve energy. Birds can be found in vehicle ruts or next to debris which can make them difficult to see. Construction workers will immediately notify the point of contact or wildlife

monitor if listed species occur in the immediate vicinity of the active work area. If Piping Plovers or Red Knots are found in the active work area, work will be stopped within an area specified by monitors until the birds leaves the construction site. Equipment will remain powered off and all personnel will be vacated from the work area until the birds has left. If the bird does not relocate (e.g., injured bird), the USFWS will be contacted to solicit additional guidance.

- Disturbed areas of the beach (e.g., ruts, tread marks, etc.) will be smoothed out and loosened upon the completion of each workday.

4.2.2 Eastern Black Rail

In Texas, breeding populations of Eastern Black Rails are found along the Gulf Coast from March to August. To minimize potential impacts, the PCCA and their contractors will implement the following Best Management Practices (USFWS, 2022c):

- Where known black rail habitat exists, disturbance activities should be avoided from March 1 to September 30.
- If potential black rail habitat is proposed for removal or impact, a black rail species surveys should be conducted prior to construction activity. The survey period for the species is from March 15 to June 15.
- Limit project activity to daytime hours. If nighttime work is required, lighting in work zones should be limited and turned off when not in use. Permanent lighting should be pointed away from potential black rail habitat, down shielded, and follow Texas Bird City guidelines.
- Black rail habitat should not all be removed within a day. Some pockets of herbaceous cover (refugia, approximately 10 feet by 20 feet) should be maintained. Refugia remaining within the project area may be cleared after two days.
- Biological monitors should ensure that equipment and vehicles moving through potential black rail habitat should follow a sufficiently slow pace to allow birds to escape ahead of equipment. Black rails run to escape oncoming disturbance and are unlikely to fly.
- Revegetation of disturbed areas should use native plants to mimic the local site composition.

4.2.3 Whooping Cranes

To protect Whooping Cranes, which winter in the Action Area and surrounding vicinity between November 1st and April 30th; the PCCA and their contractors shall lower any equipment (taller than 15 feet) at night. If equipment cannot be laid down at dusk or overnight, then such equipment will be marked using surveyors flagging tape, red plastic balls or other suitable marking devices and lighted during inclement weather conditions when low light and/or fog is present. If a Whooping Crane is observed within 1,000 feet of dredge material placement activities, the PCCA shall immediately halt work until the Whooping Crane leaves the area.

4.2.4 Sea Turtles

Peak nesting season for sea turtles begins March 15th, extending through October 1st. To minimize potential impacts to sea turtles during placement of dredged material, including beach nourishment activities, the PCCA and their contractor will implement the following measures:

- The PCCA, in coordination with the USACE, will ensure that daily turtle patrols of the proposed beach nourishment area by wildlife monitors are conducted prior to the start of work each day and continuously throughout the workday. No equipment will be powered on or working until the wildlife monitor is present and the equipment inspections are complete.
- If a sea turtle (dead or alive), sea turtle tracks, or nest is located or identified, the siting will be documented, and beach nourishment activities will immediately cease within 100 feet of the nest, tracks, or turtle. The wildlife monitor will then call Padre Island National Seashore at 1-361-949-8173 X 226 or 1-866-TURTLE5 (1-866-887-8535) or the ARK at 361-749-6793.
- All turtles, turtle tracks, turtle nests, or turtle eggs found during beach nourishment activities will be safeguarded until they can be re-located by properly permitted individual(s).
- Contractors will use the minimum amount of light necessary through reduced wattage, shielding, lowering, and the use of low-pressure sodium lights during project construction to minimize the potential effects of artificial lighting on sea turtles.

4.3 CONSTRUCTION SITE, ACCESS, AND EQUIPMENT FOR BEACH NOURISHMENT ACTIVITIES

Beach nourishment activities will be conducted mechanically by means of trucks, backhoes, front-end loaders, bulldozers, cranes, and ATVs. Other equipment could include a dredge pipe, booster pumps, generators, lighting, and fuel trucks. The following measures apply to construction access and equipment usage during beach nourishment activities.

- Materials and equipment required for the Proposed Action Alternative will be staged in upland areas and transported as needed to the proposed work sites. Staging areas will be designated before work begins and will be solely within the construction footprint.
- Construction vehicles will access the beach from public roads closest to the work sites to reduce the unnecessary vehicle traffic on the beach.
- Ingress/egress routes will be flagged/marked with wooden laths/stakes to ensure that work activities remain within the approved project work area. These items will be removed once work is complete in designated areas.
- Contractors will coordinate and sequence the work to minimize the frequency and density of vehicular traffic on the beach to the greatest extent practicable. Construction crews and vehicles will avoid the swash zone and the wrack line closest to the swash zone when possible. The swash zone is defined as the area of the beach intermittently covered and uncovered by wave run-up. The wrack line is defined as the vegetative area made up of but not limited to *Sargassum*, shell hash, vegetation, and some light trash, and litter.

- Sand placement areas will be confined to a maximum 1,000-foot-long segment within the active work corridor. Vehicle access corridors could include up to an additional 2,000 feet. Work activities will run parallel to the shoreline and will shift linearly along the work corridor as sections of the beach template are completed to allow for birds to migrate to undisturbed portions of the beach.
- The ends of the 1,000-foot-long segment within the active work area will be clearly marked with orange wooden barricades (or other temporary barriers) for the duration of project construction. Barricades will be shifted down the active work area as work is completed.
- The number of vehicles transiting from upland areas to the active work sites will be kept to a minimum. All vehicles will use the same pathways and access will be confined to the closest access point to the immediate work area. Beach nourishment activities will occur from the landward side of the beach placement area whenever possible.
- Vehicles will adhere to a reduced speed of 15 miles per hour.
- Use of construction lighting at night will be minimized, directed toward the construction activity area, and shielded from view outside of the project area to the maximum extent practicable.

4.4 BEACH-QUALITY SAND AND PLACEMENT

Measures that apply to beach-quality sand placement during beach nourishment activities include:

- Only sand that meets the specifications of the local beach quality sand (i.e., consistent in grain size, color, composition, and mineralogy) and free of hazardous substances (as defined in Volume 40 of the Code of Federal Regulations, Part 302.4) will be used for beach nourishment activities. Detail on sediment testing can be found in Sections 3.2.5 and 4.1.4 of the EIS and is briefly summarized here. The proposed dredge area does not have heavy industry located on its banks and past maintenance material testing has not shown any signs of contamination (Montgomery and Bourne, 2018). Further testing for the CCSCIP ruled out several volatile and semivolatile chemical groups including VOC, ethers, and organonitrogens, and nonvolatiles like dioxin. Testing for the remaining chemicals at the CCSC in the lower bay, Entrance Channel, and proposed channel extension, did not indicate issues with metals, polycyclic aromatic hydrocarbons, pesticides, or other chemical groups. Only beach quality sands from the CCSC should be placed as direct beach nourishment at locations previously breached by Hurricane Harvey.
- Sand will be placed and maintained at a gradual slope to minimize scarping.
- After project construction in an active work zone is complete, the project site will be regraded, and all vehicular ruts leveled.

5.0 EFFECTS ANALYSIS, AVOIDENCE, AND MINIMIZATION

The USACE presents their determination about each species potentially occurring within the study area, using the language recommended by the USFWS:

- *No effect* – The proposed action will not affect a Federally listed species or Critical Habitat;
- *May affect, but not likely to adversely affect* – the project may affect listed species and/or Critical Habitat; however, the effects are expected to be discountable, insignificant, or completely beneficial; or
- *Likely to adversely affect* – effects to the listed species and/or Critical Habitat may occur as a direct result of the proposed action or its interrelated or interdependent actions, and the effects is not discountable, insignificant or completely beneficial. Under this determination, an additional determination is made whether the action is likely to jeopardize the continued survival and eventual recovery of the species.

Following the effect determinations for the project on Federally listed species, the USFWS and NMFS will review the information and complete the Section 7 consultation process under the ESA.

5.1 OCELOT

The Ocelot are rare cats found in thornscrub forest of south Texas. The proposed CDP activities are in the bay or along the coast away from their typical habitat. There is no Federally designated Critical Habitat for the species. It would be very rare to find Ocelots along the coastal barrier island or bays. Ocelots are not expected to be impacted by the project.

Effect Determination

The CDP will have no effect on the Ocelot.

5.2 BLUE WHALE, FIN WHALE, HUMPBACK WHALE, SEI WHALE, AND SPERM WHALE

Whales are rare visitors to the Texas Gulf. Isolated observations have been made in recent years along the shallow waters near the coast, but populations of the species remain rare in Texas. Marine mammal species could be impacted by collision with ships, decreased water quality, and disorientation from vessel traffic and sonar. Conservation measures to protect any whales or marine mammals within the construction area would include the use of NMFS-approved observers on dredge vessels, reporting protocols to NMFS, and dredging operational changes (additional information can be found in Section 4.0). However, if incidental take occurs, it would not jeopardize the continued existence or recovery of the species.

Effect Determination

The likelihood of adverse effects, including incidental take, during channel dredging and construction would be greatly reduced by full implementation of avoidance, minimization, and conservation measures outlined above. Of the five species of whales with the potential of occurrence within the project area, only sperm whales are sighted near the Texas coast. Sperm Whales are considered rare within the Gulf. The CDP is expected to decrease the volume of vessel traffic traversing the CCSC. This would lower the risk of a collision between marine mammals and ships within the CCSC. Offshore vessel traffic is expected to remain the same after completion of the project. Therefore, the risk of vessel collision offshore with marine mammals are expected to stay the same. The effect determinations are presented in Table 3. Incidental take, if it occurs, would not jeopardize the continued existence or potential recovery of any of the whale species.

Table 3
Effect Determinations for Whales Relative to the Proposed Action Alternative

Common Name	Scientific Name	Dredging Activity Determination	Placement of Dredged Material Determination
Blue Whale	*Balaenoptera musculus*	No Effect	No Effect
Fin Whale	*Balaenoptera physalus*	No Effect	No Effect
Humpback Whale	*Megaptera novaeangliae*	No Effect	No Effect
Sei Whale	*Balaenoptera borealis*	No Effect	No Effect
Sperm Whale	*Physeter macrocephalus*	May affect, but not likely to adversely affect	May affect, but not likely to adversely affect

5.3 WEST INDIAN MANATEE

West Indian Manatees are uncommon migrants to the Texas Gulf coast. Isolated observations have been made in recent years along the coast, but populations of the species remain rare in Texas. Manatees could be impacted by ship collisions, incidental take from the operation of dredge hoppers, decreased water quality, and habitat modification. Vessel traffic within the project area is projected to decrease after completion of the CDP compared to the No-Action Alternative. Therefore, the likelihood of injury or mortality from ship collision is expected to decrease. During channel deepening, conservation measures to protect any manatees within the construction area would include the use of NMFS-approved observers on hopper dredges, reporting to USFWS, and dredging operational changes (additional information can be found in Section 4.0). However, incidental take, if it occurs, would not jeopardize the continued existence or recovery of the species.

Effect Determination

The project may affect, but not likely to adversely affect West Indian Manatees.

5.4 GIANT MANTA RAY

Giant Manta Rays are common within the Gulf and around the Corpus Christi Bay area. Giant Manta Rays are found in shallow coastal waters and in open oceans. Manta Rays could be impacted by vessel collision, decreased water quality from dredging, trawling, and habitat modifications. The CDP is expected to decrease the volume of vessel traffic traversing the CCSC. This would in effect, lower the risk of a collision between marine species and ships within the CCSC. During construction, conservation measures to protect Manta Rays within the construction area can include the use of NMFS-approved observers, reporting protocols to NMFS, and best management practices (additional information can be found in Section 4.0).

Effect Determination

The project may affect, but not likely to adversely affect Giant Manta Rays.

5.5 NORTHERN APLOMADO FALCON

There is no designated Critical Habitat for Northern Aplomado Falcons along the Texas coastline. According to eBird data (2022a), Northern Aplomado Falcons have been observed throughout the project area. The placement of dredge material would not impact the species or their habitat. After construction is completed, falcons are expected to benefit from the stabilized shoreline for additional or improved habitat.

Effects Determination

The proposed project would not affect Northern Aplomado Falcons.

5.6 PIPING PLOVER

Dredging activity offshore or nearshore would not directly impact Piping Plover. The greatest potential for impacts to Piping Plovers would be associated with placement of fill material for beneficial use near potential habitat. Dredge material placement and construction on the beach and in inshore areas could disturb and impact Piping Plover foraging, roosting and loafing areas where they overwinter on the Texas coast. Wintering Piping Plovers have been observed using uplands for resting between placement areas. A pre-construction survey should be conducted to determine presence or absence of Piping Plovers. Noise from construction operations, placement of sediments on habitat, and earth moving would temporarily disturb individuals and bury some Critical Habitat. Birds would likely become acclimated to the noise and vessel traffic or relocate to adjacent habitats. According to eBird data (2022b), Piping Plovers have been observed throughout the Texas Gulf coast. This includes Federally designated Critical Habitat units TX-6, 7, 8, 14, 15, and 16 where the project area is located (see Figure 4).

Conservation measures include survey for presence or absence prior to construction, construction outside of Piping Plover wintering season, and avoidance of Critical Habitat. Additional information can be found in Section 4.0.

After construction is completed, dredge material placement areas would result in a positive effect on Piping Plovers by increasing the extent of suitable habitat within the project area. Disturbance of Piping Plovers along the project area would not jeopardize the continued existence or the potential recovery of the species.

Effect Determination

The proposed project may affect, but not likely to adversely affect Piping Plover and their Critical Habitat.

5.7 RUFA RED KNOT

Rufa Red Knots would not be directly impacted by open-water dredging. Rufa Red Knots typically utilize large areas of wide exposed intertidal flats, beaches, and oyster reefs similarly used by piping plovers. Rufa Red Knots are anticipated to be directly impacted by placement of sediments, construction activity and noise, and buried foraging resources. Some beneficial use placement actions would impact tidal habitats but would also create or improve tidal habitats. There is no Federally-designated Critical Habitat associated with Rufa Red Knots in Texas. A survey should be performed prior to construction to determine the presence or absence of Rufa Red Knots within the project area.

After dredge material placement, Rufa Red Knots are expected to benefit from the increased habitat and stabilized shoreline. The disturbance of Rufa Red Knots along the project area would not jeopardize the continued existence or the potential of recovery for the species.

Effect Determination

The proposed project may affect, but not likely to adversely affect Rufa Red Knot.

5.8 WHOOPING CRANE

There will be project related construction activities located near Port Aransas, Corpus Christi Bay, and other wintering areas where Whooping Cranes are common. Whooping Cranes may occur in brackish bays, marshes, and salt flats along the mid-Texas coast. Some beneficial use placement actions would impact tidal habitats but would also create or improve tidal habitats. A survey should be performed prior to construction activity to determine the presence or absence of Whooping Cranes within the project area. During dredging activities, noise, and turbidity may indirectly impact wintering Whooping Cranes. Changes in water quality from dredging and fill placement may also affect the foraging ability of Whooping Cranes in marshes and bays. Impacts from the project are expected to be temporary.

After dredge material placement, Whooping Cranes are expected to benefit from restored marshes and stabilized shorelines for additional or improved foraging and wintering habitat.

Effect Determination

The proposed project may affect, but not likely to adversely affect Whooping Cranes.

5.9 EASTERN BLACK RAIL

Eastern Black Rails may occur in brackish bays, marshes, and tidal wetlands along the mid-Texas coast, and tidal wetlands would be directly impacted by placement actions. Dredging, noise, and turbidity may indirectly impact Eastern Black Rails near tidal marshes. A survey should be performed prior to construction activity to determine the presence or absence of Eastern Black Rails within the project area. Some beneficial use placement actions would impact tidal habitats but would also create or improve tidal habitats. Other impacts from the project are expected to be temporary.

After dredge material placement, Eastern Black Rails are expected to benefit from restored marshes and stabilized shorelines for additional or improved habitat.

Effect Determination

The proposed project may affect, but not likely to adversely affect Eastern Black Rail.

5.10 ATTWATER'S GREATER PRAIRIE CHICKEN

There is no designated Critical Habitat for Attwater's Greater Prairie Chicken along the Texas coast. According to eBird data (2022e), Attwater's Greater Prairie Chickens have not been observed within the project area. Suitable habitat for the prairie chicken is not found within the vicinity of the project.

Effect Determination

The proposed project will have no effect on the Attwater's Greater Prairie Chicken.

5.11 SEA TURTLES

The responsibility for agency coordination on marine reptiles is divided between two Federal agencies: the NMFS for sea turtles in the water and the USFWS for nesting sea turtles. Juvenile and adult sea turtles may be present in the water within the project area during certain times of the year. There are five sea turtle species with the potential to be found in Texas Gulf waters: Hawksbill Sea Turtle, Green Sea Turtle, Kemp's Ridley Sea Turtle, Leatherback Sea Turtle, and Loggerhead Sea Turtle.

5.11.1 In-water Impacts

Dredging could result in impacts to the sea turtles, if they are present in the project area. The effects of these impacts are expected to be localized and temporary in terms of construction. It is assumed that the deepening of the channel would be constructed with a cutterhead suction hydraulic or single large-capacity hopper dredge. However, the construction contractor may opt to employ two or more mid-capacity hopper dredges, or a cutterhead hydraulic pipeline dredged, or a mix of hopper and cutterhead dredges. Sea turtles can easily avoid pipeline dredges because of the slow movement of the dredge. The use of hopper dredges can increase the potential of mortality or injury for sea turtles. If hopper dredging is utilized, additional best management practices, like deflectors or relocation trawls, would be required to avoid impacts (Ramirez et al., 2017). Dredging the ship channel is expected to take 3 years. Between 1995 and 2021, the Galveston District of USACE has recorded 155 incidental takes of sea turtles along the entire Texas Gulf coast including 72 Green, 58 Loggerhead, and 25 Kemp's Ridley Sea Turtles (Operations and Dredging Endangered Species System, 2021). Other types of impacts to sea turtle from dredging activity include noise, increased turbidity, lighting from dredging vessels, resuspension of heavy metal and contaminants, and decreased dissolved oxygen around the dredge and placement area. The increased work boat traffic associated with construction activity could potentially increase vessel collision, contaminant spills and debris and trash, which could potentially impact sea turtles. Cutter suction dredging has been shown to be less harmful to sea turtles than hopper dredging. However, there have been rare incidences where cold-stunned sea turtles were unable to move away from the cutterhead (Ramirez et al., 2017). Sea turtles can become lethargic and less mobile when water temperatures fall below 50°F. Cold stunning can lead to shock, pneumonia, frostbite, and death if the sea turtle is unable to swim to warmer waters (Turtle Island Restoration Network, 2018; Shaver et al., 2017). The potential for incidental take of sea turtles by cutter suction dredges would be minimized using sea turtle observers, relocation trawling, seasonal dredging window, and other conservation measures. The likelihood of adverse effects during construction can be greatly reduced when avoidance, minimalization, and conservation measures are performed. A summary of avoidance, minimization, and conservation measures to reduce incidental take of sea turtles during dredging operations provided by NMFS (2007) can be found in Section 4.0.

The CDP is expected to decrease the volume of lightering vessel traffic traversing the CCSC. This would lower the risk of a collision between sea turtles and ships within the CCSC.

5.11.2 Nesting Impacts

Sea turtle nesting season in Texas extends from April to September (Palmer, 2017). Sea turtles arriving on shore during the nesting season may be impacted by dredge material placement activities. Beach nourishment can affect aspects of a beach, including sand density, shear resistance, moisture content, slope, sand color, grain size, and sand shape. Changes in the physical nature of the beach can in turn affect nest site selection, digging behavior, cultch viability, and hatching emergence (Gallaher, 2009). During the actual dredge material placement activities, sea turtles can be impacted by noise, ship collision, obstruction of the beach from dredge piping, and excess sand over nests (Crain et al., 1995).

Methods such as restricting beach nourishment activities during sea turtle nesting season, testing sand grains before placement, beach tilling to reduce compaction, and grading the beach to its original profile can prevent or reduce impacts to nesting sea turtles (Crain et al., 1995; Gallaher, 2009). Beach nourishment can reduce nesting success for the first season after nourishment but can return to normal levels in subsequent years (Crain et al., 1995). Nesting success is expected to return to pre-nourishment levels following material placement. Brock et al. (2009) found that nesting success for Loggerhead and Green Sea Turtles returned to pre-nourishment rates two seasons after beach nourishment. Beach nourishment is expected to increase available sea turtle nesting habitat. While a Leatherback Sea Turtle nest was located in South Padre Island in 2021, this is the first instance of a viable nest in Texas within 100 years, the likelihood of the species nesting within the project area is extremely low. The likelihood of adverse effects during beach nourishment activities can be greatly reduced if avoidance, minimalization, and conservation measures are performed. A summary of avoidance, minimization, and conservation measures to reduce incidental take of nesting sea turtles can be found in Section 4.0.

Beneficial placement of dredge material can lead to sediment transport of material to the shoreline and an accretion of beachfront habitat. Additional nesting habitat and stabilized shorelines would be available for nesting sea turtles and hatchlings. Constructed beach profile should mimic the natural slope and sand composition (grain size, shell content, etc.) as the original beach to promote sea turtle nesting (Brock et al., 2007). The net benefit from the project will include increased nesting habitat availability, increased submerged aquatic vegetation and foraging habitat, and improved bay and Gulf hydrology (Sea Turtle Conservancy, 2021). In the absence of the project, habitat quality would continue to diminish over time due to sea level rise.

Effect Determination

The likelihood of adverse effects, including incidental take, during channel dredging and construction would be greatly reduced by full implementation of avoidance, minimization, and conservation measures outlined above during dredging and beach nourishment activities. Leatherback Sea Turtles are less likely to be impacted since they are less likely to occur in the proposed project area. Hawkbill sea turtles would be less likely impacted by beach nourishment activities since the species has not been known to next on Texas beaches since 1998 (NPS, 2021). The effect determinations are presented in Table 4. Incidental take, if it occurs, would not jeopardize the continued existence or potential recovery of any of the sea turtle species.

5.12 FALSE SPIKE AND GUADALUPE ORB

There are no Federally designated Critical Habitats for the False Spike or Guadalupe Orb within the project area. Freshwater mussels are intolerant of brackish or saltwater and would not be found near the project area. It is highly unlikely that the species would be affected directly or indirectly from channel dredging or construction activity.

Effect Determination

The proposed project will have no effect on the False Spike or Guadalupe Orb.

Table 4
Sea Turtle Effect Determination Relative to the Proposed Action Alternative

Common Name	Scientific Name	Dredging Activity Determination	Beach Nourishment Determination
Green Sea Turtle	*Chelonia mydas*	Likely to adversely affect	Likely to adversely affect
Hawksbill Sea Turtle	*Eretmochelys imbricate*	Likely to adversely affect	May affect, but not likely to adversely affect
Kemp's Ridley Sea Turtle	*Lepidochelys kempii*	Likely to adversely affect	Likely to adversely affect
Leatherback Sea Turtle	*Dermochelys coriacea*	May affect, but not likely to adversely affect	May affect, but not likely to adversely affect
Loggerhead Sea Turtle	*Caretta caretta*	Likely to adversely affect	Likely to adversely affect

5.13 MONARCH BUTTERFLY

There are no Federally designated Critical Habitats for the Monarch Butterfly. Populations of the plant species are well-documented throughout Texas and within the project area. However, the project will not affect monarch butterfly habitat or milkweed, its host plant.

Effect Determination

The proposed project will have no effect on the Monarch Butterfly or its associated habitats.

5.14 SLENDER RUSH-PEA, SOUTH TEXAS AMBROSIA, AND BLACK LACE CACTUS

There are no Federally designated Critical Habitats for the slender rush-pea, South Texas ambrosia, or black lace cactus. Populations of the plant species are well-documented and exist further inland in upland habitats, away from the project area. It is highly unlikely that the species would be affected directly or indirectly from channel dredging or construction activity.

Effect Determination

The proposed project will have no effect on the slender rush-pea, South Texas ambrosia, black lace cactus or their associated habitats.

6.0 SUMMARY

Table 5 presents a summary of effects determination for the Federally threatened and endangered species covered in this BA.

Table 5
Effects Determinations Summary for the Proposed Action Alternative

Common Name	Scientific Name	Effects Determination – USFWS
MAMMALS		
Ocelot	*Leopardus pardalis*	No Effect
Blue Whale	*Balaenoptera musculus*	No Effect
Fin Whale	*Balaenoptera physalus*	No Effect
Humpback Whale	*Megaptera novaeangliae*	No Effect
Sei Whale	*Balaenoptera borealis*	No Effect
Sperm Whale	*Physeter macrocephalus*	May affect, but not likely to adversely affect
West Indian Manatee	*Trichechus manatus*	May affect, but not likely to adversely affect
FISH		
Giant Manta Ray	*Manta birostris*	May affect, but not likely to adversely affect
BIRDS		
Northern Aplomado Falcon	*Falco femoralis septentrionalis*	No Effect
Piping Plover	*Charadrius melodus*	May affect, but not likely to adversely affect
Red Knot (Rufa)	*Calidris canutus rufa*	May affect, but not likely to adversely affect
Whooping Crane	*Grus americana*	May affect, but not likely to adversely affect
Eastern Black Rail	*Laterallus jamaicensis jamaicensis*	May affect, but not likely to adversely affect
Attwater's Greater Prairie Chicken	*Tympanuchus cupido attwateri*	No Effect
REPTILES		
Green Sea Turtle	*Chelonia mydas*	Likely to adversely affect[1]
Hawksbill Sea Turtle	*Eretmochelys imbricata*	Likely to adversely affect[2]
Kemp's Ridley Sea Turtle	*Lepidochelys kempii*	Likely to adversely affect[1]
Leatherback Sea Turtle	*Dermochelys coriacea*	May affect, but not likely to adversely affect
Loggerhead Sea Turtle	*Caretta caretta*	Likely to adversely affect
CLAMS		
False Spike	*Fusconaia mitchelli*	No Effect
Guadalupe Orb	*Cyclonaias necki*	No Effect
INSECT		
Monarch Butterfly	*Danaus plexippus*	No Effect
PLANTS		
Slender rush-pea	*Hoffmannseggia tenella*	No Effect
South Texas ambrosia	*Ambrosia cheiranthifolia*	No Effect
Black lace cactus	*Echinocereus reichenbachii albertii*	No Effect

[1]Effect determination for NMFS in-water impacts – likely to adversely affect

[2]Effect determination for NMFS in-water impacts – may affect, but not likely to adversely affect

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Attachment 1

U.S. Fish and Wildlife Service
County Species List

IPaC **U.S. Fish & Wildlife Service**

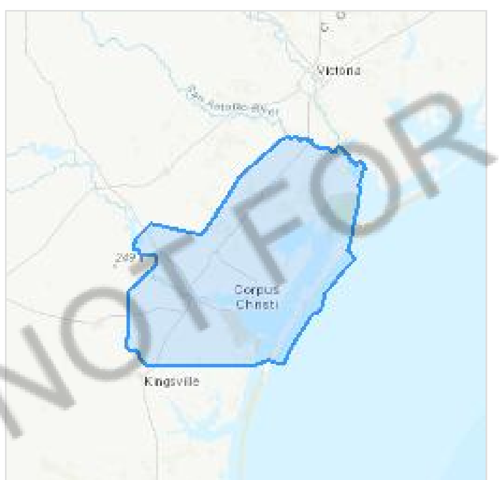
IPaC resource list

This report is an automatically generated list of species and other resources such as critical habitat (collectively referred to as *trust resources*) under the U.S. Fish and Wildlife Service's (USFWS) jurisdiction that are known or expected to be on or near the project area referenced below. The list may also include trust resources that occur outside of the project area, but that could potentially be directly or indirectly affected by activities in the project area. However, determining the likelihood and extent of effects a project may have on trust resources typically requires gathering additional site-specific (e.g., vegetation/species surveys) and project-specific (e.g., magnitude and timing of proposed activities) information.

Below is a summary of the project information you provided and contact information for the USFWS office(s) with jurisdiction in the defined project area. Please read the introduction to each section that follows (Endangered Species, Migratory Birds, USFWS Facilities, and NWI Wetlands) for additional information applicable to the trust resources addressed in that section.

Location

Texas



Local office

Texas Coastal Ecological Services Field Office

(281) 286-8282
(281) 488-5882

4444 Corona Drive, Suite 215
Corpus Christi, TX 78411

http://www.fws.gov/southwest/es/TexasCoastal/
http://www.fws.gov/southwest/es/ES_Lists_Main2.html

Endangered species

This resource list is for informational purposes only and does not constitute an analysis of project level impacts.

The primary information used to generate this list is the known or expected range of each species. Additional areas of influence (AOI) for species are also considered. An AOI includes areas outside of the species range if the species could be indirectly affected by activities in that area (e.g., placing a dam upstream of a fish population even if that fish does not occur at the dam site, may indirectly impact the species by reducing or eliminating water flow downstream). Because species can move, and site conditions can change, the species on this list are not guaranteed to be found on or near the project area. To fully determine any potential effects to species, additional site-specific and project-specific information is often required.

Section 7 of the Endangered Species Act **requires** Federal agencies to "request of the Secretary information whether any species which is listed or proposed to be listed may be present in the area of such proposed action" for any project that is conducted, permitted, funded, or licensed by any Federal agency. A letter from the local office and a species list which fulfills this requirement can **only** be obtained by requesting an official species list from either the Regulatory Review section in IPaC (see directions below) or from the local field office directly.

For project evaluations that require USFWS concurrence/review, please return to the IPaC website and request an official species list by doing the following:

1. Draw the project location and click CONTINUE.
2. Click DEFINE PROJECT.
3. Log in (if directed to do so).
4. Provide a name and description for your project.
5. Click REQUEST SPECIES LIST.

Listed species[1] and their critical habitats are managed by the Ecological Services Program of the U.S. Fish and Wildlife Service (USFWS) and the fisheries division of the National Oceanic and Atmospheric Administration (NOAA Fisheries[2]).

Species and critical habitats under the sole responsibility of NOAA Fisheries are **not** shown on this list. Please contact NOAA Fisheries for species under their jurisdiction.

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1. Species listed under the Endangered Species Act are threatened or endangered; IPaC also shows species that are candidates, or proposed, for listing. See the listing status page for more information. IPaC only shows species that are regulated by USFWS (see FAQ).
2. NOAA Fisheries, also known as the National Marine Fisheries Service (NMFS), is an office of the National Oceanic and Atmospheric Administration within the Department of Commerce.

The following species are potentially affected by activities in this location:

Mammals

NAME	STATUS
Ocelot Leopardus (=Felis) pardalis Wherever found No critical habitat has been designated for this species. https://ecos.fws.gov/ecp/species/4474	Endangered
West Indian Manatee Trichechus manatus Wherever found There is **final** critical habitat for this species. The location of the critical habitat is not available. https://ecos.fws.gov/ecp/species/4469	Threatened Marine mammal

Birds

NAME	STATUS
Attwater's Greater Prairie-chicken Tympanuchus cupido attwateri Wherever found No critical habitat has been designated for this species. https://ecos.fws.gov/ecp/species/7259	Endangered
Eastern Black Rail Laterallus jamaicensis ssp. jamaicensis Wherever found No critical habitat has been designated for this species. https://ecos.fws.gov/ecp/species/10477	Threatened
Northern Aplomado Falcon Falco femoralis septentrionalis No critical habitat has been designated for this species. https://ecos.fws.gov/ecp/species/1923	Endangered
Piping Plover Charadrius melodus There is **final** critical habitat for this species. Your location overlaps the critical habitat. https://ecos.fws.gov/ecp/species/6039	Threatened
Red Knot Calidris canutus rufa Wherever found There is **proposed** critical habitat for this species. The location of the critical habitat is not available. https://ecos.fws.gov/ecp/species/1864	Threatened
Whooping Crane Grus americana There is **final** critical habitat for this species. Your location overlaps the critical habitat. https://ecos.fws.gov/ecp/species/758	Endangered

Reptiles

NAME	STATUS
Green Sea Turtle Chelonia mydas There is **final** critical habitat for this species. The location of the critical habitat is not available. https://ecos.fws.gov/ecp/species/6199	Threatened
Hawksbill Sea Turtle Eretmochelys imbricata Wherever found There is **final** critical habitat for this species. The location of the critical habitat is not available. https://ecos.fws.gov/ecp/species/3656	Endangered
Kemp's Ridley Sea Turtle Lepidochelys kempii Wherever found There is **proposed** critical habitat for this species. The location of the critical habitat is not available. https://ecos.fws.gov/ecp/species/5523	Endangered
Leatherback Sea Turtle Dermochelys coriacea Wherever found There is **final** critical habitat for this species. The location of the critical habitat is not available. https://ecos.fws.gov/ecp/species/1493	Endangered
Loggerhead Sea Turtle Caretta caretta There is **final** critical habitat for this species. The location of the critical habitat is not available. https://ecos.fws.gov/ecp/species/1110	Threatened

Clams

NAME	STATUS
False Spike Fusconaia mitchelli Wherever found There is **proposed** critical habitat for this species. The location of the critical habitat is not available. https://ecos.fws.gov/ecp/species/3963	Proposed Endangered
Guadalupe Orb Cyclonaias necki There is **proposed** critical habitat for this species. The location of the critical habitat is not available.	Proposed Endangered

Insects

NAME	STATUS
Monarch Butterfly Danaus plexippus Wherever found No critical habitat has been designated for this species. https://ecos.fws.gov/ecp/species/9743	Candidate

Flowering Plants

NAME	STATUS
Black Lace Cactus Echinocereus reichenbachii var. albertii Wherever found No critical habitat has been designated for this species. https://ecos.fws.gov/ecp/species/5560	Endangered
Slender Rush-pea Hoffmannseggia tenella Wherever found No critical habitat has been designated for this species. https://ecos.fws.gov/ecp/species/5298	Endangered
South Texas Ambrosia Ambrosia cheiranthifolia Wherever found No critical habitat has been designated for this species. https://ecos.fws.gov/ecp/species/3331	Endangered

Critical habitats

Potential effects to critical habitat(s) in this location must be analyzed along with the endangered species themselves.

This location overlaps the critical habitat for the following species:

NAME	TYPE
Piping Plover Charadrius melodus https://ecos.fws.gov/ecp/species/6039#crithab	Final
Whooping Crane Grus americana https://ecos.fws.gov/ecp/species/758#crithab	Final

Migratory birds

Certain birds are protected under the Migratory Bird Treaty Act[1] and the Bald and Golden Eagle Protection Act[2].

Any person or organization who plans or conducts activities that may result in impacts to migratory birds, eagles, and their habitats should follow appropriate regulations and consider implementing appropriate conservation measures, as described below.

1. The Migratory Birds Treaty Act of 1918.
2. The Bald and Golden Eagle Protection Act of 1940.

Additional information can be found using the following links:

- Birds of Conservation Concern http://www.fws.gov/birds/management/managed-species/birds-of-conservation-concern.php
- Measures for avoiding and minimizing impacts to birds http://www.fws.gov/birds/management/project-assessment-tools-and-guidance/conservation-measures.php
- Nationwide conservation measures for birds http://www.fws.gov/migratorybirds/pdf/management/nationwidestandardconservationmeasures.pdf

MIGRATORY BIRD INFORMATION IS NOT AVAILABLE AT THIS TIME

Tell me more about conservation measures I can implement to avoid or minimize impacts to migratory birds.

Nationwide Conservation Measures describes measures that can help avoid and minimize impacts to all birds at any location year round. Implementation of these measures is particularly important when birds are most likely to occur in the project area. When birds may be breeding in the area, identifying the locations of any active nests and avoiding their destruction is a very helpful impact minimization measure. To see when birds are most likely to occur and be breeding in your project area, view the Probability of Presence Summary. Additional measures or permits may be advisable depending on the type of activity you are conducting and the type of infrastructure or bird species present on your project site.

What does IPaC use to generate the migratory birds potentially occurring in my specified location?

The Migratory Bird Resource List is comprised of USFWS Birds of Conservation Concern (BCC) and other species that may warrant special attention in your project location.

The migratory bird list generated for your project is derived from data provided by the Avian Knowledge Network (AKN). The AKN data is based on a growing collection of survey, banding, and citizen science datasets and is queried and filtered to return a list of those birds reported as occurring in the 10km grid cell(s) which your project intersects, and that have been identified as warranting special attention because they are a BCC species in that area, an eagle (Eagle Act requirements may apply), or a species that has a particular vulnerability to offshore activities or development.

Again, the Migratory Bird Resource list includes only a subset of birds that may occur in your project area. It is not representative of all birds that may occur in your project area. To get a list of all birds potentially present in your project area, please visit the AKN Phenology Tool.

What does IPaC use to generate the probability of presence graphs for the migratory birds potentially occurring in my specified location?

The probability of presence graphs associated with your migratory bird list are based on data provided by the Avian Knowledge Network (AKN). This data is derived from a growing collection of survey, banding, and citizen science datasets .

Probability of presence data is continuously being updated as new and better information becomes available. To learn more about how the probability of presence graphs are produced and how to interpret them, go the Probability of Presence Summary and then click on the "Tell me about these graphs" link.

How do I know if a bird is breeding, wintering, migrating or present year-round in my project area?

To see what part of a particular bird's range your project area falls within (i.e. breeding, wintering, migrating or year-round), you may refer to the following resources: The Cornell Lab of Ornithology All About Birds Bird Guide, or (if you are unsuccessful in locating the bird of interest there), the Cornell Lab of Ornithology Neotropical Birds guide. If a bird on your migratory bird species list has a breeding season associated with it, if that bird does occur in your project area, there may be nests present at some point within the timeframe specified. If "Breeds elsewhere" is indicated, then the bird likely does not breed in your project area.

What are the levels of concern for migratory birds?

Migratory birds delivered through IPaC fall into the following distinct categories of concern:

1. "BCC Rangewide" birds are Birds of Conservation Concern (BCC) that are of concern throughout their range anywhere within the USA (including Hawaii, the Pacific Islands, Puerto Rico, and the Virgin Islands);
2. "BCC - BCR" birds are BCCs that are of concern only in particular Bird Conservation Regions (BCRs) in the continental USA; and
3. "Non-BCC - Vulnerable" birds are not BCC species in your project area, but appear on your list either because of the Eagle Act requirements (for eagles) or (for non-eagles) potential susceptibilities in offshore areas from certain types of development or activities (e.g. offshore energy development or longline fishing).

Although it is important to try to avoid and minimize impacts to all birds, efforts should be made, in particular, to avoid and minimize impacts to the birds on this list, especially eagles and BCC species of rangewide concern. For more information on conservation measures you can implement to help avoid and minimize migratory bird impacts and requirements for eagles, please see the FAQs for these topics.

Details about birds that are potentially affected by offshore projects

For additional details about the relative occurrence and abundance of both individual bird species and groups of bird species within your project area off the Atlantic Coast, please visit the Northeast Ocean Data Portal. The Portal also offers data and information about other taxa besides birds that may be helpful to you in your project review. Alternately, you may download the bird model results files underlying the portal maps through the NOAA NCCOS Integrative Statistical Modeling and Predictive Mapping of Marine Bird Distributions and Abundance on the Atlantic Outer Continental Shelf project webpage.

Bird tracking data can also provide additional details about occurrence and habitat use throughout the year, including migration. Models relying on survey data may not include this information. For additional information on marine bird tracking data, see the Diving Bird Study and the nanotag studies or contact Caleb Spiegel or Pam Loring.

What if I have eagles on my list?

If your project has the potential to disturb or kill eagles, you may need to obtain a permit to avoid violating the Eagle Act should such impacts occur.

Proper Interpretation and Use of Your Migratory Bird Report

The migratory bird list generated is not a list of all birds in your project area, only a subset of birds of priority concern. To learn more about how your list is generated, and see options for identifying what other birds may be in your project area, please see the FAQ "What does IPaC use to generate the migratory birds potentially occurring in my specified location". Please be aware this report provides the "probability of presence" of birds within the 10 km grid cell(s) that overlap your project; not your exact project footprint. On the graphs provided, please also look carefully at the survey effort (indicated by the black vertical bar) and for the existence of the "no data" indicator (a red horizontal bar). A high survey effort is the key component. If the survey effort is high, then the probability of presence score can be viewed as more dependable. In contrast, a low survey effort bar or no data bar means a lack of data and, therefore, a lack of certainty about presence of the species. This list is not perfect; it is simply a starting point for identifying what birds of concern have the potential to be in your project area, when they might be there, and if they might be breeding (which means nests might be present). The list helps you know what to look for to confirm presence, and helps guide you in knowing when to implement conservation measures to avoid or minimize potential impacts from your project activities, should presence be confirmed. To learn more about conservation measures, visit the FAQ "Tell me about conservation measures I can implement to avoid or minimize impacts to migratory birds" at the bottom of your migratory bird trust resources page.

Marine mammals

Marine mammals are protected under the Marine Mammal Protection Act. Some are also protected under the Endangered Species Act[1] and the Convention on International Trade in Endangered Species of Wild Fauna and Flora[2].

The responsibilities for the protection, conservation, and management of marine mammals are shared by the U.S. Fish and Wildlife Service [responsible for otters, walruses, polar bears, manatees, and dugongs] and NOAA Fisheries[3] [responsible for seals, sea lions, whales, dolphins, and porpoises]. Marine mammals under the responsibility of NOAA Fisheries are **not** shown on this list; for additional information on those species please visit the Marine Mammals page of the NOAA Fisheries website.

The Marine Mammal Protection Act prohibits the take (to harass, hunt, capture, kill, or attempt to harass, hunt, capture or kill) of marine mammals and further coordination may be necessary for project evaluation. Please contact the U.S. Fish and Wildlife Service Field Office shown.

1. The Endangered Species Act (ESA) of 1973.
2. The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) is a treaty to ensure that international trade in plants and animals does not threaten their survival in the wild.
3. NOAA Fisheries, also known as the National Marine Fisheries Service (NMFS), is an office of the National Oceanic and Atmospheric Administration within the Department of Commerce.

The following marine mammals under the responsibility of the U.S. Fish and Wildlife Service are potentially affected by activities in this location:

NAME
West Indian Manatee Trichechus manatus https://ecos.fws.gov/ecp/species/4469

Facilities

National Wildlife Refuge lands

Any activity proposed on lands managed by the National Wildlife Refuge system must undergo a 'Compatibility Determination' conducted by the Refuge. Please contact the individual Refuges to discuss any questions or concerns.

This location overlaps the following National Wildlife Refuge lands:

LAND	ACRES

ARANSAS NATIONAL WILDLIFE REFUGE	115,882.14 acres

Fish hatcheries

THERE ARE NO FISH HATCHERIES AT THIS LOCATION.

Wetlands in the National Wetlands Inventory

Impacts to NWI wetlands and other aquatic habitats may be subject to regulation under Section 404 of the Clean Water Act, or other State/Federal statutes.

For more information please contact the Regulatory Program of the local U.S. Army Corps of Engineers District.

WETLAND INFORMATION IS NOT AVAILABLE AT THIS TIME

This can happen when the National Wetlands Inventory (NWI) map service is unavailable, or for very large projects that intersect many wetland areas. Try again, or visit the NWI map to view wetlands at this location.

Data limitations

The Service's objective of mapping wetlands and deepwater habitats is to produce reconnaissance level information on the location, type and size of these resources. The maps are prepared from the analysis of high altitude imagery. Wetlands are identified based on vegetation, visible hydrology and geography. A margin of error is inherent in the use of imagery; thus, detailed on-the-ground inspection of any particular site may result in revision of the wetland boundaries or classification established through image analysis.

The accuracy of image interpretation depends on the quality of the imagery, the experience of the image analysts, the amount and quality of the collateral data and the amount of ground truth verification work conducted. Metadata should be consulted to determine the date of the source imagery used and any mapping problems.

Wetlands or other mapped features may have changed since the date of the imagery or field work. There may be occasional differences in polygon boundaries or classifications between the information depicted on the map and the actual conditions on site.

Data exclusions

Certain wetland habitats are excluded from the National mapping program because of the limitations of aerial imagery as the primary data source used to detect wetlands. These habitats include seagrasses or submerged aquatic vegetation that are found in the intertidal and subtidal zones of estuaries and nearshore coastal waters. Some deepwater reef communities (coral or tuberficid worm reefs) have also been excluded from the inventory. These habitats, because of their depth, go undetected by aerial imagery.

Data precautions

Federal, state, and local regulatory agencies with jurisdiction over wetlands may define and describe wetlands in a different manner than that used in this inventory. There is no attempt, in either the design or products of this inventory, to define the limits of proprietary jurisdiction of any Federal, state, or local government or to establish the geographical scope of the regulatory programs of government agencies. Persons intending to engage in activities involving modifications within or adjacent to wetland areas should seek the advice of appropriate federal, state, or local agencies concerning specified agency regulatory programs and proprietary jurisdictions that may affect such activities.

Appendix E

Essential Fish Habitat Assessment

Job No. PCA20166

APPENDIX E

DRAFT
ESSENTIAL FISH HABITAT ASSESSMENT
FOR THE
PROPOSED CORPUS CHRISTI SHIP CHANNEL DEEPENING PROJECT

Prepared for:

U.S. Army Corps of Engineers

Prepared by:

Freese and Nichols, Inc.
10431 Morado Circle, Suite 300
Austin, Texas 78759

June 2022

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Acronyms and Abbreviations

°F	degrees Fahrenheit
BU	beneficial use
CCSC	Corpus Christi Ship Channel
CDP	Channel Deepening Project
CFR	*Code of Federal Regulations*
CWA	Clean Water Act
EFH	Essential Fish Habitat
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
GMFMC	Gulf of Mexico Fisheries Management Council
Gulf	Gulf of Mexico
mcy	million cubic yards
MLLW	mean lower low water
MSFCMA	Magnuson-Stevens Fishery Conservation and Management Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
ODMDS	Ocean Dredged Material Disposal Sites
PA	Placement Area
PCCA or Applicant	Port of Corpus Christi Authority
ppt	parts per thousand
SAV	submerged aquatic vegetation
SPM	Single Point Mooring
TDSHS	Texas Department of State Health Services
TPWD	Texas Parks and Wildlife Department
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
VLCC	Very Large Crude Carriers

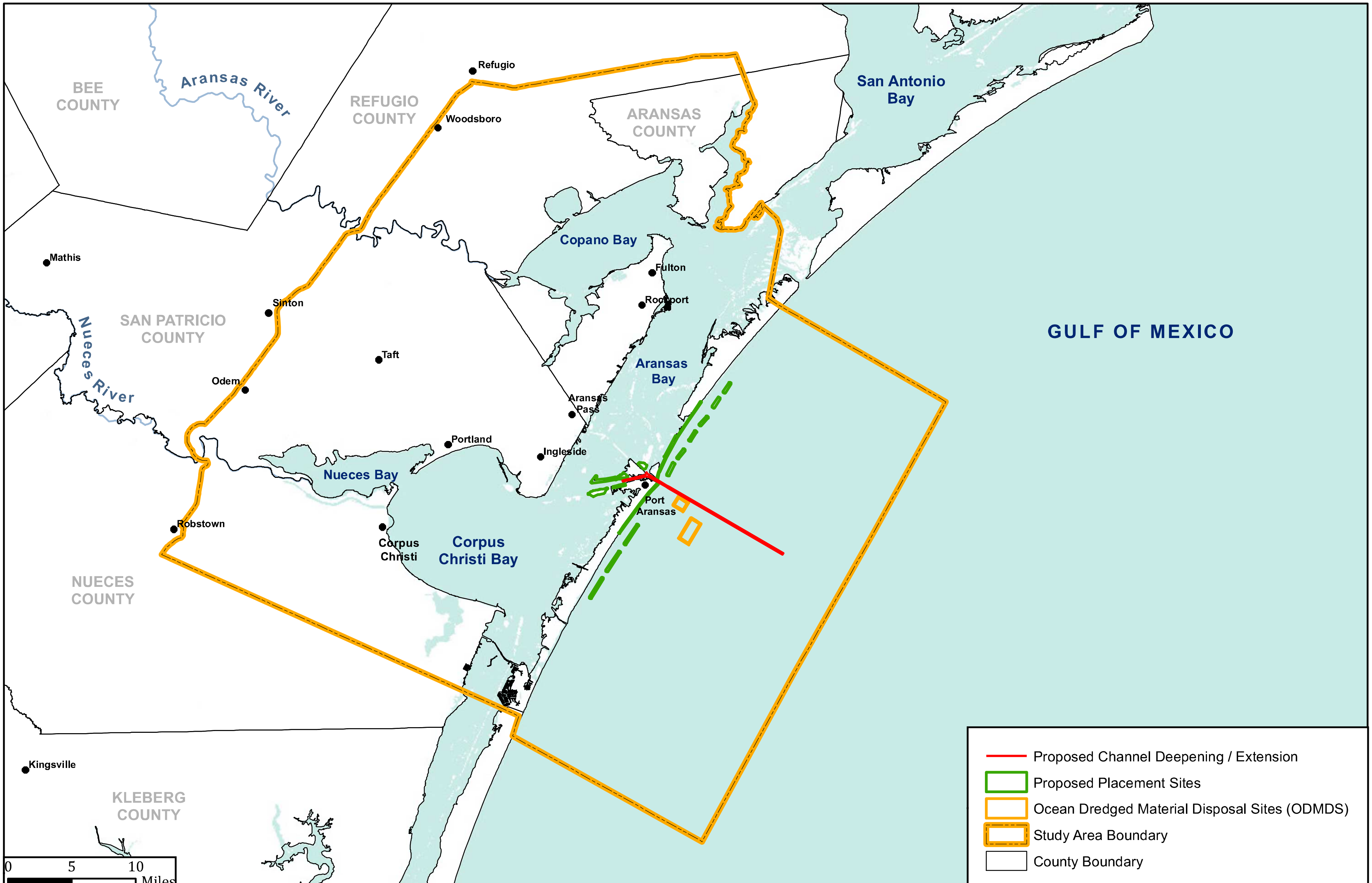
1.0 INTRODUCTION

The Port of Corpus Christi Authority (PCCA or Applicant) applied to the U.S. Army Corps of Engineers (USACE), Galveston District, for a Department of Army Permit, under Section 10 of the Rivers and Harbors Act of 1899, Section 404 of the Clean Water Act (CWA), and Section 103 of the Marine Protection, Research, and Sanctuaries Act (33 USA 1413) for activities related to the proposed channel improvements to the Corpus Christi Ship Channel. The proposed PCCA Channel Deepening Project (CDP) is located in Port Aransas, Nueces County, Texas within the existing channel bottom of the Corpus Christi Ship Channel (CCSC) near the southeast side of Harbor Island, and traversing easterly through Aransas Pass and extending an additional 5.5 miles beyond the existing terminus of the channel (Figure 1). The purpose of the proposed CDP is to accommodate transit of fully laden very large crude carriers (VLCCs) that draft approximately 68 feet. The deepening activities would be completed within the footprint of the authorized PCCA channel width.

Due to the potential impacts to Essential Fish Habitat (EFH), it was determined that preparation of an EFH Assessment pursuant to 50 *Code of Federal Regulations* (CFR) Section 600.920(i) would be required. This report presents an evaluation of potential EFH and fisheries within the project area. For this EFH, the project area is defined as the footprint of the construction area within the channel, 1-mile buffer, around the channel, and the proposed placement sites (Figure 2). The purpose of the investigation was to determine the location and extent of fisheries considered to occur within the project area and those protected under the 1996 Amendment to the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA), which mandated the identification of EFH for all federally managed species. This EFH assessment is included as part of an Environmental Impact Statement (EIS).

1.1 ROLE OF NATIONAL MARINE FISHERIES SERVICE IN ESSENTIAL FISH HABITAT CONSULTATION

Congress enacted amendments to the MSFCMA (PL 94-265) in 1996 that established procedures for identifying EFH and required interagency coordination to further the conservation of federally managed fisheries. Rules published by the National Marine Fisheries Service (NMFS) (50 CFR Sections 600.805–600.930) specify that any Federal agency that authorizes, funds, or undertakes, or proposes to authorize, fund, or undertake an activity that could adversely affect EFH is subject to the consultation provisions of the above-mentioned act and identifies consultation requirements. EFH is defined as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." EFH is separated into estuarine and marine components. The estuarine component is defined as "all estuarine waters and substrates (mud, sand, shell, rock, and associated biological communities); subtidal vegetation (seagrasses and algae); and adjacent intertidal vegetation (marshes and mangroves)." The marine component is defined as "all marine waters and substrates (mud, sand, shell, rock, and associated biological communities) from the shoreline to the seaward limit of the Exclusive Economic Zone" (Gulf of Mexico Fisheries Management Council [GMFMC], 2004). Adverse effect to EFH is defined as, "any impact,



PROJECT NO. PCA20166
DATE CREATED Date: 2/7/2022
DATUM & COORDINATE SYSTEM NAD83 State Plane (feet) Texas South Central
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PREPARED BY KLC

Port of Corpus Christi Authority
Corpus Christi Ship Channel Deepening Project

Study Area Boundary

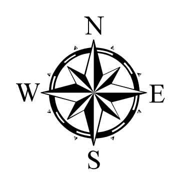

FIGURE 1

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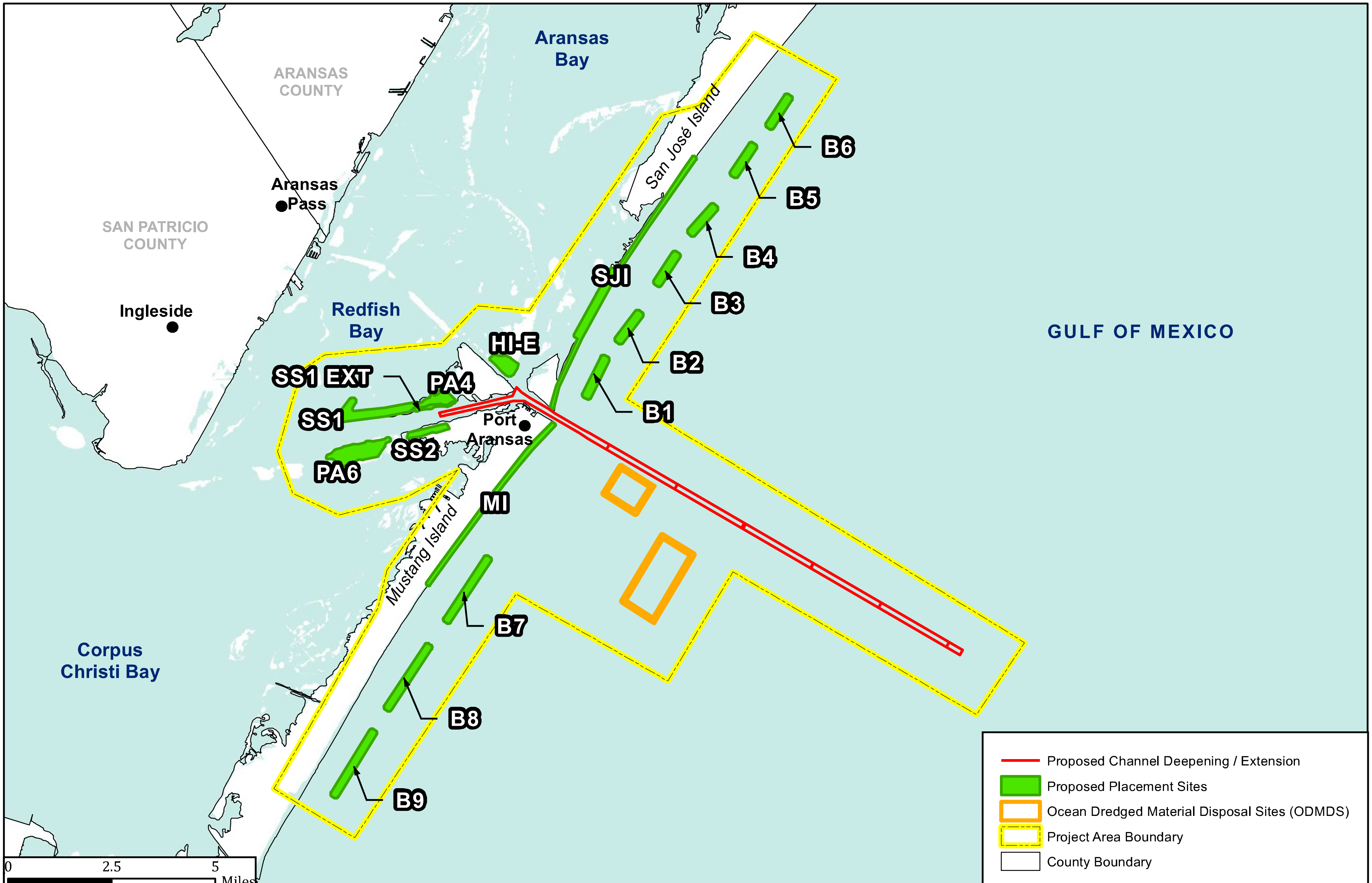


PROJECT NO. PCA20166 DATE CREATED Date: 1/19/2022 DATUM & COORDINATE SYSTEM NAD83 State Plane (feet) Texas South Centra FILE NAME Name: Fig_2_Project Area Boundary PREPARED BY KLC	Port of Corpus Christi Authority Corpus Christi Ship Channel Deepening Project **Project Area Boundary**	N W E S	FIGURE 2

Date Saved: 1/19/2022 12:09:18 PM Path: H:\ENVIRONMENTAL\Final_Exhibits\EFH Assessment Figures\Fig_2_Project Area Boundary.mxd which reduces quality and/or quantity of EFH…"and may include direct, indirect, site specific or habitat impacts, including individual, cumulative, or synergistic consequences of actions.

1.2 PROJECT DESCRIPTION

The PCCA applied to the USACE, Galveston District, on January 3, 2019, for a Department of Army Permit, under Section 10 of the Rivers and Harbors Act, Section 404 of the CWA, and Section 103 of the Marine Protection, Research, and Sanctuaries Act for activities subject to the jurisdiction of the USACE that include filling discharge of dredged or fill material into waters of the United States, the construction of structures and/or work that may affect navigable waters, and ocean disposal of dredged material. The project proposed in the permit application was revised based on comments provided by the USACE on May 23, 2019. The Port submitted a revised application on June 4, 2019. Based on the Department of Army Permit application submitted by PCCA, the USACE determined that the permitting action for the proposed dredge and fill activities constitutes a major Federal action with potentially significant effects and/or substantial public interest. In accordance with the National Environmental Policy Act, this EFH Assessment is part of an EIS that has been prepared to analyze and disclose the potential impacts of the proposed project on EFH.

1.3 PROJECT AREA AND EXISTING CHANNEL

The CCSC provides deep water access from the Gulf of Mexico (Gulf) to the Port of Corpus Christi, via the Port Aransas Channel, through Redfish Bay and Corpus Christi Bay. The waterway extends from the jettied Port Aransas entrance 20.75 miles to the landlocked portion of the CCSC, known as the Inner Harbor. Access points to the CCSC include the La Quinta Channel, the Gulf Intracoastal Waterway, and the Rincon Canal. The La Quinta Channel extends from the CCSC near Ingleside, Texas, and runs parallel to the eastern shoreline of Corpus Christi Bay for 5.9 miles to the La Quinta Turning Basin. The Corpus Christ Ship Channel Improvement Project is presently underway. This project has deepened the offshore section outside of the jetties from –49 feet mean lower low water (MLLW) to –56 feet MLLW. The inshore sections will be deepened from –47 feet MLLW to –54 feet MLLW. This project will also widen the CCSC from 500 feet to 530 feet in the reach from Port Aransas to Ingleside and from 400 feet to 530 feet in the Bay, with the addition of barge lanes. The USACE is responsible for the continued maintenance dredging of the CCSC.

1.4 PROPOSED ACTION AND ALTERNATIVES

The proposed CDP is located within the existing channel bottom of the CCSC starting near the southeast side of Harbor Island, traversing east through the Aransas Pass, and extending into the Gulf for an approximate distance of 13.8 miles. To address changing market needs, the proposed CDP would deepen this portion of the CCSC beyond the current authorized channel depths of –54 feet and –56 feet MLLW to maximum depths of –75 feet and –77 feet MLLW to accommodate transit of fully loaded VLCCs with vertical distances between the waterline and the bottom of the hull, or drafts, of approximately 68 feet. An estimated 46.3 million cubic yards (mcy) of new work dredged material would be generated from the channel deepening.

Additionally, the proposed CDP includes:

- Extending the existing terminus of the authorized channel, an additional 29,000 feet into the Gulf to reach –77 MLLW;
- Placement of the new work dredged material into Waters of the United States for beneficial use (BU) sites located in and around Corpus Christi and Redfish bays;
- Placement of dredged material on San José Island for beach and dune restoration;
- Placement of dredged material in nearshore berms to indirectly nourish San José and Mustang Islands; and
- Transport of new work dredged material to the New Work Ocean Dredged Material Disposal Site (ODMDS).

The proposed CDP does not include widening the channel; however, some minor incidental widening of the channel is expected to meet side slope requirements and to maintain the stability of the channel.

1.4.1 No-Action Alternative

The No-Action Alternative provides a means to evaluate the environmental impacts that would occur if the USACE were to deny the permit for the proposed channel improvements. The characterization of the No-Action Alternative provides a baseline for comparison of performance and impacts of the proposed action alternative. Under the No-Action Alternative, the CCSC would not be deepened to –77 feet MLLW and would remain at –54 feet MLLW. VLCCs would continue to be partially loaded and reverse-lightered offshore. The No-Action Alternative does not meet the project purpose and need but is carried forward for detailed analysis in this EIS for comparison purposes.

1.4.2 Alternative 1: Channel Deepening (Applicant's Proposed Action Alternative)

Alternative 1 consists of deepening the CCSC to –77 feet and –75 feet MLLW from the Gulf to station 110+00 near Harbor Island, including the approximate 10 mile-extension to the Entrance Channel necessary to reach sufficiently deep waters. As a result of one-way transit assumed for VLCCs, the planned widths for the –54-foot currently authorized project are nominally sufficient. Therefore, no widening other than the minor incidental widening to keep these bottom widths and existing channel slopes at the proposed deeper depths would occur. Deepening would take place largely within the footprint of the currently authorized –54-foot channel. Under this alternative, only berths at Axis Midstream and Harbor Island Terminals would be capable of fully loading VLCCs. However, partially loaded outbound VLCCs at Ingleside could top off at Harbor Island and potentially reduce or eliminate reverse lightering.

Dredging 46.3 mcy would be required with inshore and Gulf placement of the material. Placement would occur in a mix of Placement Areas (PAs), BU sites, and/or the New Work ODMDS. PCCA selected these potential PAs through a process that included agency input and consideration of State and Federal coastal restoration plans.

The Applicant's Proposed Action Alternative consists of the following elements (see Figure 2):

- Deepening from the authorized –54 feet MLLW to approximately –75 feet MLLW, with 2 feet of advanced maintenance and 2 feet of allowable overdredge, from Station 110+00 into the Gulf of Mexico to Station 72+50 (3.5 miles).
- Deepening from the authorized –56 feet MLLW to approximately –77 feet MLLW, with 2 feet of advanced maintenance and 2 feet of allowable overdredge, from Station –72+50 to Station 620+00 in the Gulf of Mexico (10.4 miles).
- Placement of new work dredged material at the following BU and PA sites (Table 1, and see Figure 2):
  - SS1: Restoring eroded shorelines
  - SS2: Restore eroded shoreline along Port Aransas Nature Preserve/Charlie's Pasture
  - SS1 Extension: Reestablish eroded shoreline and land loss in front of PA4
  - PA4: Upland placement
  - HI-E: Bluff and shoreline restoration with site fill
  - PA6: Raise levee 5-foot and fill with new work material
  - SJI: Dune and beach restoration San José Island
  - B1–B9: Nearshore berms offshore of San José Island and Mustang Island
  - MI: Beach nourishment for Gulf side of Mustang Island
  - ODMDS: Place within New Work ODMDS
- Incremental future maintenance material may be placed at the following PA sites as material suitability allows:
  - Existing Maintenance ODMDS in the vicinity of the CCSC
  - Proposed nearshore berms B1 through B9

Table 1
Description of Placement Sites

Placement Site	Description	Total Volume (cubic yards [cy])	Features Being Built		
			Purpose	From Dredged Material	Others (Armoring etc.)
SS1	Restoring eroded shorelines	2,793,000	Restore eroded shoreline landmass and provide protection to Harbor Island seagrass area	Dikes, landmass backfill	Slope armoring/riprap
SS2	Restore two shoreline breaches and landmass along Port Aransas Nature Preserve resulting from Hurricane Harvey. Would add land mass behind FEMA shoreline bulkhead project.	250,000	Restore shoreline washed out by Hurricane Harvey to protect piping plover sand flat critical habitat	Interior dikes, landmass backfill	Bulkhead
SS1 Extension (PA4 Shoreline Restoration)	Reestablish eroded shoreline and land loss in front of PA4	1,676,000	Restore eroded shoreline and land loss; provide protection to Harbor Island seagrass. Raise levees for placement of new work material unsuitable for BU	Exterior containment dike, landmass backfill, raise interior levee	Slope armoring/riprap
PA4 (Upland Placement)	Upland placement within PA4	2,861,400	No environmental benefit, material unsuitable for BU	PA interior fill	
HI-E	Bluff and shoreline land mass restoration with site fill on eastern Harbor Island	1,824,800	Restore eroded bluff and shoreline to historic profiles	Containment levees, landmass backfill	Slope armoring/riprap
PA6	Raise PA dike 5 feet and fill with 4 feet of new work material	1,796,400	No environmental benefit, material unsuitable for BU	Raise levee, PA interior fill	
SJI	Dune and beach restoration on San José Island	4,000,000	Restores dune washouts and several miles of beach profile that was washed away during Hurricane Harvey	Dunes and beach	
B1–B9	Nearshore berms offshore of San José Island and Mustang Island	8,100,000	Nearshore berms within transport zone to indirectly nourish barrier islands	Nearshore berms	
MI	Beach nourishment for Gulf side of Mustang Island	2,000,000	Mustang Island beach nourishment to enhance shoreline	Beach	
New Work ODMDS	Place material in existing New Work ODMDS	38,888,600	No environmental benefit, material suitable for ocean placement	Placement mound	

1.4.3 Alternative 2: Offshore Single Point Mooring

Under Alternative 2, the CCSC would not be deepened to –77 feet MLLW and would remain at –54 feet MLLW. The Offshore Single Point Mooring (SPM) Alternative is a multi-buoy, single-point mooring system consisting of multiple sets in an array of SPM buoys (also known as Single Buoy Moorings). It would be in the Gulf approximately 15 miles from the Gulf-side shoreline. To meet the project purpose, eight individual SPM buoys or four sets in an array would be required. Vessels would be loaded entirely offshore, eliminating the need to traverse the CCSC. This alternative would also eliminate dredging of the channel and the impacts associated with dredged material placement.

1.4.4 Alternative 3: Inshore/Offshore Combination

Under Alternative 2, the CCSC would not be deepened to –77 feet MLLW and would remain at –54 feet MLLW. Like Alternative 2, the Inshore/Offshore Combination Alternative is a SPM buoy located in the Gulf approximately 15 miles from the Gulf-side shoreline. Each set consists of two SPMs that would be serviced by either one or two pipelines from shore originating in Ingleside or Harbor Island facilities. Vessels are partially loaded inshore then traverse the CCSC offshore to the SPM to fully load. This alternative would also eliminate dredging of the channel and the impacts associated with dredged material placement.

2.0 EXISTING ENVIRONMENT

For the discussion of the existing environment, habitat types are described within the study area (see Figure 1), while the evaluation of potential EFH and fisheries resources focuses on the project area footprints (see Figure 2). It should be noted that the study and project areas are similar in habitat and community types.

2.1 HABITAT/COMMUNITY TYPES

Ecoregions are typically considered large geographic areas that are easily distinguished from adjacent regions by differing biotic and environmental factors or ecological processes. Fundamental differences among ecoregions often include changes in climate, physical geography, soils, and large-scale vegetative structure and composition. The study area is located entirely within the Western Gulf coastal plain (U.S. Environmental Protection Agency [EPA] level III ecoregion), which is a low-elevation area adjacent to the Gulf (Griffith et al. 2004; EPA, 2013). Due to its nutrient-rich soils and abundance of rain, much of the land has been converted to cropland and pastures for livestock. About a third of the State’s population resides within 100 miles of the coast along with a large part of the State’s industry. The large expanses of intact wetlands and coastal marshes along the coast are also important rest stops and wintering habitats for waterfowl and migrating birds. The warm Gulf waters are home to a variety of fish and shellfish, while the marshes and wetlands provide an abundance of habitat for birds and migrating waterfowl (Griffith et al., 2007).

The Western Gulf coastal plain can be further categorized into nine distinct EPA level IV ecoregions (Griffith et al., 2004; 2007). These level IV ecoregions are divided based on similarities of soils, vegetation, climate, geology, wildlife, and human factors. The following sections describe the four level IV ecoregions found within the study area.

Mid Coast Barrier Islands and Coastal Marshes: Stretching from Galveston Bay to Corpus Christi Bay, this ecoregion generally receives less annual precipitation than the Texas-Louisiana marshes. This region is characterized by barrier islands, tidal marshes, dunes, and salt/brackish/freshwater marshes. Cordgrass (*Spartina* spp.), saltgrass (*Distichlis* sp.), and sedges (*Cyperaceae* spp.) are typically found in the marsh habitats, while seacoast bluestem (*Schizachyrium scoparium*), and sea oats (*Uniola paniculata*) are found on sandy barrier islands. During the fall, endangered Whooping Cranes (*Grus americana*) migrate to the brackish marshes of Aransas National Wildlife Refuge to feed on blue crabs (*Callinectes sapidus*) (Griffith et al., 2007). This is the most dominant coastal ecoregion within the study area, including the entire barrier island strip from Packery Channel to Matagorda Island.

Floodplains and Low Terraces: This ecoregion consists of Holocene floodplains and alluvial deposits. Bottomland forests are the dominant vegetation type in this region. Large swaths of these floodplain woodlands have been converted to cropland, pastures, and forests. Freshwater flows through these historic floodplains have also been redirected for municipal, industrial, and agricultural uses. Combined with recent droughts in Texas and the Southwest, the Nueces River has experienced greatly diminished flows, which affect the salinity and productivity of downstream estuaries and bays (Griffith et al., 2007). Only a small portion of the study area contains this ecoregion type, occurring in the uppermost reaches of the Nueces River delta.

Southern Subhumid Gulf Coastal Prairies: Generally drier than the northern humid Gulf Coastal Prairie, this region only receives about 26 to 37 inches of rain annually. The regional soil temperature is hyperthermic meaning it stays above 71.6 degrees Fahrenheit (°F). Decades of fire suppression, overgrazing, and other landscape alterations have led to an increased abundance of woody and thorny-scrub plants such as honey mesquite (*Prosopis glandulosa*), huisache (*Acacia farnesiana*), and blackbrush (*Vachellia rigidula*). Prairie grassland species such as seacoast bluestem, Gulf muhly (*Muhlenbergia capillaris*), and switchgrass (*Panicum virgatum*) can still be found but in less abundance than described in historical records (Griffith et al., 2007).

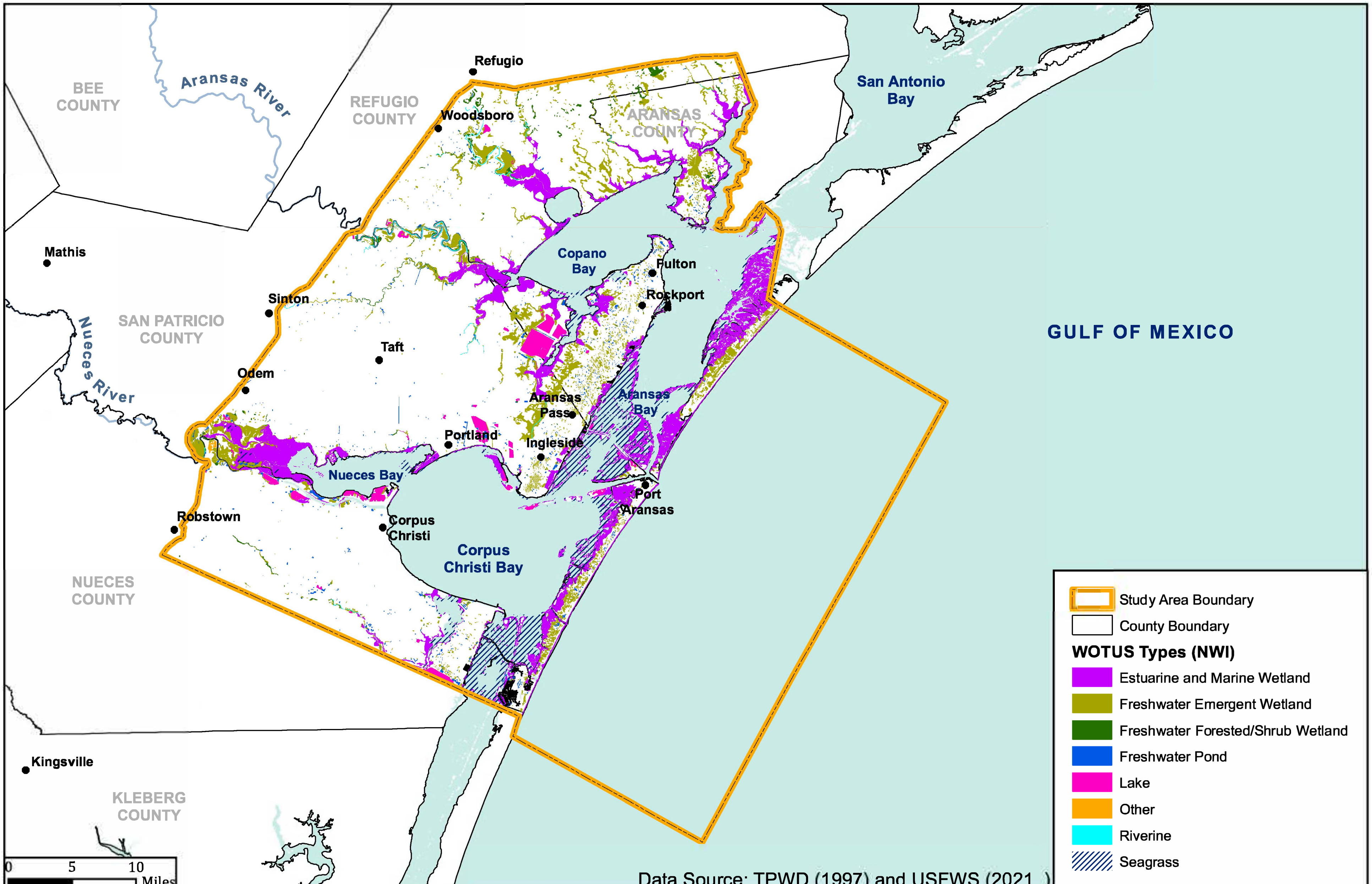
Southern Subhumid Gulf Coastal Prairies: This ecoregion is categorized by tidal mud flats, barrier island, seagrass meadows, and hypersaline lagoons. Seagrass meadows grow in the shallow, clear waters along the Laguna Madre. The seagrass beds serve as a productive nursery habitat for Red Drum (*Sciaenops ocellatus*) and grazing for sea turtles and Redhead Ducks (*Aythya americana*). Seacoast bluestem, sea oats, and other grassy vegetation can be found along the 113-mile-long island, the longest barrier island in the world. Ponds and marshes are populated with cordgrass, cattails (*Typha* spp.), and bulrush (*Seirpus* spp.). Sea turtles including the Leatherback (*Dermochelys coriacea*), Green (*Chelonia mydas*), Atlantic Hawksbill (*Eretmochelys imbricata*), and Kemp's Ridley (*Lepidochelys kempii*) are dependent on the sandy barrier islands for nesting habitat (Griffith et al., 2007). The study area includes only the northern-most reaches of this ecoregion along the Texas coast.

Non-tidal Wetlands: Non-tidal wetlands within the study area include depressional wetlands located inland of the tidal zone and palustrine fringe wetlands associated with the upper reaches of river systems in the study area, including the Nueces, Mission, and Aransas rivers. Depressional wetlands are regionally known as prairie potholes and are generally low topography divots within the prairie mosaic landscape. Rainfall and groundwater sources contribute to depressional wetland hydrology, along with poorly drained soils that increase water holding times and result in a hydrophytic vegetation community (Cowardin et al., 1979). These wetland types are also converted for agricultural uses, often in the form of upland cattle stock tanks or wetland rice farming (Moulton et al., 1997). Included within the depressional category are PAs with earthen levees and poor drainage, and the U.S. Fish and Wildlife Service (USFWS) National Wetlands Inventory geospatial maps identify several placement actions targeting BU that are mapped as wetlands (USFWS, 2021). Depressional wetlands are often dominated by herbaceous vegetation, and common wetland plant species include: spike rush (*Eleocharis* spp.), smartweed (*Polygonum hydropiperoides*), various sedges (*Carex* spp.), soft rush (*Juncus effusus*), and cattail (*Typha latifolia*). Some woody species can also be found in depressional wetlands, such as: black willow (*Salix nigra*), rattlebush (*Sesbania drummondii*), eastern baccharis (*Baccharis halimifolia*), and the non-native Chinese tallow (*Triadica sebifera*).

Palustrine fringe and riverine wetlands are also common within the study area and are located within the alluvial floodplains of the larger river systems and above the influence of tides. Like depressional wetlands, the plant communities are primarily herbaceous in nature, although later successional scrub-shrub and forested types are found in smaller amounts within the study area (USFWS, 2021). These wetlands include low-lying areas within floodplains and areas adjacent or abutting riverbanks. Wetland hydrology is often provided through a direct hydrologic nexus to riverine features or by seasonal and temporary flooding. While the sources of hydrology differ, there are often great similarities between wetlands lying adjacent to lakes or rivers and isolated wetlands of the same class in the same region (Cowardin et al., 1979).

Tidal Wetlands: Tidal wetlands include features that are in the brackish transition between freshwater and tidally influenced saltwater marshes all the way to the subtidal unconsolidated bottom of bay systems, known as deepwater habitats. Not including persistently inundated bay bottoms or the marine environment, estuarine emergent wetlands are the most prevalent within the study area, followed by intertidal unvegetated mud or sand flats and estuarine shrubs (USFWS, 2021). Common herbaceous species that occur in estuarine wetlands include glasswort (*Salicornia depressa*), salt marsh bulrush (*Scirpus maritimus*), smooth cordgrass (*Spartina alterniflora*), saltgrass (*Distichlis spicata*), and sea-oxeye (*Borrichia frutescens*). Black mangrove (*Avicennia germinans*) is the primary estuarine shrub species. Coastal estuarine wetlands of the bay systems within the study area play an important part in sustaining the health and abundance of life within the ecosystem. They are extremely important natural resources that provide essential habitat for fish, shellfish, and other wildlife (Rozas and Minello, 1998; Sather and Smith, 1984; Turner, 1977). Coastal wetlands also serve to filter and process agricultural and urban runoff and buffer coastal areas against storm and wave damage. Geospatial data from the National Wetlands Inventory was used to map existing estuarine and coastal wetland features in the study area (Figure 3).

Seagrass: Submerged aquatic vegetation (SAV) includes the true seagrasses such as shoal grass (*Halodule wrightii*), turtle grass (*Thalassia testudinum*), manatee grass (*Syringodium filiforme*), and clover grass (*Halophila engelmannii*), but also includes widgeon grass (*Ruppia maritima*) which is not considered a true seagrass because it also grows in freshwater environments. Seagrasses typically occur in water shallower than 4 feet mean low tide. In the study area, they occur primarily in Redfish Bay and the Upper Laguna Madre in large, contiguous tracts, and along the bay side of Mustang Island and San José Island inlets and shallow, relatively low energy areas (Texas Parks and Wildlife Department [TPWD], 2021a). Seagrass communities generate high primary productivity and provide refuge for numerous species including shrimp, fish, crabs, and their prey. Animal abundances in seagrass beds can be 2 to 25 times greater than in adjacent unvegetated areas (TPWD, 1999). All five taxa are found within the study area, with shoalgrass being the most abundant seagrass species across the bay systems (Congdon and Dunton, 2019).



PROJECT NO. PCA20166	Port of Corpus Christi Authority Corpus Christi Ship Channel Deepening Project	N W E S	FIGURE 3
DATE CREATED Date: 9/8/2021			
DATUM & COORDINATE SYSTEM NAD83 State Plane (feet) Texas South Central	**Wetlands and other Waters of the U.S.**		
FILE NAME Name: Fig_3-16_Wetlands			
PREPARED BY KLC			

Date Saved: 9/8/2021 12:47:20 PM

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There are approximately 41,583 acres of seagrass within the study area boundary (TPWD, 2021a). The net acreage of seagrass within the combined estuarine systems has remained relatively stable since 1958, although there has been fragmentation of this habitat and some local losses in Redfish Bay/Harbor Island. Seagrass beds dominated by turtle grass in southern Redfish Bay saw losses in 2017 following Hurricane Harvey that have not fully recovered. It remains to be seen whether the loss of slow growing turtle grass would lead to colonization by more opportunistic species like shoal grass and manatee grass (Congdon and Dunton, 2019). Seagrass beds in Nueces Bay are limited to the shoal grass and widgeon grass (Pulich et al., 1997).

The most currently available geospatial data for seagrass mapping was downloaded from the National Oceanic and Atmospheric Administration (NOAA) and TPWD Geographic Information System data sites and combined to provide mapping of seagrass (TPWD, 2021a). Figure 3 shows the seagrass mapped in the study area. Within the proposed project footprint, the depth of the existing channel, side slopes and regular maintenance are not conducive to supporting seagrasses. Therefore, the proposed project location is currently devoid of seagrass, and there are some small seagrass areas mapped adjacent to the channel in the shallow margins of dredge spoil islands near Ingleside, Texas (TPWD, 2021a).

Aquatic Communities: The open bay community is composed of plankton and nekton. Phytoplankton (microscopic algae) are the major primary producers (plant life) in the open bay, taking up carbon through photosynthesis and nutrients for growth. Phytoplankton are fed upon by zooplankton (small crustaceans), fish, and benthic consumers. Nekton (organisms that swim freely in the water column) consist mainly of secondary consumers, which feed on zooplankton and smaller nekton (Armstrong et al., 1987; Britton and Morton, 1989). Diverse and abundant plankton and nekton communities occur throughout the entire study area. Phytoplankton assemblages in Aransas Bay are comprised primarily of *Coscinodiscus* spp. in the winter and *Rhizosolenia alata* in the summer. Blue-green and green algae dominate the upper portions of the Mission-Aransas Estuary, whereas diatoms dominate the lower estuary. Diatoms (*Thalassionema nitzschioides*, *Thalassiothrix frauenfeldii*, and *Chaetoceros* spp.) make up over 70 percent of the phytoplankton community in Corpus Christi Bay. In Nueces Bay and the Upper Laguna Madre, the same diatoms dominate abundance, especially during the winter months, followed by the dinoflagellate *Ceratium furca* (Tunnell et al., 1996; Hildebrand and King, 1977). Salinity appears to be the controlling factor of phytoplankton abundance, with low salinities corresponding with high phytoplankton numbers and high salinities (greater than 60 parts per thousand [ppt]) corresponding with low to nonexistent numbers, as occurs in some areas of the Upper Laguna Madre (Armstrong et al., 1987; Hildebrand and King, 1977).

Armstrong et al. (1987) and Tunnel et al. (1996) describe the dominant zooplankton in Copano and Aransas bays as calanoid copepod *Acartia tonsa* with maximum abundances occurring in the winter and spring. Barnacle nauplii and *Acartia tonsa* dominated zooplankton assemblages in Corpus Christ and Nueces bays during every season except late winter and early spring when the dinoflagellate *Noctiluca scintillans* dominated. Calanoid copepods, especially *Acartia tonsa,* were the dominant species in Oso Bay and the Upper Laguna Madre with peak abundance occurring in the spring (Armstrong et al., 1987; Tunnell et al., 1996).

Texas bay systems support a diverse nekton population including fish, shrimp, and crabs. Some of these are resident species, spending their entire life in the bay, whereas others are migrant species spending only a portion of their life cycle in the estuary (Armstrong et al., 1987). Many of these species are estuarine-dependent, migrating through passes of the Gulf to use the different habitats in the bay including SAV, marsh, and oyster reefs as nursery habitat (Tunnell and Judd, 2002). With respect to the Upper Laguna Madre, the hypersaline waters can affect fish osmotic balance and decrease dissolved oxygen; however, fish occupying these areas are euryhaline (able to tolerate a wide range of salinities) and better able to cope with the harsh conditions (Gunter, 1967).

Dominant nekton inhabiting the study area include blue crab, white shrimp (*Litopenaeus setiferus*), brown shrimp (*Farfantepenaeus aztecus*), pink shrimp (*Farfantepenaeus duorarum*), Atlantic Croaker, Bay Anchovy (*Anchoa mitchilli*), Code Goby (*Gobiosoma robustum*), Black Drum (*Pogonias cromis*), Gulf Menhaden (*Brevoortia patronus*), Hardhead Catfish (*Arius felis*), Pinfish (*Lagodon rhomboides*), Sheepshead (*Archosargus probatocephalus*), silversides (*Menidia* sp.), Southern Flounder (*Paralichthys lethostigma*), Spot (*Leiostomus xanthurus*), and Spotted Seatrout (*Cynoscion nebulosus*) (Nelson et al., 1992; Tunnell et al., 1996; Pattillo et al., 1997; EPA, 2020). These species are ubiquitous along the Texas coast and are unaffected by salinity changes. Differences in abundance occur seasonally, with the fall usually the lowest in biomass and number. Newly spawned fish and shellfish begin migrating into the bays in winter and early spring with the maximum biomass during the summer (Pattillo et al., 1997).

Open-bay Bottom: The open-bay bottoms in the study area include all unvegetated subtidal areas with various sediment types. These are open systems that greatly interact with the overlying waters and adjacent habitats (Armstrong et al., 1987; Tunnell and Judd, 2002). Benthic organisms are divided into two groups: epifauna, such as crabs and smaller crustaceans that live on the surface of substrate, and infauna, such as mollusks and polychaetes that burrow into the substrate (Green et al., 1992). Mollusks and other infaunal organisms are filter feeders that strain suspended particles from the water column. Other infauna, such as polychaetes, feed by ingesting sediments and extracting nutrients. Many of the epifauna and infauna feed on plankton, which are fed upon by numerous fish and birds (Armstrong et al., 1987; Lester and Gonzales, 2011).

The distribution of benthic macroinvertebrates is primarily influenced by bathymetry and sediment type (Calnan et al., 1989). Mud (silt and clay) is the dominant sediment type throughout this bay-estuary-lagoon system; however, sandier sediments occur along bay margins and is more common in the Laguna Madre and Redfish Bay. Benthic macroinvertebrates found in these sediments are primarily polychaetes (including *Polydora caulleryi*, *Tharyx setigera*, and *Mediomastus ambiseta*), bivalves, crustaceans (including *Listriella clymenellae*), and gastropods (White et al., 1983; Montagna and Froeschke, 2009).

Benthic samples were also collected in the study area as part of the EPA National Coastal Assessment Program (EPA, 2020). These samples were dominated primarily by polychaetes, amphipods, and gastropods, same as were observed by White et al. (1983) and Montagna and Froeschke (2009). Polychaetes dominated the samples, including *Paleanotus heteroseta*, *Aricidea fragilis*, *Capitella capitata*, *Mediomastus* sp., *Tharyx annulosus*, *Paraonides lyra*, and *Asychis elongata* (EPA, 2020).

Oyster Reef: Most oyster reefs are subtidal or intertidal and found near passes and cuts, and along the edges of marshes. Within the study area Eastern oyster (*Crassostrea virginica*) are found within Copano Bay (142 acres total), Aransas Bay (91 acres total), Mesquite Bay (199 acres total), and Redfish Bay/Harbor Island (113 acres total), growing perpendicular to the shoreline, with some small patch reefs scattered in Nueces (25 acres total) and Corpus Christi (1.14 acres total) bays. Most oyster reefs in Corpus Christi Bay are dead; but living oyster reefs were found in Nueces Bay and the intertidal zone (Pulich, et al., 1997; Tunnell et al., 1996).

Oyster reefs are formed where a hard substrate and adequate currents are plentiful, and they are ecologically important. Currents carry nutrients to the oysters and sediment and waste are filtered from the water by the oyster. Oysters can filter water 1,500 times the volume of their body per hour, which, in turn, influences water clarity and phytoplankton abundance (Lester and Gonzalez, 2011; Powell et al., 1992). Due to their lack of mobility and their tendency to bioaccumulate pollutants, oysters are an important indicator species for determining contamination (Lester and Gonzalez, 2011).

While oysters can survive in salinities ranging from 5 to 40+ ppt, they thrive within a range of 10 to 25 ppt where pathogens and predators are limited. The low-salinity end of the range is critical for osmotic balance. Oysters can survive brief periods of salinities less than 5 ppt by remaining tightly closed. Oysters will remain closed until normal salinities are reestablished or until they deplete their internal reserves and perish. In contrast, predators, such as oyster drills, welks, and crabs reduce oyster populations during long periods of high salinities (Cake, 1983). *Perkinsus marinus* (Dermo) is the most common and deadly oyster pathogen in the bays bordering the Gulf. It is a primary factor affecting habitat suitability.

Many organisms, including mollusks, barnacles, crabs, gastropods, amphipods, polychaetes, and isopods, are found living on oyster reefs, forming a very diverse community (Sheridan et al., 1989). Oyster reef communities are dependent upon food resources from the open bay and marshes. Many organisms feed on oysters, including fish such as black drum, crab, and gastropods, such as the oyster drill (*Thais haemastoma*) (Lester and Gonzales, 2011; Sheridan et al., 1989). When oyster reefs are exposed during low tides, shore birds will use the reef areas for resting (Armstrong et al., 1987).

Some commercial harvesting of oysters occurs in Aransas Bay, but none in Corpus Christi Bay or the Upper Laguna Madre (Pers. Comm., D. Topping [TPWD], 2016). In Texas, all molluscan shellfish must be harvested from areas that have been approved or conditionally approved as designated by the Texas Department of State Health Services (Texas Department of State Health Services [TDSHS], 2021). This status is subject to change to prohibited or restricted by the TDSHS at any time due to extreme weather conditions, oil spills, and red tides. Currently, oysters are approved for harvesting from much of Corpus Christi, Aransas, and Copano bays (TDSHS, 2021).

Jetty Communities: Jetty communities occurring within the study area include the Aransas Pass and Packery Channel jetties. Found along the mouth of inlets, these granite jetties serve to stabilize channels by extending into the Gulf beyond sandbars and breaking waves (Fikes and Lehman, 2010). These man-made jetties exhibit a diverse rocky shore community that can effectively transport larva into and out of these passes (Britton and Morton, 1989).

Jetty communities are comprised of stone crab (*Menippe adina*), porcelain crab (*Petrolisthes armatus*), hermit crab (*Clibanarius vittatus*), tree oysters (*Isogonom bicolor*), horse oyster (*Ostrea equestris*), fragile barnacle (*Chthamalus fragilis*), striped barnacle (*Balanus amphitrite*), ivory barnacle (*Balanus eburneus*), lined periwinkle (*Nodilittorina lineolata*), Atlantic Needlefish (*Strongylura marina*), Sergent Major (*Abudefduf saxatilis*), common octopus (*Octopus vulgaris*), false limpet (*Siphonaria pectinata*), sea lettuce (*Ulva fasciata*, *Gelidium crinale*, *Pandina vickersiae*), red sea urchin (*Arbacia punctulata*), anemones (*Bunodosoma cavernata*, *Anthopleura krebsi*, *Aiptasiomorpha texaensis*), common hydroids (*Bougainvilla inaequalis*, *Obelia adichotoma*, *Gonothyraea gracilis*), (Britton and Morton, 1989). Numerous macroalgae inhabit this rocky intertidal habitat including *Gelidium pusillum*, *Gracilaria tikvahiae*, *Grateloupia filicina*, and *Hypnea musciformis* (Fikes and Lehman, 2010). Gorgonian (soft) corals, known to be successful in jetty environments, can also be found including *Leptogorgia virgulate*, *Leptogorgia setacea*, and *Leptogorgia hebes* (Williamson et al., 2011).

Offshore Bottom Communities: There are few seagrasses or attached algae found in the offshore sands due to the strong currents and unstable sediments. Most of the bottom surface is populated with macroinfauna such as an occasional hermit crab (Paguroidea), portunid crab (Portunidae), or ray (Batoidea). Even though there is little life on the sand surface, the overlying waters are highly productive. Phytoplankton are abundant, including microscopic diatoms, dinoflagellates, and other algae (Britton and Morton, 1989).

Much of the faunal diversity lies buried in the sand and relies on phytoplankton for food. Bivalves found in offshore sands include the blood ark (*Anadara ovalis*), incongruous ark (*Anadara brasiliana*), southern quahog (*Mercenaria campechiensis*), giant cockle (*Dinocardium robustum*), disk dosini (*Dosinia discus*), pen shells (*Atrina serrata*), common egg cockle (*Laevicardium laevigatum*), crossbarred venus (*Chione cancellata*), tellins (*Tellina* spp.), and the tusk shell (*Dentalium texasianum*). One of the most common species occurring in the shallow offshore sands is the sand dollar (*Mellit quinquiesperforata*), followed by several species of brittle stars (*Hemipholis elongata*, *Ophiolepis elegans*, and *Ophiothrix angulata*). Many gastropods are common, including the moon snail (*Polinices duplicatus*), ear snail (*Sinum perspectivum*), Atlantic auger (*Terebra dislocata*), Salle's auger (*Terebra salleano*), scotch bonnet (*Phalium granulatum*), distorted triton (*Distrosio clathrata*), wentletraps (*Epitonium* sp.), and whelks (*Busycon* spp.). Crustaceans inhabit these waters, including white and brown shrimp (both commercially harvested species), rock shrimp (*Sicyonia brevirostris*), blue crabs, mole crabs (*Albunea* spp.), speckled crab (*Arenaeus cribrarius*), box crab (*Calappa sulcata*), calico crab (*Hepatus epheliticus*), and pea crab (*Pinotheres maculatus*). The most abundant infaunal organisms with respect to the number of individuals are polychaetes (Capitellidae, Orbiniidae, Magelonidae, and Paraonidae) (Britton and Morton, 1989).

Artificial Reefs: In the Gulf, two types of artificial reefs exist: those structures placed to serve as oil and gas production platforms and those intentionally placed to serve as artificial reefs (GMFMC, 2004). The more than 4,500 oil and gas structures in the Gulf form unique reef ecosystems that extend throughout the water column, providing a large volume and surface area, dynamic water-flow characteristics, and a strong profile (Ditton and Falk, 1981; Dokken, 1997; Stanley and Wilson, 1990; Vitale and Dokken, 2000). Fish are attracted to oil platforms because these structures provide food, shelter from predators and ocean currents, and a visual reference, which aids in navigation for migrating fishes (Bohnsack, 1989; Duedall and Champ, 1991; Meier, 1989; Vitale and Dokken, 2000). The size and shape of the structure affect community characteristics of pelagic, demersal, and benthic fishes (Stanley and Wilson, 1990). Many scientists believe that the presence of oil platform structures allows fish populations to grow, which increases fishery potential (Scarborough-Bull and Kendall, 1994).

Artificial reefs are colonized by a diverse array of microorganisms, algae, and sessile invertebrates, including shelled forms (barnacles, oysters, and mussels), as well as soft corals (bryozoans, hydroids, sponges, and octocorals) and hard corals (encrusting, colonial forms). These organisms (referred to as the biofouling community) provide habitat and food for many motile invertebrates and fishes (GMFMC, 2004).

Species associated with the platforms that are not dependent on the biofouling community for food or cover include the Red Snapper (*Lutjanus campechanus*), Atlantic Spadefish (*Chaetodipterus faber*), Lookdown (*Selene vomer*), Atlantic Moonfish (*Selene setapinnis*), Creole-fish (*Paranthias furcifer*), Whitespotted Soapfish (*Rypticus maculatus*), Gray Triggerfish (*Balistes capriscus*), and Lane Snapper (*Lutjanus synagris*), all transients (move from platform to platform) and resident species (always found on the platforms), including Red Snapper, Large Tomate (*Haemulon aurolineatum*), and some large groupers. Other resident species that are dependent upon the biofouling community for food or cover include numerous blennies, Sheepshead, and small grazers (butterflyfishes, Chaetodontidae). Highly transient, large predators associated with these structures include Barracuda (*Sphyraena barracuda*), Almaco Jack (*Seriola rivoliana*), Hammerhead Sharks (*Sphyrna* spp.), Cobia (*Rachycentron canadum*), mackerels (Scombridae), other jacks (*Caranx* spp.), and the Little Tunny (*Euthynnus alletteratus*) (GMFMC, 2004).

A total of 15 active oil and gas platforms occur within the study area, far fewer than are found in the northern Gulf (U.S. Energy Information Administration, 2021). In addition, the TPWD operates the Texas Artificial Reef Program that insures the continued enrichment of the Texas Gulf fishery and fishing opportunities (Stephan et al., 1990). There are three TPWD artificial reef sites that occur within the study area: Boatmen's Reef, located 4.7 miles from Aransas Pass; Lonestar Reef, located 8.8 miles from Mustang Island; and Mustang Island-775 Reef, located 10.6 miles from Mustang Island. These reefs are each 40 acres in size and are at depths from 60 to 73 feet. The materials of these nearshore reefs consist of barges and/or boats, well heads, concrete culverts, and reef pyramids. The Mustang Island Liberty Ship Reef site is located 18.1 miles from Mustang Island, just outside the study area. This artificial reef site consists of two Liberty Ships including: the Charles A. Dana (bow and stern) and the Conrad Weiser, Rachael Jackson. Water depth at this site ranges from 108 to 111 feet (TPWD, 2021b).

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3.0 ESSENTIAL FISH HABITAT

Essential Fish Habitat is defined as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity" (16 United States Code 1802(10)). EFH is found in the tidally influenced or estuarine emergent wetland communities and brackish or marine open-water communities within the proposed project areas (see Figure 1). These communities play an important role in the cycling of nutrients and food energy through coastal ecosystems. Communities, such as wetlands, produce detritus that is transferred to food energy for higher trophic levels via zooplankton, bivalves, crustaceans, and small fish. Some organisms that serve as intermediate stages of the food web utilize benthic, epibenthic, and nearshore Gulf habitats. Dominant motile benthic species likely to occur in the shallow fringes of these communities include serpulid worms (polychaetes), gastropods, such as the oyster drill, and crustaceans, such as the hermit crab (*Clibanarius vittatus*) and mud crabs (*Rhithropanopeus harrisii*, *Neopanope texana*, and *Panopeus herbstii*). Other common invertebrates that may occur within the study and project areas are bivalves, such as the common rangia (*Rangia cuneata*) and Eastern oyster. Sessile macroepifauna, such as the sea pansy (*Renilla mulleri*) and acorn barnacles (*Balanus* sp.), are found throughout the nearshore Gulf and are likely to occur within the study area on hard surfaces, such as pilings, rock jetties, and other structures (Hoese and Moore, 1998). Many of these species are dominant food items in the diet of fish species, including sciaenids and flounder, as well as large marine fishes such as grouper and snapper.

Estuaries such as Corpus Christi Bay often contribute to the shellfish resources of the Gulf. Shellfish species range from those located only in brackish wetlands to those found mainly in saline marsh and inshore coastal waters. Multiple species of penaeid shrimp are expected to occur in the vicinity of the proposed CDP; however, brown shrimp and white shrimp are the most numerous (Nelson et al., 1992). At least eight species of portunid (swimming) crabs are common residents of the coastal and estuarine waters of the northern Gulf. Brown shrimp, white shrimp, and blue crabs are the primary shellfish located throughout the study area that comprise a substantial fishery (Pattillo et al., 1997).

Life histories of many Gulf fish can be characterized as estuarine dependent. These species typically spawn in the Gulf, and their larvae are carried inshore by currents. Juvenile fish generally remain in these estuarine nurseries for about a year, taking advantage of the greater availability of food and protection that estuarine habitats afford. Upon reaching maturity, estuarine-dependent fishes migrate to sea to spawn (returning to the estuary on a seasonal basis) or migrate from the shallow estuaries to spend the rest of their lives in deeper, offshore waters (Pattillo et al., 1997).

Estuary-dependent species potentially occurring within the study area include menhaden, shrimps, crabs, and sciaenids. Common species occurring in the study area include Striped Mullet (*Mugil cephalus*), Red Drum, Atlantic Croaker, Spot, Sand Seatrout (*Cynoscion arenarius*), and Spotted Seatrout. Resident estuarine fishes, which inhabit estuaries throughout their entire life cycle, likely to occur within the study area include killifishes (*Fundulus* spp.), Sheepshead Minnow (*Cyprinodon variegatus*), and silversides (Nelson et al., 1992; Pattillo et al., 1997).

Non-estuarine-dependent fishes, including coastal pelagic marine fishes, are also likely to occur in the vicinity of the proposed CDP. The common coastal pelagic families occurring in the region are Carcharhinidae (requiem sharks), Elopidae (ladyfish), Engraulidae (anchovies), Clupeidae (herrings), Scombridae (mackerels and tunas), Carangidae (jacks and scads), Mugilidae (mullets), Pomatomidae (bluefish), and Rachycentridae (Cobia). Coastal pelagic species traverse shelf waters of the region throughout the year. Some species form large schools (e.g., Spanish Mackerel [*Scomberomorus maculatus*]), while others travel singly or in smaller groups (e.g., Cobia).

Table 2 provides a list of representative commercial and game fish species known to occur in the study area.

3.1 FISHERIES OF SPECIAL CONCERN

Fish and macroinvertebrate species of special concern (including those of economic importance) that occur in the vicinity of the project area include those with designated EFH and those of commercial and recreational value. In 1996, the MSFCMA mandated the identification of EFH for all Federally managed species. For a list of commercial and recreational fisheries species within and adjacent to the project areas, refer to Table 2. The categories of EFH that occur within the project area include estuarine water column, estuarine mud and sand bottoms (unvegetated estuarine benthic habitats), estuarine shell substrate (oyster reefs and shell substrate), estuarine emergent wetlands, seagrasses, and mangroves. Additionally, portions of the project area are in marine waters and include the marine water column and unconsolidated marine water bottoms.

3.2 RECREATIONAL AND COMMERCIAL FISHERIES

Table 2 provides a list of representative commercial and recreational fish and shellfish known to occur in the study area. The main commercial species in Aransas Bay, Corpus Christi Bay, and the Upper Laguna Madre are Black Drum, Southern Flounder, Sheepshead, mullet (*Mugil* sp.), blue crab, brown shrimp, white shrimp, and pink shrimp. Of the bay systems included in the study area, the Upper Laguna Madre had the highest commercial finfish harvest of all bays on the Texas coast, with 43.8 percent of the total finfish landings, followed by Corpus Christi Bay with the fourth-highest (9.3 percent) and Aransas Bay with the sixth-highest (3.0 percent) (pers. com. D. Topping [TPWD], 2021).

In the Gulf portion of the study area, commercially harvested species include Black Drum, flounder, mullet, Cobia, grouper, snapper, and other. Snapper make up most of the commercial harvest, followed by grouper (Serranidae), Cobia, and mullet (pers. com. D. Topping [TPWD], 2021). Shrimp and blue carb are also commercially harvested from this area of the Gulf, with brown shrimp comprising the majority, followed by white and pink shrimp (NOAA, 2021a).

Table 2
Representative Recreational and Commercial Fish and Shellfish Species Known to Occur in the Study Area

Common Name	Scientific Name[1]
Brown shrimp	*Farfantepenaeus aztecus*
Pink shrimp	*F. duorarum*
White shrimp	*Litopenaeus setiferus*
Blue crab	*Callinectes sapidus*
Bull Shark	*Carcharhinus leucas*
Blacktip Shark	*C. limbatus*
Atlantic Sharpnose Shark	*Rhizoprionodon terraenovae*
Gulf Menhaden	*Brevoortia patronus*
Striped Mullet	*Mugil cephalus*
Cobia	*Rachycentron canadum*
Greater Amberjack	*Seriola dumerili*
Lesser Amberjack	*S. fasciata*
Red Snapper	*Lutjanus campechanus*
Lane Snapper	*Lutjanus synagris*
Sheepshead	*Archosargus probatocephalus*
Sand Seatrout	*Cynoscion arenarius*
Spotted Seatrout	*Cynoscion nebulosus*
Atlantic Croaker	*Micropogonias undulatus*
Black Drum	*Pogonias cromis*
Red Drum	*Sciaenops ocellatus*
Little Tunny	*Euthynnus alletteratus*
King Mackerel	*Scomberomorus cavalla*
Spanish Mackerel	*S. maculatus*
Southern Flounder	*Paralichthys lethostigma*

Source: Nelson et al. (1992); Pattillo et al. (1997); NOAA (2021a); Personal communication with Darin Topping (September 2021) from the TPWD, Rockport Marine Lab, Rockport, Texas.

[1] Fish species according to Page et al. (2013).

During 2014 to 2020, recreational bay fishing represented 12.1 percent of the Upper Laguna Madre catch, 10.8 percent of the Aransas Bay catch, and 7.6 percent of the Corpus Christi Bay catch. The main recreational species include Spotted Seatrout (*Cynoscion nebulosus*), Black Drum, Red Snapper, and King Mackerel (*Scomberomorus cavalla*) (pers. com. M. Fisher [TPWD], 2021).

3.2.1 Life History Characteristics

A description of life history characteristics, habitat preferences, and distribution of commercially and recreationally important species, except for those described in Section 3.4, is provided in the following sections. These estuarine-dependent species serve as prey for other fisheries managed under the GMFMC.

Blue Crab (*Callinectes sapidus*)

Blue crabs are harvested commercially and recreationally throughout the coastal waters of the Gulf. These fisheries have become increasingly important in the Gulf, with reported landings exceeding 3.4 million pounds in 2020 (NOAA, 2021a). Blue crabs occupy a variety of habitats, including the upper, middle, and lower estuaries, as well as associated marine environments, depending on their life history stage. Larvae occupy the lower estuary and marine water with salinities greater than 20 ppt. Blue crabs first enter the estuary during the megalopae life stage where they begin a benthic existence. Spawning occurs during the spring, summer, and fall (Pattillo et al., 1997).

Factors that affect the distribution and survival of blue crabs are substrate, food availability, water temperature, and salinity. Blue crabs are opportunistic omnivores and feed on fish, detritus, crustaceans, mollusks, and other blue crabs. They are also prey for higher trophic levels, including diving ducks, herons, and predatory fish, including commercial and recreational species (Perry and McIlwain, 1986).

Blue crabs may be found throughout the tidally influenced emergent wetlands and open water areas of the study area. All life stages of blue crab are common to highly abundant year-round in the study area (Nelson et al., 1992; Pattillo et al., 1997).

Gulf Menhaden (*Brevoortia patronus*)

Gulf Menhaden occur throughout the northern Gulf from the Caloosahatchee River, Florida, to the Yucatan, Mexico (Hoese and Moore, 1998). Juvenile menhaden prefer low salinity, open-water habitats adjacent to emergent marsh. Adults often occur offshore. This species makes up a majority of the commercial "pogy" purse-seine fishery. As filter feeders, they feed on phytoplankton, zooplankton, and organic detritus. Spawning season usually occurs from October through March but may begin in August and last as late as May. Spawning may occur multiple times during a single spawning season (Lassuy, 1983a; Pattillo et al., 1997). In the study area, juvenile Gulf Menhaden are common to abundant year-round, adults are common and juveniles abundant July through November, and larvae are common to abundant September through November (Nelson et al., 1992).

Striped Mullet (*Mugil cephalus*)

Striped Mullet spawn offshore near the surface from October to March. Eggs and sperm are released into the water column for fertilization. Once they reach the pre-juvenile stage, they enter the bays and estuaries to mature. Sexual maturity is reached at 3 years of age, and adults remain near shore throughout their life. Striped mullet feed mainly on microalgae, detritus, and sediment particles (Pattillo et al., 1997). Adult and juvenile Striped Mullet are common to abundant year-round in the study area, while larval Striped Mullet are found October through May the Laguna Madre (Nelson et al., 1992).

Sheepshead (*Archosargus probatocephalus*)

Sheepshead is an estuarine-dependent species that inhabits much of the Atlantic and Gulf coasts of the United States. Spawning occurs offshore from February through April, with the peak in March and April. Eggs typically are laid over the inner continental shelf (Pattillo et al., 1997). Larvae are pelagic, but move into estuaries, seeking refuge in seagrass (Lee et al., 1980; Pattillo et al., 1997). Juveniles begin leaving seagrass in late summer, congregating with adults around nearshore reefs as they mature (Jennings, 1985; Pattillo et al., 1997). Adults also use oyster reefs, shallow muddy bottoms, marshes, piers and rocks, and bare sands of the surf zone. Larval and juvenile Sheepshead consume primarily zooplankton, whereas larger juveniles and adults prey on blue crab, oysters, clams, and small fish (Pattillo et al., 1997).

All life stages of Sheepshead are common to highly abundant year-round in the study area (Nelson et al., 1992; Pattillo et al., 1997). Since juveniles are typically associated with vegetation (Pattillo et al., 1997), they may occur in the tidally influenced brackish marshes in the study area. Adults may occur in open-water habitat and probably would not occur in brackish marsh habitats in the study area.

Sand Seatrout (*Cynoscion arenarius*)

Sand Seatrout is an estuarine species that occurs throughout the Gulf coast in nearshore habitats (Pattillo et al., 1997). Spawning occurs primarily in shallow, higher salinity habitats from February through October (Pattillo et al., 1997; Sutter and McIlwain, 1987). Typical habitats preferred by juvenile sand seatrout are flooded marshes and seagrass meadows with soft organic substrates. Adults are found in open water over most substrates. Sand Seatrout migrate to the Gulf in late fall or winter to spawn. Eggs and sperm are released into the water column for fertilization. Larvae are carried into the estuary by the currents and migrate to the upper areas of the estuary, preferring channels, small bayous, and shallow marshes to develop (Pattillo et al., 1997). Adult Sand Seatrout reach sexual maturity at 12 months (Pattillo et al., 1997). They feed mainly on fish and shrimp (Overstreet and Heard, 1982).

Juveniles and adults are common to abundant almost year-round in the project areas, while larvae are common January through March in Corpus Christi Bay (Nelson et al., 1992). There is a high probability of juvenile and adult Sand Seatrout occurring in the study area, especially in tidally influenced emergent wetlands and open-water habitats.

Spotted Seatrout (*Cynoscion nebulosus*)

Spotted Seatrout are estuarine residents, spending their entire life cycle in estuarine waters (Lassuy, 1983b). Spawning typically occurs from March to October, with a peak between April and August. Spawning takes place in passes and in shallow, grassy habitats in bays with moderate salinities. Adults and juveniles prefer seagrass meadows and sandy to muddy substrates. Larval Spotted Seatrout feed on zooplankton while juveniles feed on larger invertebrates and small fish. As adults their diet consists primarily of fish (Pattillo et al., 1997).

Juvenile Spotted Seatrout are common year-round occurring in tidally influenced emergent wetlands in the study area; adults are common and may be found throughout the study area all year. Larvae are common during March through October throughout the study area (Nelson et al., 1992).

Atlantic Croaker (*Micropogonias undulatus*)

Atlantic Croaker spawn near passes in the Gulf from September through May. Eggs and sperm are randomly released into the water column for fertilization. Early larval stages are usually offshore and are carried by currents inshore to estuarine habitats. Juvenile Atlantic Croaker move into tributaries where they spend 6 to 8 months before migrating offshore starting in March and lasting until November (Lassuy, 1983c; Pattillo et al., 1997). Adults have seasonal migrations moving into estuarine waters typically in the summer and then into marine waters typically in the fall (Pattillo et al., 1997).

Adult Atlantic Croaker are common to abundant year-round within the study area (Nelson et al., 1992; Pattillo et al., 1997). Juveniles are highly abundant in the study area through the spring before migrating to the Gulf in April or early summer (Lassuy, 1983c; Nelson et al., 1992). There is a high probability of juvenile and adult Atlantic Croaker occurring in the study area, especially in fresh-intermediate marshes and open-water habitats.

Black Drum (*Pogonias cromis*)

Black Drum is an estuarine-dependent species that occurs in open bays and estuaries. Mature Black Drum spawn in the open bay, in nearshore Gulf waters, or in connecting passes from January to mid-April. During spawning, eggs and sperm are released into the water column for fertilization. Black Drum larvae and juveniles move into upper bay areas and tidal creeks, where they remain until they reach about 4 inches in length and then move into the open bay. Black Drum remain in the bay until they reach sexual maturity (about 2 years) (Pattillo et al., 1997).

Adult and juvenile Black Drum are common and occur throughout the study area year-round (Nelson et al., 1992; Pattillo et al., 1997). Larval Black Drum occur from February through April over the continental shelf. Juveniles inhabit muddy bottoms in marsh habitats year-round and adults are predominantly estuarine, preferring unvegetated sand and mud bottoms and oyster reefs year-round (Nelson et al., 1992; Pattillo et al., 1997; Sutter et al., 1986).

Southern Flounder (*Paralichthys lethostigma*)

Southern Flounder are distributed throughout estuarine and coastal waters of the Gulf from Florida to Texas (Hoese and Moore, 1998). Spawning occurs during late fall and early winter in nearshore waters (Gilbert, 1986). Once they reach sexual maturity at 2 years of age, they begin migrating to the Gulf to spawn (Daniels, 2000; Pattillo et al., 1997). Juveniles and adults are demersal and prefer estuarine, riverine, or marine environments, depending on the hydrography (Pattillo et al., 1997). This species is found over unconsolidated clayey silts and organic muds or may be associated with seagrass meadows or flooded marsh

(Pattillo et al., 1997). Southern Flounder are carnivorous during most life history stages, feeding mostly on crustaceans (Gilbert, 1986).

Juvenile Southern Flounder are common to abundant throughout the study area January through October. Adults are most common in the study area from the spring through late fall. During late fall, they move to deeper offshore waters to spawn (Nelson et al., 1992; Pattillo et al., 1997; Reagan and Wingo, 1985). Within the study area, Southern Founder may occur in the tidally influenced emergent wetlands and within or adjacent to open-water areas.

3.3 FEDERALLY MANAGED SPECIES

Information regarding Federally managed species was obtained through the NOAA EFH Mapper (NOAA, 2021c), NOAA Gulf of Mexico Essential Fish Habitat: Offshore Products (NOAA, 2013), and NMFS Consolidated Atlantic Highly Migratory Species Fishery Management Plan (NMFS, 2009).

NMFS and the GMFMC had identified the study area as using EFH for brown, pink, and white shrimp; Gulf stone crab; Blacknose, Spinner, Silky, Finetooth, Bull, Blacktip, Tiger Lemon, Atlantic Sharpnose, Scalloped Hammerhead, and Bonnethead sharks; Red and Gag Grouper; Scamp; Cobia; Dolphin; Greater and Lesser Amberjack; Red, Gray, Lane, and Vermilion Snapper; Red Drum; Little Tunny; King and Spanish Mackerel; and Sailfish. The categories of EFH that occur within the study area include estuarine water column, estuarine mud and sand bottoms (unvegetated estuarine benthic habitats), estuarine shell substrate (oyster reefs and shell substrate), estuarine emergent wetlands, seagrasses, and mangroves. Additionally, portions of the project located in marine waters include the marine water column, unconsolidated marine water bottoms, and natural structural features.

Within areas identified as EFH, Habitat Areas of Particular Concern may be designated to focus conservation priorities on areas that are important to the life cycles of Federally managed species and may warrant more-targeted protection measures. Designation of specific Habitat Areas of Particular Concern is based on ecological function, habitats sensitive to human-induced environmental degradation, stressors of development activities, and habitat rarity (Dobrzynski and Johnson, 2001). No Habitat Areas of Particular Concern are designated in the study area (NOAA, 2021c).

In addition, the EPA CWA Section 404(b)(1) (40 CFR 230) designates Special Aquatic Sites as sanctuaries and refuges, wetlands, mud flats, vegetated shallows, coral reefs, and riffle and pool complexes. Triton Environmental Solutions (2021, 2022) and Mott MacDonald (2021, 2022) performed an aquatic survey and wetland delineation of the proposed placement sites for the CDP for SAV, live oysters, and wetlands. It should be noted that these surveys included a 500-foot buffer beyond the direct project footprint. No wetlands or SAV occur within the proposed channel dredging footprint, however a total of 16.61 acres of tidal wetlands and 181.22 acres of non-tidal wetlands would be impacted with construction of placement actions targeting BU. A total of 0.10 acres of live oyster reef habitat occurs at placement site HI-E. A total of 6.88 acres of SAV would be impacted by the CDP; 3.46 acres in PA4, 0.01 acres in SS1, and 3.41 acres in HI-E.

3.4 LIFE HISTORY CHARACTERISTICS OF FEDERALLY MANAGED SPECIES

The following describes the preferred habitat, life history stages, and relative abundance of each Federally managed species occurring in the study area. Table 3 describe the relative abundance and adult and juvenile presence of EFH managed species occurring in the study area. Relative abundance is defined as follows (Nelson et al., 1992):

- Highly Abundant: Species numerically dominant relative to others
- Abundant: Species often encountered in substantial numbers relative to others
- Common: Species generally encountered but not in large numbers and not evenly distributed over specific salinity zones
- Rare: Species present but not frequently encountered
- Not Present: Species not found in area

Brown Shrimp (*Farfantepenaeus aztecus*)

Adult brown shrimp are most abundant off the coasts of Texas, Louisiana, and Mississippi from March to December (Pattillo et al., 1997). They inhabit a wide range of water depths up to approximately 360 feet. Nonspawning adults prefer turbid waters and soft sediment. Brown shrimp eggs are demersal and are deposited offshore. The larvae begin to migrate through passes with flood tides into estuaries as postlarvae. Migration occurs at night, mainly from February to April, with some migration in the fall. Brown shrimp postlarvae and juveniles are associated with shallow vegetated habitats in estuaries but are also found over silty sand and nonvegetated mud bottoms. Postlarvae and juveniles occur in salinity ranging from 0 to 70 ppt. The density of postlarvae and juveniles is highest in emergent marsh edge habitat and SAV, followed by tidal creeks, inner marsh, shallow open water, and oyster reefs (Clark et al., 2004). Juveniles and subadults of brown shrimp occur from secondary estuarine channels out to the continental shelf, but prefer shallow estuarine areas, particularly soft, muddy areas, shell substrates, or plant-water interfaces (Baltz et al., 1993; GMFMC, 2004; Peterson and Turner, 1994; Rakocinski et al., 1992). Subadult brown shrimp migrate from estuaries at night on ebb tides during new and full moon phases in the Gulf. Their abundance offshore correlates positively with turbidity and negatively with low dissolved oxygen. Adult brown shrimp inhabit nearshore areas on the continental shelf and are associated with silt, muddy sand, and sandy substrates (GMFMC, 2004). Larval brown shrimp feed on phytoplankton and zooplankton. Postlarvae brown shrimp feed on phytoplankton, epiphytes, and detritus. Juvenile and adult brown shrimp prey on amphipods, polychaetes, and chironomid larvae and graze on algae and detritus (Lassuy, 1983d; Pattillo et al., 1997).

Table 3
Adult and Juvenile Presence for Identified Essential Fish Habitat Within the Study Area by Species

Common/Scientific Name*	Bay		Marine	
	Juvenile	Adult	Juvenile	Adult
Brown shrimp (*Farfantepenaeus aztecus*)	common to highly abundant year-round nursery area	not present	spawning area year-round	major adult area spring, summer, fall
Pink shrimp (*Farfantepenaeus duorarum*)	common Aug-Jun	not present	nursery area year-round	present year-round spawning area in summer
White shrimp (*Litopenaeus setiferus*)	abundant July-Oct common Nov-Jun nursery area	common Apr-Jun abundant Sept-Nov	not present	present year-round spawning Mar-Oct
Blacknose Shark (*Carcharhinus acronotus*)	not present		present	
Spinner Shark (*Carcharhinus brevipinna*)	not present		present	
Silky Shark (*Carcharhinus falciformis*)	not present		present	
Finetooth Shark (*Carcharhinus isodon*)	present		present	
Bull Shark (*Carcharhinus leucas*)	common Mar-Oct	present	present	
Blacktip Shark (*Carcharhinus limbatus*)	not present		present	
Tiger Shark (*Galeocerdo cuvier*)	not present		present	
Lemon Shark (*Negaprion brevirostris*)	present		present	not present
Atlantic Sharpnose Shark (*Rhizoprionodon terraenovae*)	present		present	
Scalloped hammerhead shark (*Sphyrna lewini*)	present		present	

Common/Scientific Name*	Bay		Marine	
	Juvenile	Adult	Juvenile	Adult
Bonnethead Shark (*Sphyrna tiburo*)	present		present	
Red Grouper (*Epinephelus morio*)	not present		nursery area year-round	adult occurrence
Gag Grouper (*Mycteroperca microlepis*)	not present		not present	adult occurrence
Scamp (*Mycteroperca phenax*)	not present		not present	adult occurrence
Cobia (*Rachycentron canadum*)	nursery area year-round	not present	nursery area year-round	present summer
Dolphin (*Coryphaena hippurus*)	not present		present year-round	
Greater Amberjack (*Seriola dumerili*)	not present		present year-round	adult and spawning area year-round
Lesser Amberjack (*Seriola fasciata*)	not present		not present	present
Red Snapper (*Lutjanus campechanus*)	nursery area year-round	not present	nursery area year-round	not present
Gray Snapper (*Lutjanus griseus*)	nursery area	present year-round spawn Jun-August	not present	major adult area year-round spawn Jun-August
Lane Snapper (*Lutjanus synagris*)	present Jun-Nov nursery area	not present	nursery area	not present
Vermilion Snapper (*Rhomboplites aurorubens*)	not present		nursery area	not present
Red Drum (*Sciaenops ocellatus*)	common year-round nursery area	common year-round	spawning area fall and winter	present year-round spawning area fall and winter
Little Tunny (*Euthynnus alletteratus*)	not present		present	

Common/Scientific Name*	Bay		Marine	
	Juvenile	Adult	Juvenile	Adult
King Mackerel (*Scomberomorus cavalla*)	not present		nursery area year-round	present year-round spawning area May-Nov
Spanish Mackerel (*Scomberomorus maculatus*)	nursery area year-round	common Apr-Oct	nursery area year-round	present year-round spawning area summer and fall
Sailfish (*Istiophorus platypterus*)	not present		present	

Source: Nelson et al. (1992); NMFS (2009); NOAA (2013, 2021c).

* Species according to Page et al. (2013).

Although adult brown shrimp typically inhabit offshore waters (Pattillo et al., 1997), there is a high probability that they occur within the study area, as the open-water habitat is supportive of habitat preferred by adult brown shrimp (e.g., turbid waters and soft sediments) (Lassuy, 1983d; Pattillo et al., 1997). Juvenile brown shrimp are abundant within mid and upper coast bays year-round, while adult brown shrimp are common to highly abundant from April to October (Table 3) (Nelson et al., 1992). In the Gulf, adult brown shrimp are common year-round and spawning year-round at depths greater than 40 feet (Nelson et al., 1992; Pattillo et al., 1997). Brown shrimp are likely to occur in the study and project areas.

Pink Shrimp (*Farfantepenaeus duorarum*)

Pink shrimp inhabit Gulf and estuarine waters and are pelagic or demersal, depending on their life stage. After spawning offshore, postlarval pink shrimp recruitment into the estuaries occurs in the spring and fall through passes. Juveniles can be found in SAV meadows where they burrow into the substrate; however, postlarvae, juvenile, and adults may prefer a mixture of coarse sand/shell/mud. Densities of pink shrimp are lowest or absent in marshes, low in mangroves, and greatest near or in SAV. Adults occur offshore at depths from 30 to 145 feet and prefer substrates of coarse sand and shell (GMFMC, 2004). Pink shrimp feed on phytoplankton and zooplankton. Postlarvae feed on phytoplankton, epiphytes, and detritus. Juveniles and adults prey on amphipods, polychaetes, chironomid larvae, algae, and detritus (Pattillo et al., 1997).

Juvenile pink shrimp are common within mid coast bays, and adults are common on the mid to upper coast bays, while in the Gulf, adults are present year-round (Table 3) (Nelson et al., 1992; Pattillo et al., 1997). Pink shrimp are likely to occur in the study and project areas.

White Shrimp (*Litopenaeus setiferus*)

White shrimp inhabit Gulf and estuarine waters and are pelagic or demersal, depending on their life stage. Their eggs are demersal and larval stages are planktonic and both occur in nearshore Gulf waters. Postlarvae migrate into estuaries through passes from May to November with most migration in June and September. Migration occurs in the upper water column at night and at mid-depths during the day. Postlarval white shrimp become benthic once they reach the estuary where they seek shallow water with mud or sand bottoms high in organic detritus or rich marsh. Postlarvae and juveniles prefer mud or peat bottoms with large quantities of decaying organic matter or SAV. Densities are usually highest along marsh edge and in SAV, followed by marsh ponds and channels, inner marsh, and oyster reefs. Juvenile white shrimp prefer salinities less than 10 ppt and occur in tidal rivers and tributaries (Muncy, 1984). As juveniles mature, they migrate to coastal areas where they spawn. Adult white shrimp are demersal and inhabit soft mud or silt bottoms (GMFMC, 2004). Nonspawning adults are tolerant of temperatures between 45 and 100 ºF, and survival is high between 2 and 35 ppt, while spawning adults prefer salinity above 27 ppt. White shrimp larvae feed on phytoplankton and zooplankton. White shrimp post larvae feed on phytoplankton, epiphytes, and detritus. Juvenile and adult white shrimp prey on amphipods, polychaetes, and chironomid larvae, but also graze on algae and detritus (Pattillo et al., 1997). Adult and juvenile white shrimp are common to abundant in mid to upper coast bays throughout the year. Adult white shrimp also occur year-round throughout the Gulf to depths of about 131 feet (Table 3) (Muncy, 1984; Nelson et al., 1992; Pattillo et al., 1997). White shrimp are likely to occur in the study and project areas.

Blacknose Shark (*Carcharhinus acronotus*)

The Blacknose Shark is a common tropical and warm temperate species found on the continental shelf mainly over sand, shell, and coral bottoms to depths of 60 to 210 feet (Compagno, 1984; Driggers et al., 2007; Carlson, Charvet, Avalos, Blanco-Parra et al., 2021). These sharks undergo seasonal migrations to the northern portion of their range, where they reside from March to November. Although little is known about their migrations in the Gulf it is thought that they move offshore during the late autumn, winter, and early spring months (Driggers et al., 2007; Sulikowski et al., 2007). Blacknose Sharks reproduce once per year in the Gulf, which is in contrast to their biennial reproductive cycle in the south Atlantic (Carlson, Charvet, Avalos, Blanco-Parra et al., 2021; Sulikowski et al., 2007). They feed on small fish, including Pinfish (*Lagodon rhomboids*) and Porcupine Fish (Diodontidae) (Compagno, 1984). Adult and juvenile Blacknose Sharks occur in Gulf waters of the study and project areas (Table 3) (Bethea et al., 2008; NMFS, 2009).

Spinner Shark (*Carcharhinus brevipinna*)

The Spinner Shark is a common coastal pelagic species found both inshore and offshore to depths of approximately 240 feet, but most commonly at depths of less than 100 feet. It is a schooling species that commonly leaps spinning out of the water. Spinner sharks are highly migratory, although its patterns are poorly known. They move inshore during the spring and summer to spawn and feed and possibly southward, into deeper water, during the fall and winter (Burgess and Branstetter, 2009; Compagno, 1984). Spinner Sharks feed primarily on fish including sardines, herring, anchovies, catfish, mullet, bluefish, tunas, and jacks (Burgess and Branstetter, 2009; Compagno, 1984). Adult and juvenile Spinner Sharks are present in estuarine and Gulf waters of the study and project areas (Table 3) (NMFS, 2009; NOAA, 2021c).

Silky Shark (*Carcharhinus falciformis*)

Silky Sharks are a tropical, oceanic, coastal pelagic species that have a circumglobal distribution. They can be found along the edge of the continental shelf to depths of greater than 1,640 feet, preferring warmer waters, and often associated with deep-water reefs, islands, and insular slopes (Compagno, 1984; Rigby et al., 2017). Silky Sharks are quick moving, aggressive, and active sharks (Compagno, 1984). They give birth to live young with nursery areas typically found in shallower coastal waters while adults occupy deeper waters farther offshore. Silky Sharks leave the nursery areas as subadults to move to deeper offshore waters. Atlantic populations of Silky Sharks were on the decline through the 1990s as a result of longlines and purse seine fisheries, but since 2000 their numbers appear to be increasing (Rigby et al., 2017). They are primarily piscivorous, feeding on tuna, mackerel, sea catfish, and porcupine fish, but also crabs and squid (Compagno, 1984). Silky Sharks are likely to occur in the Gulf portions of the study and project areas and south Texas estuaries (Table 3) (NMFS, 2009; NOAA, 2021c).

Finetooth Shark (*Carcharhinus isodon*)

Finetooth Sharks are a Gulf species occurring in shallow coastal waters including bays, estuaries, along beaches, and near river mouths to about 66 feet. They are common in the Gulf during the summer when the water is warmer, migrating south in the fall and winter when water temperatures decline (Carlson, Charvet, Avalos, Briones Bell-Lloch et al., 2021). Documented nursery habitat is located off the Texas and Louisiana coasts (NMFS, 2009). They probably feed on small boney fish and cephalopods including mackerel, croakers, and mullet (Compagno, 1984; Carlson, Charvet, Avalos, Briones Bell-Lloch et al., 2021). Adult and juvenile Finetooth Sharks are found in the estuarine and Gulf portions of the study and project areas (Table 3) (NMFS, 2009; NOAA, 2021c).

Bull Shark (*Carcharhinus leucas*)

Bull Sharks are a common tropical and subtropical species having a wide range along the coast inhabiting shallow waters, especially in bays, rivers, and lakes. They frequently move between fresh and brackish water and can travel great distances inland. They are the only species of shark capable of existing in freshwater for extended periods (Simpfendorfer and, Burgess 2009). Bull Sharks are viviparous, have a gestation period of a little less than 1 year, and it is assumed their reproductive cycle occurs every 2 years. Juveniles are found at depths less than 80 feet in shallow coastal waters, inlets, and estuaries (Compagno, 1984; NMFS, 2009). They have a diverse diet, feeding on sea turtles, birds, dolphins, bony fish, sharks, rays, shrimp, crabs, squid, and sea urchins (Simpfendorfer and Burgess, 2009). Adult and juvenile Bull Sharks are present in the estuarine and Gulf portion of the study and project areas (Table 3) (NMFS, 2009; NOAA, 2021c).

Blacktip Shark (*Carcharhinus limbatus*)

Blacktip Sharks are widespread inhabiting tropical and subtropical shallow waters and offshore surface waters of the continental shelf. This species commonly occurs in loose aggregations in bays, estuaries, off beaches, and near mouths of rivers (Burgess and Branstetter, 2009). They are viviparous (giving birth to live young), and young are born in coastal bays and estuaries in late May and early June after a 1-year gestation period. Their reproductive cycle occurs every 2 years. Juveniles inhabit shallow coastal waters from the shore to the 82-foot isobath (Burgess and Branstetter, 2009; NMFS, 2009). They feed mainly on pelagic and benthic fish, cephalopods, crustaceans, small rays and sharks (Burgess and Branstetter, 2009; Compagno, 1984). Juvenile and adult Blacktip Sharks occur in the Gulf and estuarine portions of the study and project areas (Table 3) (NMFS, 2009; NOAA, 2021c).

Tiger Shark (*Galeocerdo cuvier*)

The Tiger Shark is a global coastal pelagic species occurring in both very shallow and deep (up to 460 feet) waters (Compagno, 1984; Ferreira and Simpfendorfer, 2019). They prefer turbid areas, often occurring in river estuaries and near wharves and jetties in coastal waters. It is the only shark species in the Carcharhinidae family that is ovoviviparous (Compagno, 1984). Mating occurs in the spring with pupping the following spring to summer. Litters are produced every 2 years or less (Ferreira and Simpfendorfer, 2019). Tiger Sharks have the most diverse diet of any shark species, eating both plants and animals, including boney fishes, sharks and rays, sea turtles, sea birds, marine mammals, crustaceans, carrion of terrestrial wildlife, and floating garbage (Compagno, 1984; Ferreira and Simpfendorfer, 2019). They are one of the most aggressive and dangerous of the shark species, known to consume humans (Compagno, 1984). Juvenile and adult Tiger Sharks occur in the Gulf portions of the study and project areas (Table 3) (NMFS, 2009; NOAA, 2021c).

Lemon Shark (*Negaprion brevirostris*)

Lemon Sharks are a large coastal species that inhabit inshore waters of the continental and insular shelves occurring to depths of 300 feet, but favoring shallow areas (Compagno, 1984; Carlson, Charvet, Ba et al., 2021). They can be found around coral reefs, mangroves, docks, enclosed bays, sounds, and river mouths, occasionally venturing into the open ocean during migrations (Compagno, 1984; NMFS, 2009). The Lemon Shark is viviparous with mating occurring in shallow water during the spring and summer, followed by a 10- to 12-month gestation period, giving birth in shallow nursery areas (Compagno, 1984; Carlson, Charvet, Ba et al., 2021). The young feed mainly on boney fish, crabs, shrimp, and octopus while adults eat boney and cartilaginous fishes and sea birds (Carlson, Charvet, Ba et al., 2021). Adult Lemon Sharks occur in the estuarine portions of the study and project areas, and adults and juveniles are found in the Gulf portions (Table 3) (NMFS, 2009; NOAA, 2021c).

Atlantic Sharpnose Shark (*Rhizoprionodon terraenovae*)

The Atlantic Sharpnose Shark is abundant in warm temperate and tropical waters and is one of the most common shark species in the northern Gulf (Carlson, Charvet, Blanco-Parra et al., 2021; Hoese and Moore, 1998). Migrations are seasonal, limited to inshore/offshore movements, moving to deeper water in the winter and returning inshore during the spring (Compagno, 1984). They inhabit intertidal to deeper waters, often in the surf zone off sandy beaches, bays, estuaries, and river mouths mostly over mud and sand bottoms (Carlson, Charvet, Blanco-Parra et al., 2021). During the summer, juveniles and adults inhabit shallow inshore waters. They are viviparous, and mating occurs in June, with a gestation period of about 1 year using enclosed bays as nursery areas (Carlson, Charvet, Blanco-Parra et al., 2021; NMFS, 2009). Juvenile Atlantic Sharpnose Sharks are found in higher salinity estuaries and the surf zone during the summer (Hoese and Moore, 1998). They feed on fish, shrimp, crab, mollusks, and segmented worms (Carlson, Charvet, Blanco-Parra et al., 2021). Juvenile and adult Atlantic Sharpnose Shark occur in the Gulf and estuarine portions of the study and project areas (Table 3) (NMFS, 2009; NOAA, 2021c).

Scalloped Hammerhead Shark (*Sphyrna lewini*)

Scalloped Hammerhead sharks are a very common coastal, pelagic species, which occur over the continental shelf and deeper water, often entering bays and estuaries (Compagno, 1984). They are found inshore and offshore from intertidal and surface to depths of approximately 900 feet (Rigby et al., 2019). They migrate seasonally forming large schools of small migrating individuals that move to higher latitudes in the summer in certain areas (Compagno, 1984). Adults spend most of the time offshore, with females migrating to coastal areas to birth pups (Rigby et al., 2019). Juvenile Scalloped Hammerhead sharks occur close to shore in bays and nearshore coastal waters, moving to deeper waters as they grow before moving habitat offshore habitats (Rigby et al., 2019; Compagno, 1984). Adults feed on a variety of fish and cephalopods, while juveniles feed mainly on demersal fish, benthic reef fish, and crustaceans (Rigby et al., 2019; Compagno, 1984). Juvenile and adult Scalloped Hammerhead sharks occur in the Gulf and estuarine portions of the study and project areas (Table 3) (NMFS, 2009; NOAA, 2021c).

Bonnethead Shark (*Sphyrna tiburo*)

Bonnethead Sharks are an abundant coastal species inhabiting shallow estuaries and bays over grass, sand, or mud bottoms and in the Gulf at depths of 30 to 260 feet (Compagno, 1984; Pollom et al., 2020). They are found in small schools of 3 to 15 individuals, and very rarely alone (Compagno, 1984). Bonnethead sharks exhibit little or no long-distance migratory behavior, preferring to stay in one location (Heupel et al., 2006). They reproduce once a year, having the shortest gestation period of any of the shark species at 4½ to 5 months. Nursery areas are located inshore in shallow seagrass habitat (Pollom et al., 2020). Bonnethead sharks feed primarily on crustaceans including crabs (especially blue crabs), shrimp, barnacles, and bivalves (Compagno, 1984; Heupel et al., 2006). They are specialist hunters appearing to have higher food consumption rates than other species of shark (Pollom et al., 2020). Adult and juvenile Bonnethead Sharks are present in the estuarine and Gulf portions of the study and project areas (Table 3) (NMFS, 2009; NOAA, 2021c).

Red Grouper (*Epinephelus morio*)

Red Groupers are a demersal species occurring throughout the Gulf from depths of 10 to 660 feet (GMFMC, 2004). Adults are found mainly on muddy and rocky bottoms, usually resting on the bottom substrate. Juveniles prefer seagrass beds in shallower water and inshore reefs until they reach larger sizes when they move offshore to rocky bottom and reef habitats (Froese and Pauly, 2019; Brule et al., 2018). Spawning occurs offshore during the spring in the same areas as they reside. Eggs are pelagic, requiring at least 32 ppt for buoyancy. Juveniles prefer grass beds, shallow reefs, and rock formations that are utilized as nursery areas where they remain until mature before moving to deeper offshore waters. They feed mainly on fish, shrimp, crabs, octopus, and lobsters (GMFMC, 2004). Adult and juvenile Red Grouper occur in the Gulf portions of the study and project areas (Table 3) (NOAA, 2013, 2021c).

Gag Grouper (*Mycteroperca microlepis*)

Gag Grouper are demersal and are most common in the eastern Gulf. Eggs are pelagic and are spawned from December through April (Koenig et al., 2018; GMFMC, 2004). Larvae are pelagic and most abundant in the early spring (GMFMC, 2004). Post-larvae and pelagic juveniles move through inlets into high salinity estuaries from April through May, where they become benthic and settle into grass flats and oyster beds (Koenig et al., 2018; GMFMC, 2004). Older juveniles move offshore in the fall to shallow reef habitat in depths of 3 to 170 feet. Adults prefer depths of 30 to 330 feet and utilize hard bottoms, oil platforms, and artificial reefs (GMFMC, 2004). Adult Gag Grouper school in groups of 5 to 50 individuals or may be found solitary (Koenig et al., 2018). They feed on estuarine-dependent organisms such as shrimp, small fish, and crabs during their juvenile stages. As they mature and move farther offshore, they become opportunistic predators, feeding on a variety of fish and crustaceans (Koenig et al., 2018; GMFMC, 2004). Adult Gag Grouper occur in Gulf waters within the study and project areas (Table 3) (NOAA, 2013, 2021c).

Scamp (*Mycteroperca phenax*)

Scamp are a deep-water demersal species that is widely distributed throughout the Gulf and found over ledges and high-relief rocky bottoms, congregating at depths of 40 to 240 feet in the Gulf (GMFMC, 2004; Afonso et al., 2018). It is estimated that this species lives for at least 30 years. Spawning occurs in aggregations at the shelf edge from February to July in the Gulf (Afonso et al., 2018). Eggs and larvae are pelagic and occur offshore in the spring (GMFMC, 2004). Juveniles can be found in shallow-water mangrove areas and at jetties (Afonso et al., 2018). Adult Scamp occur in Gulf waters within the study and project areas (Table 3) (NOAA, 2013, 2021c).

Cobia (*Rachycentron canadum*)

Cobia are a widely distributed large, pelagic fish, found over rocky shores, shallow coral reefs, and occasionally in estuaries (Collette et al., 2015; GMFMC, 2004). They are often associated with pilings, platforms, buoys, anchored boats, and flotsam (Florida Museum of Natural History, 2021a). Spawning occurs in large aggregations from April through September in coastal waters (Collette et al., 2015). While cobia rarely use estuarine environments, estuaries are important for most of their prey. They are a voracious predator often swallowing prey whole, feeding mainly on mantis shrimp, eels, crabs, squid, and Spanish Mackerel (Florida Museum of Natural History, 2021a; GMFMC, 2004). Adult and juvenile Cobia occur in the Gulf and estuarine portions of the study and project areas (Table 3) (NOAA, 2013, 2021c).

Dolphin (*Coryphaena hippurus*)

Dolphin are a pelagic offshore species often associated with *Sargassum* and other floating objects and found to depths of 280 feet. They travel together in small schools and exhibit north-south seasonal migrations (Collette et al., 2011a; GMFMC, 2004). Multiple spawning events occur throughout the year in open water when temperatures rise above 69.8°F (Collette et al., 2011a; GMFMC, 2004). Eggs and larvae are pelagic and commonly associated with *Sargassum*. Young billfishes often prey upon Dolphin larvae and juveniles are eaten by larger pelagic fishes, including other Dolphin. Adults feed on small oceanic fish, juveniles of larger pelagic fish, and invertebrates (GMFMC, 2004). Adult and juvenile Dolphin occur in the Gulf portions of the study and project areas (Table 3) (NOAA, 2013, 2021c).

Greater Amberjack (*Seriola dumerili*)

Greater Amberjack occur throughout the Gulf to depths of 1,300 feet (GMFMC, 2004). Adults are pelagic and epibenthic, occurring near reefs, artificial structures, rocky outcrops, and wrecks, usually in small schools but may be solitary (Smith-Vaniz et al., 2015a). Little is known about the spawning habits of greater amberjack; however, it is thought migrations are related to reproduction (Florida Museum of Natural History, 2021b). Spawning occurs offshore from March to July near reefs and wrecks (GMFMC, 2004; Florida Museum of Natural History, 2021b). Juveniles are pelagic and associated with floating *Sargassum* mats and debris in the offshore nursery areas (GMFMC, 2004). Adult Greater Amberjack feed on benthic and pelagic fish, squid, and crustaceans while juveniles eat plankton and other small invertebrates (Florida Museum of Natural History, 2021b). Adult and juvenile Greater Amberjack are found in the Gulf within the study and project areas (Table 3) (NOAA, 2013, 2021c).

Lesser Amberjack (*Seriola fasciata*)

Adult Lesser Amberjack occur year-round in the northern Gulf and are near the bottom associated with oil and gas platforms and irregular bottoms at depths from 180 to 430 feet (GMFMC, 2004; Smith-Vaniz et al., 2015b). Spawning occurs in the Gulf from September through December and again in February through March. There is no information on eggs, larvae, and post-larvae. Juveniles are found in the Gulf during late summer and fall, and small juveniles are associated with *Sargassum* mats (GMFMC, 2004). They feed primarily on fish and squid but will take dead bait (Smith-Vaniz et al., 2015b). Adult Lesser Amberjack are found in the Gulf within the study and project areas (Table 3) (NOAA, 2021c).

Red Snapper (*Lutjanus campechanus*)

Red Snapper are demersal, found over sand and rock substrates, around reefs, and underwater objects to depths ranging from 10 feet for juveniles to 2,000 feet for adults (GMFMC, 2004; Anderson et al., 2015). However, adult Red Snapper prefer depths ranging from 130 to 360 feet (GMFMC, 2004). Spawning occurs in the Gulf from May to July and November to December, at depths of 60 to 120 feet over a firm sand substrate (Moran, 1988). Eggs are found offshore in the summer and late fall. Larvae, post-larvae, and early juveniles occur from July through November in shelf waters (GMFMC, 2004). Early and late juveniles are often associated with underwater structures or small burrows of low relief but are also abundant over barren sand and mud bottoms (Gallaway et al., 1999; GMFMC, 2004). Juvenile Red Snapper feed mainly on shrimp, but after age one, prey primarily on fish and squid (Anderson et al., 2015; GMFMC, 2004; Moran, 1988). Of the vertebrates consumed, most are not obligate reef dwellers, indicating that Red Snapper feed away from reefs (GMFMC, 2004). Juvenile Red Snapper are found in the Gulf and estuarine portions of the study and project areas (Table 3) (NOAA, 2013, 2021c).

Gray Snapper (*Lutjanus griseus*)

Gray Snapper can be demersal, structure, or mid-water dwellers inhabiting marine, estuarine, and riverine habitats. They inhabit depths to about 550 feet in the Gulf (GMFMC, 2004). Juvenile Gray Snapper are common in shallow water around SAV, mangrove roots, docks, pilings, and jetties, while adults tend to congregate in deeper Gulf waters around natural and artificial reefs. Spawning occurs offshore in groups from June to August around structures and shoals. Their eggs are pelagic, and the larvae are planktonic, both occurring in Gulf shelf waters and near coral reefs. Post-larvae migrate into the estuaries and are most abundant over *Halodule* and *Syringodium* grassbeds. Juveniles seem to prefer *Thalassia* grassbeds, seagrass meadows, marl bottoms, and mangrove roots, and are found in estuaries, bayous, channels, grassbeds, marshes, mangrove swamps, ponds, and freshwater creeks (Lindeman et al., 2016a; Pattillo et al., 1997). Juvenile Gray Snapper feed on estuarine-dependent organisms such as shrimp, small fish, and crabs. Gray Snapper are classified as opportunistic carnivores at all life stages (Pattillo et al., 1997). In estuaries, juveniles feed on shrimp, larval fish, amphipods, and copepods. Adults feed primarily on fish, but smaller individuals will prey on crustaceans (GMFMC, 2004; Lindeman et al., 2016a). Juvenile and adult Gray Snapper are found in the Gulf and estuarine portions of the study and project areas (Table 3) (NOAA, 2013, 2021c).

Lane Snapper (*Lutjanus synagris*)

Lane Snapper are a demersal species occurring over multiple substrate types but are most commonly found near reefs and vegetated sandy bottoms in shallow inshore waters (Florida Museum of Natural History, 2021c). Lane Snapper appear to favor grass flats, reefs, and soft bottoms to depths of approximately 70 feet (GMFMC, 2004) but adult Lane Snapper can occur offshore in depths up to 430 feet near sand bottoms, natural channels, banks, and artificial and natural structures. They tend to remain in the same area their entire lives (GMFMC, 2004; Florida Museum of Natural History, 2021c). Spawning occurs in aggregations in Gulf waters from March through September (Florida Museum of Natural History, 2021c; GMFMC, 2004). Nursery areas include mangrove and grassy estuarine habitats in southern Texas and Florida and shallow waters with sand and mud bottoms along all Gulf states. Juveniles feed on estuarine-dependent organisms such as shrimp, small fish, and crabs. Lane Snapper are considered unspecialized, opportunistic predators, feeding on a variety of crustaceans and fish (Florida Museum of Natural History, 2021c; GMFMC, 2004). Juvenile Lane Snapper are found in estuaries and adult and juveniles are found in the Gulf and estuarine portions of the study and project areas (Table 3) (NOAA, 2013, 2021c).

Vermilion Snapper (*Rhomboplites aurorubens*)

Vermilion Snapper are a demersal species occurring in waters 60 to 660 feet deep over rock, gravel, or sand bottoms in the Gulf (GMFMC, 2004; Lindeman et al., 2016b). They often form large schools, especially the young (Lindeman et al., 2016b). Spawning occurs in offshore waters from April to September. Juveniles are found on hard bottoms, reefs, and artificial structures (GMFMC, 2004; Lindeman et al., 2016b). They feed on fish, benthic invertebrates, crabs, shrimp, and cephalopods (Lindeman et al., 2016b). Juvenile Vermilion Snapper are found in the Gulf portions of the study and project areas (Table 3) (NOAA, 2021c).

Red Drum (*Sciaenops ocellatus*)

Red Drum occupy a variety of habitats, ranging from offshore depths of 130 feet to very shallow estuarine waters. Spawning occurs in the Gulf near the mouths of bays and inlets from August through November, peaking in September and October (Pattillo et al., 1997). Eggs usually hatch in the Gulf, and larvae are transported with tidal currents into the estuaries where they mature. Adult Red Drum use estuaries but tend to migrate offshore where they spend most of their adult life. Red Drum occur over a variety of substrates including sand, mud, and oyster reefs and tolerate a wide range of salinities (GMFMC, 2004).

Estuaries are especially important to larval, juvenile, and subadult Red Drum. Juveniles are most abundant around marshes, preferring shallow, protected waters over mud substrate or among SAV (Stunz et al., 2002a). Juveniles show preferences for specific habitat types, occurring at higher densities in seagrass meadows (Stunz et al., 2002a) with higher growth rates in brackish emergent marsh and in seagrass meadows (Stunz et al., 2002b). Subadult and adult Red Drum prefer shallow bay bottoms and oyster reefs (GMFMC, 2004). Estuaries are also important for the prey of larval, juvenile, and subadult Red Drum. Their larvae feed primarily on shrimp, mysids, and amphipods, while juveniles prefer fish and crabs (GMFMC, 2004). Adults are an aggressive opportunistic ambush predator feeding primarily on blue crab, penaeid shrimp, and some benthic fishes (Chao, 2020). Adult and juvenile Red Drum are found in the estuarine portions and adults in the Gulf portions of the study and project areas (Table 3) (NOAA, 2013, 2021c).

Little Tunny (*Euthynnus alletteratus*)

Little Tunny are found throughout the Gulf over the continental shelf in close inshore waters in depths less than 490 feet (Collette et al., 2011b; Florida Museum of Natural History, 2021d). Adults school according to size with other members of the Scombridae family, breaking apart during certain times of the year (Florida Museum of Natural History, 2021d). Spawning occurs March through November in offshore waters. *Sargassum* mats are utilized by early life history stages as habitat (GMFMC, 2004). Little Tunny are opportunistic predators feeding mainly on clupeids (herring, sardines, scad), crustaceans, squid, and tunicates (Collette et al., 2011b; Florida Museum of Natural History, 2021d). Sharks, billfishes, dolphin, and other carnivorous fish prey on Tittle tunny (Florida Museum of Natural History, 2021d). Adults and juveniles are found in the Gulf portions of the study and project areas (Table 3) (NOAA, 2021c).

King Mackerel (*Scomberomorus cavalla*)

King Mackerel are pelagic and found in Gulf coastal waters and outer reef areas at depths of 75 to 110 feet (Collette et al., 2011c; Florida Museum of Natural History, 2021e). Migrations occur along the east coast, dependent upon warm temperatures. Spawning occurs in the Gulf over the outer continental shelf from May to September (Collette et al., 2011c; GMFMC, 2004). Eggs are pelagic, occurring over depths ranging from approximately of 100 to 600 feet in the spring and summer months (GMFMC, 2004). King Mackerel feed mainly on schooling fish, crustaceans, penaeid shrimp, squid, and occasionally mollusks. Juveniles feed on small fish (mainly anchovies) and invertebrates (Collette et al., 2011c). Adults and juveniles are found in the Gulf and estuarine portions of the study and project areas (Table 3) (NOAA, 2013, 2021c).

Spanish Mackerel (*Scomberomorus maculatus*)

Spanish Mackerel are pelagic, inhabiting depths from 30 to 120 feet throughout the coastal zone of the Gulf (Florida Museum of Natural History, 2021f; GMFMC, 2004). They frequent barrier islands and passes and are often found near the surface in very large schools (Florida Museum of Natural History, 2021f). They may also migrate seasonally into estuaries with high salinity, but this migration is infrequent (GMFMC, 2004). Spawning occurs in the northern Gulf from April through October, peaking in August and September. Larvae typically occur in the Gulf at depths up to 300 feet (Pattillo et al., 1997). Juveniles inhabit the Gulf surf and sometimes estuarine habitats. However, juvenile Spanish Mackerel prefer marine salinities and are not considered estuarine-dependent. Juveniles also prefer clean sand bottoms, but the substrate preferences of the other life stages are unknown (GMFMC, 2004). While Spanish Mackerel rarely use estuarine environments, estuaries are important for most of their prey (Pattillo et al., 1997). They feed on a variety of fishes, extensively herrings, but also on penaeid shrimp and cephalopods (Collette et al., 2011d; Pattillo et al., 1997). Spanish Mackerel are often preyed upon by sharks, tunas, and bottlenose dolphins (Florida Museum of Natural History, 2021f). Adults and juveniles are found in the Gulf and estuarine portions of the study and project areas (Table 3) (NOAA, 2013, 2021c).

Sailfish (*Istiophorus platypterus*)

Sailfish are an oceanic and epipelagic species generally found above the thermocline to depths of 130 feet (Collette et al., 2011e; NMFS, 2009). They often occur in loose aggregations over a large area, occasionally forming small schools most likely by size (Collette et al., 2011e). It is assumed that sailfish spawn in the Gulf from May to September due to the presence of larvae during these times, moving inshore into shallow waters to spawn (Collette et al., 2011e; NMFS, 2009). Sailfish are opportunistic feeders and prey mainly on fish, crustaceans, and cephalopods, occurring at the surface, mid-water, reef edges, and along the bottom (Collette et al., 2011e; NMFS, 2009). They are preyed upon by killer whales, bottlenose dolphins, and sharks, although not very often (NMFS, 2009). Adult and juvenile Sailfish are found in the Gulf portion of the study and project areas (Table 3) (NMFS, 2009; NOAA, 2021c).

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4.0 POTENTIAL IMPACTS TO EFH

Below is a discussion of the potential impacts associated with Applicant's Proposed Action Alternative. Adverse effects of this project are actions resulting in the reduction of quality or quantity of EFH. Adverse effects analyzed include direct and indirect physical, chemical, or biological alterations of the waters or substrate and loss of, or injury to benthic organisms, prey species, and their habitat-wide impacts, including individual, cumulative, or synergistic consequences. Habitats of concern, such as oyster reefs, SAV, offshore sand, and artificial reefs addressed separately.

4.1 ALTERNATIVES ANALYSIS

4.1.1 No-Action Alternative

Under the No-Action Alternative, EFH would remain as described in Section 3.0. Existing conditions and associated changes to EFH would continue. Indirect impacts are described below.

The significance of the predicted global climate change is the possibility of increasing sea levels, coastal flooding, changing estuarine salinity, and associated impacts to biological communities. Indirect impacts due to climate change and USACE dredging and maintenance dredging operations would continue to have an impact to the aquatic communities.

Trends of tidal wetland loss would continue. Increased development, hydrologic alterations, drought, flooding, and temperature extremes could affect wetlands. Sea level change and climate change, including changes to hydrology, nutrient inputs, flood or tide timing and intensity could have a variety of impacts on wetlands.

Marshes throughout the study area are declining and would likely continue this trend as sea levels continue to rise. According to the NOAA Sea Level Rise Viewer (2022) 3-foot scenario model, tidal marsh appears to decrease in the study area compared to present day. There is a potential that marshes would migrate inland in response to rising sea levels in areas where the elevation and topography are conducive for establishment (Borchert et al., 2018; Guannel et al., 2014; Murdock and Brenner, 2016; Scavia et al., 2002). However, due to urban development of low-lying areas in the study area the likelihood marsh migration and establishment would be prevented (Borchert et al., 2018).

It is anticipated that future rising sea levels would force the landward migration of wetlands and marsh and cause major spatial shifts in the natural habitats along the coast. Fisheries habitat modeling in Galveston Bay with a 3.3-foot rise in sea level indicate that as sea level changes the total footprint of suitable habitat for early life stages of blue crab, brown shrimp, southern flounder, and red drum would increase, threefold. This increase would have a positive impact on fisheries, helping to offset reductions as wetlands are lost (Guannel et al., 2014).

Other studies suggest that with a rise in sea level, salt marshes initially declined, before transitioning from low level marsh to tidal flat then to open water. This change was followed by a net increase in habitat quality resulting from marsh fragmentation (Fulford et al., 2014). This mirrors the effect on nursery production, which studies have shown is initially negatively affected by sea level change, but ultimately may produce positive changes in production due to the increase in marsh-edge habitat resulting from fragmentation. This salt marsh fragmentation correlated with a positive effect on nursery fish production (Chesney et al., 2000; Minello et al., 2003; Park et al., 1989). Organic matter and nutrients are generated and utilized by fish and shrimp at the marsh edge, which benefits nekton productivity while the marsh is disintegrating. In the long-term it is harmful. After the marsh disintegrates, there is reduced organic productivity and less (or no) nursery habitat (Zimmerman, 1992; Rozas and Reed, 1993; Chesney et al., 2000).

Under the No-Action Alternative, it is likely that rising sea levels benefits most fish species (including commercial and recreational fisheries) due to larger areas of available habitats if new marshes are created. Undeveloped areas would most likely support landward migration of wetlands as sea level changes. According to Jim Tolan of the TPWD, who serves on the Association of Fish and Wildlife Agencies Climate Change Committee, their consensus is that as long as there is sufficient habitat, fisheries and oyster reefs should adapt with little net change associated with relative sea level change (pers. comm. J. Tolan [TPWD], 2020). In addition, Watson et al. (2017) indicated that the vulnerability of Spotted Seatrout, Red Drum, and blue crab to sea level change appears low since they have the ability to adapt to the projected changes.

Increasing salinities in many areas are anticipated with global climate change resulting from higher sea levels causing barrier islands to migrate inland (Scavia et al., 2002). Increases in salinity in wetland habitats may cause small reductions in the health and biological productivity of organisms. This may cause additional stress on some marsh vegetation, which could cause some habitat-related impacts to organisms that use those areas. However, most organisms occupying these environments are ubiquitous along the Texas coast and can tolerate a wide range of salinities (Pattillo et al., 1997). Therefore, no adverse effects on fauna are expected due to salinity changes.

Under the No-Action Alternative, oyster reefs would remain as described in Section 2.1. See Section 4.2.4 (Oyster Reef) for a more detailed discussion of turbidity impacts associated with dredging.

Turbidity associated with maintenance dredging of the currently authorized deepening and widening projects would continue. Benthic organisms would continue to be buried by open-bay and ocean disposal of dredged material. No long-term effects to turbidity with the No-Action are anticipated. See Section 4.2.2 (Open Bay and Jetty Communities) for a more detailed discussion of turbidity impacts.

Under the No-Action Alternative, increased ship traffic and lightering would be expected which could slightly increase the probability of a petroleum spill. However, as described in Section 4.2.2, in the unlikely event a petroleum spill should occur, adult shrimp, crabs, and finfish are generally motile enough to avoid most areas of high oil concentration.

In the absence of BU placement to serve as protective barriers, the loss of habitat would continue which could impact EFH. The ongoing erosion of shorelines at Harbor Island and Dagger Island combined with expected rising sea levels could expose large areas of estuarine habitat to erosive forces, leading to EFH loss.

4.1.2 Alternative 1: Channel Deepening (Applicant's Proposed Action Alternative)

The Applicant's Proposed Action Alternative could adversely affect life history stages of several Federally managed species. These include the following: all life stages of brown, pink, and white shrimp, Blacknose Shark, Spinner Shark, Silky Shark, Finetooth Shark, Bull Shark, Blacktip Shark, Tiger Shark, Atlantic Sharpnose Shark, Scalloped Hammerhead Shark, Bonnethead Shark, Red Grouper, Cobia, Dolphin, Greater Amberjack, Red Snapper, Gray Snapper, Lane Snapper, Red Drum, Little Tunny, King Mackerel, Spanish Mackerel, and Sailfish; adult Lemon Shark, Gag Grouper, Scamp, Lesser Amberjack; and juvenile Vermilion Snapper. The sections below detail the potential impacts to EFH for these and recreationally and commercially important species listed in Section 3.2.

The following sections describe potential impacts to EFH based on the Applicant's Proposed Action Alternative (Table 4). Placement area construction impact acreages for various aquatic resources were based on information provided by the Applicant and NOAA (2010).

Table 4
Summary of Potential Aquatic Resource Impacts (acres)
Associated with the Applicant's Proposed Action Alternative

Project Component	Footprint	Open Water[1]	Seagrass[2]	Oysters[3]	Flats/ Beach[4]	Estuarine[5]	Palustrine[6]	Source
SS1	297.41	219.45	0.01	0	34.64	3.92	21.04	Applicant
SS2	45.21	13.74	0	0	24.20	1.25	11.25	Applicant
PA4	170.79	42.14	3.46	0	2.80	0.75	41.75	Applicant
HI-E	138.73	13.12	3.41	0.10	23.21	10.69	48.42	Applicant
SJI	592.85	163.29	0	0	199.01	0	58.76	Applicant
MI	362.08	205.58	0	0	124.11	0	0	Applicant
Channel Deepening/ Extension	1,182.33	1,182.33	–	–	–	–	–	NOAA (2010)
B1–B9	1,585.82	1,585.82	–	–	–	–	–	NOAA (2010)
New Work ODMDS	1,180.00	1,180.00	–	–	–	–	–	NOAA (2010)
Total	5,555.22	4,605.47	6.88	0.10	407.97	16.61	181.22	

[1] Open Water (E1UBL M1UBL, M2USN)
[2] Seagrass (E1ABL)
[3] Oysters (E1ABL)
[4] Flats (E2ABN, E2EM1N(1) E2USN, UPL [tidal flats above the high tide line were classified as upland])
[5] Estuarine (E2M1P, E2SS3N)
[6] Palustrine (PEM1C(1))

4.2 POTENTIAL IMPACTS TO EFH

4.2.1 Estuarine Wetlands and Submerged Aquatic Vegetation

No estuarine wetland or SAV habitat occurs within the proposed channel dredging for the Applicant's Proposed Action Alternative. The new work dredging footprint is limited to the deeper areas of the CCSC that would be separated from seagrass areas by Harbor Island during construction. The BU project footprints include areas where wetland and seagrass were delineated (Mott MacDonald, 2021, 2022; Triton Environmental Solutions, 2021, 2022). A total of 6.88 acres of seagrass and 197.82 acres of wetlands (16.61 acres tidal and 181.22 acres non-tidal) are estimated to be impacted with BU construction. Considering that the BU objective of PAs include protection of adjacent seagrass areas, the proposed placement of BU sites may be expected to benefit seagrass.

There may be short term increases in turbidity and associated reduced water clarity during the channel dredging and placement. Nichols et al. (1990) found that turbidity associated with dredging was widespread, having short-term effects on water quality. However, a study conducted in the Laguna Madre found that dredged deposits caused elevated turbidity for up to 15 months after deposition. Turbidity was strongest closest to placement areas but were also detected for greater than 0.75 miles from those areas (Onuf, 1994). The short-term reduction in water clarity during the channel dredging and placement is not expected to have any lasting effects on SAV.

Wetland and SAV impacts would occur at proposed placement sites (see Table 4). Indirect impacts could occur during construction due to turbidity increases or physical disturbances. Best management practices used during construction, such as turbidity curtains, silt fencing, or construction matting, should avoid and minimize these indirect impacts. It should be noted that dredged material would be used at all PAs to either: 1) convert deep open water areas to protect adjacent shallow bathymetry that support or can establish tidal wetlands or SAV, or 2) restore eroding shorelines that would protect larger extents of SAV. For example, some of the proposed BU sites would restore eroding shoreline and upland near Harbor Island that may offer protection to SAV present across Redfish Bay. This action may help protect SAV that could be exposed if the shoreline is breached with the continued erosion expected under the No-Action Alternative. Other proposed placement sites would convert open water areas to create tidal estuarine wetlands or SAV habitat. Considering the beneficial use nature and objective of these PAs to protect or provide more area conducive to tidal wetlands or SAV establishment, Alternative 1 may positively impact tidal wetlands and SAV. During construction and operations there is some chance of spills which may also impact wetlands or SAV.

4.2.2 Open Bay and Jetty Communities

During construction of Alternative 1, temporary disturbances and impacts to plankton and nekton assemblages would occur.

Turbidity in estuarine and coastal waters can have a complex set of impacts on organisms (Hirsch et al., 1978; Stern and Stickle, 1978; Wright, 1978; Wilber et al., 2005). The release of sediment during dredging causes sediment plumes. The extent of the plume is determined by the direction and strength of the currents and winds, and the particle size. Suspended material can play beneficial and detrimental roles in aquatic environments. Turbidity from suspended solids interferes with light penetration and reduces photosynthetic activity by phytoplankton and algae (Wilber and Clarke, 2001). Such reductions in primary productivity would be localized around the immediate area of the dredging and placement operations and would be limited to the duration of the plume. Conversely, the decrease in primary production, presumably from decreased available light, can be offset by an increase in nutrients that are released into the water column (Morton, 1977; Newell et al., 1998). Nutrients may act to enhance the area surrounding dredging, increasing productivity. Studies of turbidity and nutrients associated with dredging found the effects are both localized and temporary (May, 1973). Due to the capacity and natural variation in phytoplankton and algal populations, the impacts to phytoplankton and algae from project construction, dredging within the project area, dredged material placement of new work and maintenance material, and placement of material for actions targeting BU would be temporary.

Reduced light penetration due to turbidity may have a short-term impact on zooplankton populations since they feed on the phytoplankton (Armstrong et al., 1987; Valiela, 1995). Such reductions would be localized around the immediate area of dredging and placement operations. Impacts to zooplankton from project construction would be temporary.

Teeter et al. (2003) found the area of high turbidity extended roughly to the edge of the fluid mud flow, or about 1,300 to 1,650 feet from the dredge discharge pipe. Modeling of dredged material discharge in the Laguna Madre, Texas, determined that turbidity caused by dredging was short lived and therefore impacts to the estuarine and offshore water column would be minimal (Teeter et al., 2003). Turbidity can be expected to return to near ambient conditions within a few months after dredging ceases.

Increased suspended sediments can impact juvenile and adult finfish by disrupting foraging patterns, reducing feeding, and loss of habitat for feeding and reproduction. However, these would be temporary and occurs only during project construction (Newcombe and Jensen, 1996; Clarke and Wilber, 2000). Fine particles can coat the gills of juvenile and adult finfish, ultimately resulting in asphyxiation (Clarke and Wilber, 2000; Wilber and Clarke, 2001). However, finfish and shellfish are motile enough to avoid highly turbid areas. Under most conditions, exposure to sediment plumes would be for short durations (minutes to hours) (Clarke and Wilber, 2000; Wilber and Clarke, 2001; Newcombe and Jensen, 1996).

Effects of elevated turbidities on the adult stages of various filter-feeding organisms such as oysters, copepods, and other species include reduced filtering rates, and clogging of filtering mechanisms interfering with ingestion, respiration, and abrasion (Newcombe and Jensen, 1996; Wilber and Clarke, 2001; Stern and Stickle, 1978). These effects tend to be more pronounced when TSS concentrations are greater than 100 mg/L but are apparently reversible once turbidities return to ambient levels (Newcombe and Jensen, 1996). More sensitive species and life stages (i.e., eggs, larvae, and fry) tend to be more impacted by longer exposure to suspended sediments than less sensitive species and older life stages (Germano and Cary, 2005; Wilber and Clarke, 2001; Wilber et al., 2005; Newcombe and Jensen, 1996). Many crustaceans (such as shrimp and crabs) are less impacted by elevated suspended sediments since these organisms reside on or near the bottom where sedimentation naturally occurs (Wilber and Clarke, 2001; Wilber et al., 2005). Higher turbidity may also provide a refuge for some species from predation (Wilber and Clarke, 2001). Notwithstanding the potential harm to some individual organisms, no long-term impacts to finfish or shellfish populations are anticipated from project construction, dredging, and placement activities associated with the Alternative 1 compared with the No-Action Alternative.

Based hydrodynamic and salinity modeling analysis by W.F. Baird and Associates (2022), minor increases in salinity are anticipated because of Alternative 1 compared to the No-Action. Average salinity levels are anticipated to increase less than 1 ppt in the Corpus, Nueces, Redfish, and Aransas bays. Near the channel deepening, a salinity change of ± 3 ppt can be expected (W.F. Baird and Associates, 2022). This salinity increase is not expected to alter fauna. Most organisms occupying these environments are ubiquitous along the Texas coast and can tolerate a wide range of salinities (Pattillo et al., 1997).

With Alternative 1, current speeds are expected to decrease an average of 0.23 fps with the deeper entrance channel (W.F. Baird and Associates, 2022). This slight decrease in velocity at the entrance channel is not anticipated to impact fauna. In addition, Valseth et al. (2021) found that the change in channel depth did not substantially impact larval transport reaching nursery grounds, and may experience a slight increase in larval transport with the decreased velocities.

Vessel traffic would be expected to decrease with Alternative 1 compared to the No-Action Alternative. Vessels would be capable of fully loading at Axis and Harbor Island terminals (see Section 4.5 for further discussion), slightly decreasing the probability of a petroleum spill. In the unlikely event a petroleum spill should impact EFH, adult shrimp, crabs, and finfish are probably motile enough to avoid EFH impacted areas of high oil concentration. Larval and juvenile finfish and shellfish tend to be more susceptible to petroleum than adults and could be affected extensively by a spill during active immigration periods. Due to their lack of mobility, they are less likely to avoid these areas and could be negatively impacted if a spill were to occur. An oil spill in the project area could result in impacts to phytoplankton, algal, and zooplankton. However, since these organisms can recover rapidly from a spill, due primarily to their rapid rate of reproduction and to the widespread distribution of dominant species, long-term impacts would not be expected (Hjermann et al., 2007; Kennish, 1992).

Dredged material is to be used beneficially in placement actions targeting BU. This habitat could have the potential to be more productive than the open water habitat that would be lost under Alternative 1. Marsh creation has been shown to have a positive benefit to bay systems (Rozas et al., 2005). Refer to the Applicant’s Dredged Material Management Plan (Appendix C in the EIS) for information regarding planting that is proposed at BU site SS1.

4.2.3 Open Bay Bottom and Offshore Bottom Communities

Alternative 1 could temporarily reduce the quality of EFH in the vicinity of the project area and some individuals may be displaced. Impacts would be similar to those described in sections 4.2.1 and 4.2.2. Channel dredging (inshore and offshore) would impact 1,182 acres of open water/bottom habitat through excavation (NOAA, 2010) (see Table 4). For Gulf side placement actions, nearshore berms (B1–B9) would impact 1,586 acres of open water/bottom habitat (NOAA, 2010), MI and SJI beach nourishment placement would impact 275.19 acres of open water/bottom habitat and 58.76 acres of freshwater wetlands (Mott MacDonald, 2021, 2022), and the ODMDS would impact 1,180 acres of open water/bottom habitat (NOAA, 2010) (see Table 4).

Direct aquatic resource impacts from inshore PA construction include 563.85 acres of open water/bottom habitat, 16.61 acres of tidal wetlands, 122.46 acres of freshwater wetlands, 84.85 acres of unconsolidated shorelines (tidal sand flats/algal flats/beach), 6.88 acres of seagrass, and 0.10 acres of oyster reef (Mott MacDonald, 2021, 2022; Triton Environmental Solutions, 2021, 2022) (see Table 4). These impact acreages were provided by the Applicant. As a result, this could impact food available to Federally managed species.

Excavation removes benthic organisms, whereas placement smothers or buries benthic communities. Dredging and placement of dredged material may cause ecological damage to benthic organisms in three ways: (1) physical disturbance to benthic ecosystems and organisms; (2) mobilization of sediment contaminants, making them more bio-available; and (3) increasing the amount of suspended sediment in the water column (Montagna et al., 1998). Dredging can reduce species diversity by 30 to 70 percent and the number of individuals by 40 to 95 percent. A similar reduction in benthic fauna biomass is expected within the boundaries of dredged areas (Newell et al., 1998).

Recolonization of areas impacted by dredging and dredged material disposal occurs through vertical migration of buried organisms through the dredged material, immigration of post larval organisms from the surrounding area, larval recruitment from the water column, and/or sediments slumping from the side of the dredged area (Bolam and Rees, 2003; Newell et al., 1998; Maurer et al., 1986). The response and recovery of the benthic community from dredged material placement is affected by many factors. These include environmental (e.g., water quality, water stratification), sediment type and frequency, and timing of disposal. Communities in these dynamic ecosystems are dominated by opportunistic species tolerant of a wide range of conditions (Bolam et al., 2010; Bolam and Rees; 2003; Newell et al., 2004; Newell et al., 1998). Although change may occur, these impacts would be temporary in some dredging and disposal areas (Bolam and Rees, 2003). Shallower, higher-energy estuarine habitats can recover between 1 and 10 months, while deeper, more-stable habitats can take up to 8 years to recover (Bolam et al., 2010; Bolam and Rees, 2003; Newell et al., 1998; Sheridan, 1999; Sheridan, 2004; Wilber et al., 2006; VanDerWal et al., 2011). The release of nutrients during dredging may also enhance benthic communities outside the immediate placement area if the dredged material is not contaminated (Newell et al., 1998).

Because of the constant re-creation of "new" habitat via disturbance, new recruits continually settle and grow. Therefore, disturbed communities are dominated by small, surface-dwelling organisms with high growth rates. Consequently, dredged material placement from Alternative 1 may result in a shift in community structure rather than a decrease in production (Bolam and Rees, 2003; Montagna et al., 1998). Productivity could be enhanced following benthic community shift depending on the timing of dredged material disposal (Bolam and Rees, 2003).

4.2.4 Oyster Reef

A total of 0.10 acres of live oyster reef habitat occurs in the footprint of placement site HI-E and would be directly impacted by the CDP. GLO (2021) indicates 32 acres of mapped oyster reef habitat occur in the remainder of the project area and 3.17 acres of oysters were mapped within a 500-foot construction buffer of the inshore PAs (Triton Environmental Solutions, 2021, 2022). These oyster areas could be indirectly impacted by increased turbidity during construction of placement sites. Water column turbidity would increase during project construction that could affect survival or growth of oysters nearby. Temporary impacts to oysters include reduced filtering rates and clogging of filtering mechanisms, causing abrasion, and interfering with ingestion and respiration (Newcombe and Jensen, 1996; Stern and Stickle, 1978; Wilber and Clarke, 2001).

Average salinities in the project area range from 30 to 36 ppt, with dry years having salinity levels above 32 ppt and wet years around 25.5 ppt (Montagna et al., 2021). Oysters can tolerate relatively high salinities, temperatures, and increased water depths. However, some oyster predators (stone crabs [*Menippe mercenaria*] and oyster drills) and diseases (Dermo) may occur more frequently or in higher concentrations with higher temperatures and salinities (Cake, 1983; Murdock and Brenner, 2016; Soniat and Kortright, 1998). Oysters can survive in salinities ranging from 5 to 40+ ppt, they thrive within a range of 10 to 25 ppt where pathogens and predators are limited. The low-salinity end of the range is critical for osmotic balance. Oysters can survive brief periods of salinities less than 5 ppt by remaining tightly closed. They will remain closed until normal salinities are established or until they deplete their internal reserves and perish (Cake, 1983).

The slight increase in salinity that is expected resulting from Alternative 1 is not anticipated to cause any long-term impacts to oyster reefs in the project area. Increased nutrients from dredging activities could cause algal blooms that could impact oysters however potential changes in nutrients are expected to be localized and limited to a short time period.

As discussed in Section 4.2.2, modeling indicates that channel deepening would increase the average salinity in the Corpus Christ Bay system by less than 1 ppt (W.F. Baird and Associates, 2022). The slight salinity changes resulting from Alternative 1 are not anticipated to cause any long-term impacts to oyster reefs in the project area as oysters have the ability to tolerate a wide range of salinities as described above. Since oysters are filter-feeders, temporary increases in algal concentrations may have positive as well as negative effects on oysters. The historic loss of oysters in this system justifies increased awareness while activities are being monitored to avoid and minimize impacts to oysters.

4.3 POTENTIAL IMPACTS TO FEDERALLY MANAGED SPECIES

The potential for adverse impacts to Federally managed species within the project area is likely to differ from species to species, depending upon life history, habitat use (demersal vs. pelagic), distribution, and abundance.

4.3.1 Direct Impacts

Estuarine wetland and SAV habitat occur within the proposed project area of the Applicant's Proposed Action Alternative and would be directly impacted by the proposed project. Dredged material from channel deepening would be used beneficially around Corpus Christi and Redfish bays, for dune restoration on San José Island, and nearshore berms for beach nourishment along San José and Mustang islands. Additionally, new work dredged material would be placed in the New Work ODMDS.

Placement actions targeting BU in Corpus Christi and Redfish bays would create estuarine/aquatic habitat (according to the Applicant, see Appendix C) that may potentially be more productive than the open-water habitat that would be lost because of the Applicant's Proposed Action Alternative. The aquatic community may benefit from higher productivity within the bay. The created estuarine/aquatic habitat would provide shelter for increased survival, food for growth, and spawning sites for enhanced reproduction. The estuarine/aquatic habitat would specifically benefit the Federally managed brown, pink, and white shrimp and red drum, providing nursery and foraging habitat. In addition, it may also benefit other commercially and recreationally important species around placement actions targeting BU. While the created estuarine/aquatic habitat may not function at the same level as a natural marsh, finfish and shellfish have the potential to be greater in these areas due to the conversion of open-bay bottom habitat to marsh (Minello, 2000; Minello and Caldwell, 2006). This would create a positive benefit to the bay system throughout the life of the project when compared to the No-Action Alternative (Rozas et al., 2005).

Direct impacts to EFH include temporary displacement of species in the immediate vicinity of the project feature locations and New Work ODMDS. Fish are motile enough to avoid highly turbid areas and are expected to rapidly return to these areas once dredging and placement are complete (Clarke and Wilber, 2000). Feeding habits of shrimp would not be impacted since shrimp typically reside on or near the bottom where sedimentation naturally occurs (Wilber and Clark, 2001; Wilber et al., 2005). Since benthic habitat is similar throughout the project area, finfish would be able to find suitable, undisturbed habitat during construction activities. As benthic habitat is recolonized, finfish would be able to utilize the benthic habitat from which they were temporarily displaced. Refer to Section 4.2 for more detailed information.

Dredging and placement activities are not expected to cause direct mortality to juvenile and adult pelagic finfish since they are motile and are capable of avoiding turbid areas associated with project construction

(Clarke and Wilber, 2000). Penaeid shrimp use deeper water of the bay as a staging area from which they migrate to the Gulf during certain times of the year (GMFMC, 2004). The displacement of juvenile and adult finfish and shrimp during project construction would likely be temporary, and individuals should return to these specific areas once the project is completed. Juvenile and adult finfish and shrimp should experience minimal direct impacts from dredging and placement activities. Juvenile penaeid shrimp may be impacted due to their preference for burrowing in soft, muddy areas, although this activity is usually in association with plant/water interfaces.

Demersal eggs and larval finfish may be lost to physical abrasion, burial, or suffocation during dredging and placement activities due to their limited motility and sensitivity to elevated suspended sediments (Newcombe and Jensen, 1996; Wilber and Clark, 2001; Stern and Stickle, 1978; Germano and Cary, 2005; Wilber et al., 2005). Larvae in the latter stages of development are capable of some motility, which may allow for movement away from dredging and placement activities, thereby minimizing impacts. Predatory fish that feed on larval stages of federally managed species may be temporarily displaced from the area resulting from dredging and placement. Section 4.2.2 provides a more detailed discussion on impacts to the aquatic communities.

Anticipated increases in turbidity may negatively impact the ability of some finfish to navigate, forage, and find shelter (Newcombe and Jensen, 1996; Clarke and Wilber, 2000). However, these impacts would be short lived (Clarke and Wilber, 2000; Wilber and Clarke, 2001; Newcombe and Jensen, 1996; Teeter et al., 2003). Shrimp spend at least some of their life cycle in areas where they are exposed to turbid conditions and are likely able to move from an area when it becomes inhospitable. Many crustaceans (such as shrimp and crabs) are not impacted by elevated turbidities since they typically reside on or near the bottom where sedimentation occurs (Wilber and Clark, 2001; Wilber et al., 2005). Finfish, shrimp, and other marine organisms in this area are accustomed to fluctuations in turbidity and should not be substantially affected by the temporary increase in turbidity resulting from the Applicant's Proposed Action Alternative. Section 4.2.2 provides a more detailed discussion on impacts to the aquatic communities. Dredged material suitable for BU placement is not expected to pose contamination issues (see section 4.2.2 for further details). Oil or other chemical spills may adversely impact federally managed species. Larval and juvenile finfish tend to be more susceptible to spills than adults and could be affected extensively by a spill during their active migration periods. Due to their lack of mobility, larval and juvenile finfish are less likely to avoid these areas and could be negatively impacted by a spill.

The Applicant's Proposed Action Alternative would result in permanent loss of open-bay bottom habitat and offshore areas for placement in the New Work ODMDS. The potential harm of some individual organisms from turbidity-related impacts would be minimal compared with the existing conditions and would not substantially reduce populations of Federally managed species. Mitigation should not be required for these temporary disruptions to federally managed species since they are motile and avoid areas during dredging and placement and would be able to return to the area after these activities are completed (Clarke and Wilber, 2000).

4.3.2 Indirect Impacts

Indirect impacts of the Applicant's Proposed Action Alternative include a reduction in prey for Federally managed species due to the mortality or displacement of benthic species, associated with dredging and placement activities. Since benthic organisms serve as prey for finfish, their mortality may temporarily reduce finfish feeding. Disturbances to the benthic environment would be temporary and impacts would be minimal.

4.4 CUMULATIVE AND SYNERGISTIC IMPACTS

A cumulative impacts assessment takes into consideration the impact on the environment, which results from the incremental impact of the proposed action when added to other past, present, and reasonably foreseeable actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a given period of time. Impacts include both direct and indirect effects. Direct effects are caused by an action and occur at the same time and place as the proposed action. Indirect effects are caused by the action, occur later in time, and are farther removed in distance; however, they are still reasonably foreseeable. Ecological effects refer to effects on natural resources and the components (including listed species), structures, and functioning of affected ecosystems, whether direct, indirect, or cumulative.

The CDP would directly affect the estuarine habitats and fauna in the study area due to dredging and placement activities. Channel dredging (inshore and offshore) would impact 1,182 acres of open water/bottom habitat through excavation (NOAA, 2010). For Gulf side placement actions, nearshore berms (B1–B9) would impact 1,586 acres of open water/bottom habitat (NOAA, 2010), MI and SJI beach nourishment placement would impact 275.19 acres of open water/bottom habitat and 58.76 acres of freshwater wetlands (Mott MacDonald, 2021, 2022), and the ODMDS would impact 1,180 acres of open water/bottom habitat (NOAA, 2010).

Direct aquatic resource impacts from inshore PA construction include 563.85 acres of open water/bottom habitat, 16.61 acres of tidal wetlands, 122.46 acres of freshwater wetlands, 84.85 acres of unconsolidated shorelines (tidal sand flats/algal flats/beach), 6.88 acres of seagrass, and 0.10 acres of oyster reef (Mott MacDonald, 2021, 2022; Triton Environmental Solutions, 2021, 2022). These impact acreages were provided by the Applicant.

Past, present, and reasonably foreseeable actions with dredging or construction activities, and resultant ship traffic, can increase erosion or turbidity and potentially impact EFH. Pipeline installation can also have direct impacts to EFH; however, horizontal directional drilling can avoid and minimize potential impacts. If any of these projects undergo construction in timeframes that overlap with the Applicant's Proposed Action Alternative, there could be minor, temporary, and localized cumulative effects to EFH. Desalination projects could have impacts to EFH during extreme drought conditions by contributing to increased salinities, and those impacts could be exacerbated by hydrosalinity impacts of the Applicant's Proposed Action Alternative. Various infrastructure can convert potential EFH, and any EFH conversions associated with placement actions may contribute to cumulative impacts of habitat loss. Ecosystem restoration initiatives typically yield beneficial effects on EFH, and in conjunction with the proposed actions PAs could result in beneficial cumulative effects.

Despite the potential for cumulative effects on EFH, most effects from projects are assumed to occur primarily during construction, and those impacts are typically localized, temporary, and minor. Some projects are also assumed to have permanent impacts associated with their physical footprint, such as noise, air emissions, or induced traffic and growth. The proposed action’s impacts could contribute to cumulative effects where they overlap with impacts of past, present, and reasonably foreseeable actions. Even though potential temporary and permanent impacts may be associated with past, present, and reasonably foreseeable actions, it is also assumed that these projects were or would be implemented in compliance with applicable laws and regulations that exist to avoid and minimize project impacts, particularly Endangered Species Act, Coastal Zone Management Act, Marine Mammals Protection Act, and the MSFCMA. Lastly, beneficial cumulative impacts may be expected when considering the Applicant’s Proposed Action Alternative PAs in combination with restoration actions that are planned within the study area by State and Federal agencies, non-governmental organizations, and private entities. These include actions outlined in the Texas Coastal Resilience Master Plan.

5.0 MITIGATION MEASURES

The following mitigation information was provided by the Applicant:

The proposed channel of the Applicant's Proposed Action Alternative would not directly impact oyster reef, seagrass, wetlands, or other special aquatic sites (e.g., mudflats). However, the proposed dredged material placement would involve areas of wetlands and seagrass and minor areas of existing PAs previously identified as tidal flats. These impacts would occur over the course of constructing BU sites that would restore and enhance estuarine aquatic resources, including wetlands and seagrass or restore eroded shorelines that protect large areas of these resources. The following section discusses the mitigating or beneficial actions for these resources. Since the placement of material at these sites presents a net benefit to the surrounding environment, the Applicant does not propose direct mitigation for the project. Table 5 summarizes the proposed impacts by BU site:

Table 5
Summary of Proposed Impacts by BU Site (acres)

Site	Footprint	Open Water[1]	Seagrass[2]	Oysters[3]	Flats/ Beach[4]	Estuarine[5]	Palustrine[6]
SS1	297.41	219.45	0.01	0	34.64	3.92	21.04
SS2	45.21	13.74	0	0	24.20	1.25	11.25
PA4	170.79	42.14	3.46	0	2.80	0.75	41.75
HI-E	138.73	13.12	3.41	0.10	23.21	10.69	48.42
SJI	592.85	163.29	0	0	199.01	0	58.76
MI	362.08	205.58	0	0	124.11	0	0
Total	1,607.07	657.32	6.88	0.10	407.97	16.61	181.22

[1] Open Water (E1UBL M1UBL, M2USN)

[2] Seagrass (E1ABL)

[3] Oysters (E1ABL)

[4] Flats (E2ABN, E2EM1N(1) E2USN, UPL [tidal flats above the high tide line were classified as upland])

[5] Estuarine (E2M1P, E2SS3N)

[6] Palustrine (PEM1C(1))

5.1 PROPOSED WETLAND MITIGATION

The Applicant proposes to beneficially place dredge material from the project across approximately 1607.07 acres. Placement of material at SS1 would impact 3.92 acres of estuarine wetlands and 21.04 acres of palustrine wetlands. These wetlands would likely erode over time if the proposed placement does not occur. Additionally, the proposed placement would create approximately 252.75 acres of suitable elevations for marsh coastal prairie habitat. Placement of material at SS2 would impact 1.25 acres of estuarine wetlands and 11.25 acres of palustrine wetlands. The placement of material would restore the site to pre-Harvey elevations and contours. Additionally, the restoration will create approximately 34.28 acres of suitable elevations for marsh habitat. Placement of material at PA4 would impact 0.75 acres of estuarine wetlands and 41.75 acres of palustrine wetlands. Since these wetlands are in the confines of a former DMPA, they are considered of lower value than naturally occurring wetlands. The BU placement at PA4 would restore the shoreline along with PA4 and return the site's functionality as a DMPA. Placement of material at HI-E would result in impacting 10.69 acres of estuarine wetlands and 48.42 acres of palustrine wetlands. The BU placement at HI-E would restore the shoreline along with PA4 and return the site's functionality as a DMPA. The restoration of degraded DMPAs represents a reduction in project impact compared to the construction of new DMPAs. Placement of material at MI would not result in any impacts to wetlands. Placement of material at SJI would impact 58.75 acres of palustrine mosaic. Storm surge washouts created the wetlands identified with SJI. By filling the wetlands at SJI, the Applicant would restore the site to pre-storm conditions. The BU placement at MI and SJI will nourish eroding beaches. Additionally, material placed at SJI will restore breached dunes to pre-Harvey conditions, increasing local coastal resilience.

Altogether the BU placement across the six sites would impact 197.82 acres of wetlands. The Applicant estimates that the BU placement at SS1 and SS2 would create 287.03 acres of marsh habitat. Since the project would create more wetland habitat that it would impact, the Applicant does not propose to mitigate for wetland impacts. Additionally, the indirect benefits of the BU placements are greater than the estimated impacts (i.e., protection of Redfish Bay, beach nourishment, dune restoration, and DMPA restoration).

5.2 PROPOSED SEAGRASS MITIGATION

Through the BU placement across the six sites, the Applicant estimates the project would impact 6.88 acres of seagrass. Placement of material at PA 4 and HI-E would impact 3.46 acres and 3.41 acres of seagrass respectively. These impacts are necessary to restore the former DMPAs to a useable capacity as opposed to the creation of new DMPAs. Any new DMPA within the same distance from the proposed project as PA4 and HI-E would result in more impacts to seagrass than the proposed project. Additionally, since the Applicant designed SS1 and PA4 to protect the Redfish Bay, approximately 2,000 acres of seagrass, the project benefits to regional seagrass, outweigh the impacts.

6.0 CONCLUSIONS

The Federally managed species listed in this document utilize estuarine and Gulf habitat during some portion of their life for spawning, food, development, and/or protection. The Applicant's Proposed Action Alternative would have negative impacts, both directly and indirectly, to EFH in the project area. However, BU of dredged material also has the potential to enhance EFH.

The deepening of the CCSC would temporarily affect EFH by disturbing bottom sediments and increasing turbidity in both the marine and estuarine water column in the vicinity of the dredging activity, which can have adverse effects on finfish and shellfish species. Dredging would also directly affect estuarine and Gulf bottom habitats. Considering the nature of the sediments that would be dredged and the temporary nature of the dredging, these impacts are expected to be minimal.

Because the Applicant's Proposed Action Alternative would create more wetland and seagrass habitat than it would impact, the Applicant does not propose any mitigation for wetlands or seagrass impacts. The Applicant proposed that any indirect benefits of the BU placements are greater than the estimated impacts.

There are no Habitat Areas of Particular Concern in the project area (NOAA, 2021c). Coordination with NMFS is ongoing. The Draft EIS serves to initiate EFH consultation under the MSFCMA. Prior to Final EIS release to the public, this EFH Assessment will allow NMFS and GMFMC an opportunity to provide comments on EFH impacts.

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Appendix F

Cultural Resources Baseline Investigation Summary

Job No. PCA20166

APPENDIX F

CULTURAL RESOURCES BASELINE INVESTIGATION SUMMARY FOR THE PROPOSED CORPUS CHRISTI SHIP CHANNEL DEEPENING PROJECT

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June 2021

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Acronyms and Abbreviations

APE	Area of Potential Effects
AWOIS	Automated Wreck and Obstruction Information System
CDP	Channel Deepening Project
ENC	Electronic Navigation Chart
GIWW	Gulf Intracoastal Waterway
NAS	naval air station
NOAA	National Oceanic and Atmospheric Administration
NRHP	National Register of Historic Places
PCCA	Port of Corpus Christi Authority
SAL	State Antiquities Landmarks
SHPO	State Historic Preservation Offices
THC	Texas Historical Commission
TPWD	Texas Parks and Wildlife Department
USACE	U.S. Army Corps of Engineers
USS	United States Ship

1.0 CULTURAL RESOURCES

The proposed Port of Corpus Christi Authority (PCCA) Channel Deepening Project (CDP) is subject to various Federal and State cultural resource regulations. At the Federal level, the proposed project is subject to Section 106 of the National Historic Preservation Act of 1966, as amended (Section 106). Under this law, any Federal agency must consider how its actions might affect significant cultural resources. In the eyes of this law, "significant" resources are those that are determined to be eligible for or are listed on the National Register of Historic Places (NRHP). In simpler terms, Section 106 requires that Federal agencies ask themselves, "What could happen to important cultural resources if I issue this permit (or provide these funds, or allow construction on lands that I control)?" Section 106 is not a prohibition on impacting important cultural resources; it only requires that an agency know the potential effects of their action and take those effects into account as part of their decision-making process.

Cultural resources are often divided into archaeological and non-archaeological (buildings, objects, districts, cultural landscapes) resources at least 50 years of age. In addition, Traditional Cultural Properties are included among Federally managed cultural resources. Traditional Cultural Properties are places of cultural, ceremonial, or religious significance, most often associated with Native American Tribes, that may or may not include archaeological or non-archaeological components. The U.S. Army Corps of Engineers (USACE) issued PCCA CDP Record of Decision under the National Environmental Policy Act would be one such Section 106-triggering Federal action. The USACE takes significant cultural resource impacts into account by consulting with local interested parties, including State Historic Preservation Offices (SHPOs, in the case of Texas, the Texas Historical Commission [THC]) and Tribal Historic Preservation Officers to determine how best to identify cultural resources that may be affected by a proposed action, what resources can be considered "significant," and how best to manage those resources in relation to the proposed action. Federal agencies consult with Tribes directly for Section 106 projects on a nation-to-nation basis.

The State of Texas also manages terrestrial and underwater archaeological resources through the Antiquities Code of Texas. Under the Antiquities Code of Texas, archaeological resources located on lands owned or managed by the State of Texas or a political subdivision thereof must be identified and managed by that controlling agency in consultation with the THC. Significant archaeological sites, called State Antiquities Landmarks (SAL) must be found and assessed prior to allowing ground-disturbing activities within these public lands. The proposed PCCA CDP is located within lands that the Texas General Land Office manages, making the project subject to State-level archaeological resource regulatory oversight.

While both the Federal and State cultural resource laws have significant overlap, one important distinction is that the Antiquities Code of Texas is limited to projects' direct physical impact footprint. Federal agencies must take direct *and* indirect effects into account to comply with Section 106. As a result, Federal cultural resource review and documentation often incorporates archaeological, historical, and cultural properties that are farther away from the proposed project footprint.

The following summary details a general overview of the cultural setting and history of the study area that will form the basis of assessing the PCCA CDP-related effects.

2.0 CULTURAL HISTORY OVERVIEW

2.1 PALEOINDIAN PERIOD

Humans arrived in North and South America (collectively called "the New World") between 16,000 and 14,500 years before present (BP) (Gilbert et al., 2008; Pitblado, 2011). Until recently, archaeologists and historians thought that the Paleoindian Period in Texas did not begin until around 12,000 BP (Perttula, 2004). However, new evidence from the Debra Friedkin and Gault sites in Central Texas have pushed the date of earliest occupation back to around 15,000 BP (Swaminathan, 2014; Gault School, 2016). The Paleoindian Period in Texas is currently estimated to range from approximately 15,000 to 8,500 BP.

As the Pleistocene ended, diagnostic Paleoindian materials in the form of Clovis, Folsom, and Plainview projectile points began to enter the archaeological record. These points were lanceolate-shaped and fluted for hafting to wooden spears. Paleoindian-period hunters then used atlatls (a wooden instrument with a handle at one end and a hook at the other used to throw the "spears" – because these "spears" were thrown and not thrust, they are called "darts") to increase their throwing force and range. This allowed them to hunt large game such as mammoth, mastodons, bison, camel, and horse (Black, 1989; Hofman et al., 1989). In addition to large game, Paleoindian groups also harvested smaller prey, including antelope, turtle, frogs, and other small to medium-sized game. Stylistic changes in projectile point technology occurred during this later portion of the period. Environmental studies suggest that Late Pleistocene climates were wetter and cooler (Mauldin and Nickels, 2001; Toomey et al., 1993), gradually shifting to drier and warmer conditions during the Early Holocene (Bousman, 1998). The end of the Pleistocene was arid to semiarid, and prickly pear and agave populations were high (Bousman et al., 1990).

2.1.1 Offshore Pre-European-Contact (Pre-Contact/Prehistoric) Cultural Resources

The Gulf of today is 200 to 300 feet higher than it was when the first humans arrived on the North American continent during the closing centuries of the last Ice Age more than 14,000 years ago when much of the Earth's water was locked up in ice sheets and glaciers. At the height of the Ice Age, the Texas Coast was roughly 100 miles farther out than it is today and the modern-day Corpus Christi Bay Estuary was not coastal at all; it was composed of inland prairie terraces and river valleys that were probably like the environment surrounding Kenedy or Poteet, Texas of today. The plant and animal communities native to these inland prairies would have had a much larger range that would have extended into what is now the Outer Continental Shelf. Early humans in the region would have occupied this same, extended landform during this time as well (Joy, 2018). Over time, global temperatures rose which, in turn, melted the ice sheets and lifted sea levels across the planet. Geological data indicate that these rising waters first flooded the study area around 9,000 years ago, creating the Corpus Christi Bay estuary (Ricklis, 2021). As the Gulf Coast receded, so did prehistoric peoples of Texas, creating a band of previously exposed upland landforms that have the potential to hold submerged, intact cultural deposits (Joy, 2018; 2020).

This phenomenon of rising sea levels over a period of thousands of years has distinct implications for the archaeological and cultural record of the study area. Paleoindian occupants in the study area would not have been coastal peoples; sites of this age submerged in the study area would be prairie Paleoindian occupation sites of inland peoples. These inland sites would have been clustered along paleochannels that are now inundated by Gulf waters. Coastal communities from the Paleoindian period are far offshore on the Outer Continental Shelf, and these types of sites have only just begun to receive intensive archaeological attention (Joy, 2020).

Cultural resource management laws do not make management distinctions between historic and prehistoric resources; identifying and assessing the significance of *all* cultural resources is central to Section 106's objective. Despite this, finding the remnants of these earliest communities in offshore environments has been opportunistic and passive. This is largely because most of the remnants of ancient human occupation sites – primarily stone tools and tool-making-byproducts, flakes that archaeologists call "lithic debitage" – are difficult for archaeologists to detect using traditional underwater remote sensing tools like magnetometers and side-scan sonar. Despite the high concentrations of Pre-Clovis, Clovis, and Folsom sites along the Gulf Coast, not a single unequivocal coastal Paleoindian site has ever been identified on the Gulf or Atlantic Ocean Outer Continental Shelf (Joy, 2018; Lowery, 2012; Stanford and Bradley, 2012). Archaeologists are learning that lithic debitage scatters, indicative of pre-contact occupation sites of this period, can be detected on the sea floor using sub-bottom profiler data (Grøn et al., 2018; 2021). By coupling these new methods with ongoing marine paleo-landscape modeling and sediment coring, researchers are conducting more offshore studies dedicated to exploring these first human occupations in the region (Evans, 2016).

2.2 ARCHAIC PERIOD

Archaeological sites attributed to the Archaic Period in the Central Coast region exhibit a shift from more mobile hunting strategies to a heavier reliance on a diverse spectrum of local plants and animals, centered at seasonal campsites associated with springs and/or drainages (Hofman et al., 1989). The Archaic broadly dates from 8500 to 1250 BP (Hofman et al., 1989; Perttula, 2004). Increased numbers of ground and pecked stones, roasting pits, and stone-lined hearths at archaeological sites of this periot suggest that populations relied more heavily on specialized processing of plants for food (Hofman et al., 1989).

Early Archaic sites in this region primarily consist of dense oyster shell piles, called middens, with few stone artifacts. A notable lack of land animal or fish bones shows that these were not yet important food sources during this period. The massive glaciers of the last Ice Age melted during the Early and Middle Archaic, and the Texas region transitioned to a period of intense heat and aridity, called the altithermal. Archaeologists note that site densities were lower than earlier prehistoric occupations. This indicates that fewer people lived in the region, presumably because of the hotter, drier conditions along the coast. By the Late Archaic, sea levels stabilized, and the present-day bays, lagoons, and barrier islands began to take form (Ricklis, 1995). Some Late Archaic sites tend to have thicker deposits and greater densities of artifacts than Early Archaic sites which suggests a larger population and more intensive resource use. Although few cemeteries from the Early Archaic period have been recorded (Ricklis et al., 2012), the number of archaeologically recorded cemeteries appears to have increased dramatically during the Late Archaic period. This indicates a transition in settlement patterns from more nomadic bands of hunter-gatherers, to more permanent settlements based around productive fishing and hunting grounds (Ricklis et al., 2012).

2.3 LATE PREHISTORIC PERIOD

The Late Prehistoric period in the study area corresponds with the introduction of the bow and arrow. Despite this technological advancement, hunting and foraging activities were similar between the Late Archaic and the beginning of the Late Prehistoric. Beginning around 1000 to 300 BP, the Toyah culture came to prominence in Central and Southern Texas. This corresponds with the time when bison herds returned to the Southern Plains, and bison bones are common at Toyah sites. Toyah material culture includes a distinctive “toolkit” of Perdiz arrow points, beveled knives, end scrapers, and drills, all of which were useful in processing bison and deer hides (Kenmotsu and Boyd, 2012).

2.4 HISTORIC/POST-EUROPEAN-CONTACT PERIOD

The Texas Coast’s Post-Contact, Historic Period begins in the early 16th century with the first European explorers visiting the region and documenting their observations. The Historic Period then continues to the modern day. The Texas Gulf Coast consists of several barrier islands, bays, ports, and channels whose history is closely tied to early maritime exploration, 18th and 19th century settlement, and 20th century trade and development. By the mid-19th century, most development in the region stayed closest to the coast (Long, 2020a).

2.4.1 Early European Maritime Exploration

In 1519, Governor of Jamaica, Francisco de Garay, authorized an expedition to explore the Gulf Coast between Florida and the Río Pánuco of Mexico (at modern-day Tampico, Veracruz, Mexico) in the hopes of finding a waterway that would lead to Asia. Lieutenant Alonso Álvarez de Piñeda was chosen to lead four ships and a contingent of 270 men on the voyage. Between the early spring and late fall of 1519, Piñeda’s team documented many prominent features along their voyage, such as the mouth of the Mississippi River, and produced the first known chart of the Gulf Coast that includes the study area region (Weddle, 2021; Lowery, 2020). Piñeda is credited with naming the Corpus Christi Bay system, claiming it for the Spanish King on the Feast of Corpus Christi Day, in June of 1519 (Leatherwood, 2021a).

Nearly a decade later, in 1528, Álvar Núñez Cabeza de Vaca and his crew were among a large expedition party that wrecked along the Texas Coast while documenting the Coast between the Rio Grande and the Cape of Florida. Cabeza de Vaca’s group was among the few who survived when they wrecked on Galveston Island (Long, 2020a). Over the next six years, Cabeza de Vaca and his companions walked west to the Pacific Coast then headed south, eventually to Mexico City. Along their journey they visited the study area. His account is regarded as Texas’ first ethnological study of the region’s Indigenous populations and is an often-cited resource for Texas archaeologists interpreting prehistoric lifeways from sites and features (Chipman, 2021; Thoms et al., 2021).

The French explorer Robert Cavelier, Sieur de La Salle was the next prominent European explorer to visit the area. La Salle and 300 crew and settlers sailed from France in 1684 with four ships – *La Belle*, *l'Aimable*, *Le Joly*, and *Le Saint-Francois* – to find the mouth of the Mississippi River and set up a permanent settlement (Bruseth and Turner, 2005). La Salle's flagship, *La Belle*, sank in Matagorda Bay during a storm in 1686 and was the subject of an extensive archaeological excavation in the 1990s (41GM86; Bruseth and Turner, 2005). The earliest known map thought to depict the Copano Bay region from LaSalle's voyage provides possible evidence La Salle reached Aransas and Corpus Christi bays (Dowling et al., 2010).

In 1746, Colonel José de Escandón built the fort Aranzazu at Live Oak Point to defend the bay from the French. On the opposite side of the bay, the Spanish founded the port of El Cópano, the first seaport in Texas. El Cópano, found at the northern end of Copano Bay, remained unpopulated until the 19th century. With little Spanish activity occurring along the Texas Coast, the area fell victim to piracy, smuggling, and illegal trading (Dowling et al., 2010).

Twenty years later, Escandón, then governor of Nuevo Santander, authorized Captain Blas María de la Garza Falcón to explore the coast between the Rio Grande and Garza Falcón's ranch outpost, Estancia de Santa Petronila south of present Corpus Christi. Garza Falcón settled the area, as well as provided a report of Padre Island in 1766. The report included descriptions of the landscape: small clumps of stunted laurels and willows, red grass, and ships' timbers littering the beach. While waiting for Garza Falcón's report, Escandón received information from fisherman and settler, José Antonio de Garabito, describing the Texas Coast between the Rio Grande and the Nueces River as "large pastureland surrounded by lagoons." He noted sandbanks, which became fully submerged during a storm surge, and therefore, the area could not be identified as an island (Weddle, 2020).

In September of that year, 25 soldiers, led by Garza Falcón, supported Ortiz Parilla's expedition, as tensions rose between the French and Spanish. He and the soldiers set camp along the Laguna Madre, located between Padre Island and the mainland, referring to it as Playa de la Bahía de Corpus Christi, or Playa de Corpus Christi. Ortiz Parilla's expedition produced a map, including an accurate depiction of Padre Island and Corpus Christi Bay, Mustang Island, Copano Bay (referred to as Bahía de Santo Domingo), and San José Island. However, the Nueces River is missing from the sketches (Weddle, 2020).

2.4.2 Post-Contact Native American Tribal history in the Region

The Karankawa people were the primary occupants of the Texas Gulf Coast when European explorers first arrived in the region. Their name means "dog lovers" in their native language (Calhoun County Museum, 2020; Bruseth and Turner 2005). These early Texas inhabitants were nomadic; they seasonally occupied the barrier islands in the Gulf Coast and retreated to the Texas inlands in the off season. They lived in small huts, made of a ring of poles drawn together at the center and covered with hides or mats (Bruseth and Turner 2005). The Karankawas navigated between the islands and the Texas interior maritime pathways on large dugout canoes. Fishing, hunting, and foraging were their main form of subsistence (Lipscomb, 2020). Early written accounts depicted the Karankawas as tall, with body piercings and linear or animal-shaped tattoos (Calhoun County Museum, 2020; Bruseth and Turner 2005).

The Karankawa people were familiar with Spanish and French interests in the region and were known to have clashed with both groups in the early years of European exploration. Following La Salle's tepid claim to the region in the early 18th century, Spain bolstered its efforts to colonize the region and convert the local inhabitants to loyal Spanish citizens. The Karankawas resisted the conversion to Catholicism and more violence ensued. The Spaniards used the Karankawa-Spanish War as justification for their eradication and as an opportunity to gain control of the Texas Coast. Conflicts continued for more than a decade (Lipscomb, 2020; Seiter, 2020).

When Texas fell under Mexican control in 1821, the Mexican government encouraged white settlers to immigrate to the underpopulated region that the Karankawa had called home. Anglo-American Texans flooded in, straining the region's natural resources. The settlers waged constant war against the Karankawa to drive them off. During the Texas Republic era, the Karankawas were politically demonized and pushed into Mexico, then back into Texas. To survive, many of them took Mexican last names or allied themselves with white ranchers and assimilated into those communities. The last band of Karankawas was eradicated in 1858 in Rio Grande City along the Texas/Mexico border (Lipscomb, 2020; Seiter, 2020).

Modern Karankawas call themselves "the Karankawa Kadla," meaning mixed or partial Karankawa, and they have made considerable efforts to revitalize their language and cultural traditions in the region (Lipscomb, 2020). They are not a Federally recognized Tribe.

2.4.3 Merchant Vessels and Harbors of the 18th and 19th Centuries

Ports developed along the lower Texas Coast supported various industries, including fishing, cattle and sheep ranching, and ship building. Local leaders saw the economic advantages the bay area could bring if further developed. Families settled into the area, businesses and schools opened, and a system of channels and harbors supported maritime shipments. In the 1780s, Governor Bernardo de Gálvez established a port of entry and customhouse in what is now Refugio County, named El Cópano. The port served Refugio and neighboring towns, and its formidable reputation encouraged settlement in the area. (Long, 2020a; Leffler, 2020).

White settlers were not permanently established in the Corpus Christi Bay area until September 1839 when entrepreneurs Henry Lawrence Kinney and his partner, William P. Aubrey, established a trading post on the west shore of Corpus Christi Bay (Long, 2020a; 2020b). The town was small with no more than 20 reported residences.

When the United States acquired the Texas Republic, the nation feared that Mexican forces would try to reclaim portions of their former territory. The U.S. government sent Army General Zachary Taylor to the beach at Corpus Christi in July of 1845 to stand ready to enforce its claim on the southern border. More than half of the U.S. Army camped at Fort Marcy – as Taylor called it – along a mile-long site near the site where United States Ship (USS) *Lexington* is moored today until the following March of 1846 (Payne, 1970). The seven-month encampment spurred the growth of Corpus Christi. Various traders, entrepreneurs, and Federal resources poured into the area to service the almost 4,000 men stationed on a desolate stretch of sand. Larger trade routes were set up to connect the camp by land to the other military forts and by sea to the greater Gulf Coast for provisions, mail, and general trade. The summer months were favorable, but the winter made the area's shortcomings clear. Inadequate housing and a lack of wood for heat and cooking left scores of men ill and bedridden. Future U.S. Presidents Zachary Taylor and Ulysses S. Grant, in addition to a host of future high-ranking military leaders of the Civil War, lived at the camp before moving south during the Mexican American War (Payne, 1970).

Corpus Christi's shortcomings compared to other Texas coastal communities became increasingly clear as populations rose during the second half of the 19th century. Corpus Christi lacked access to fresh water and a deep-water port, making it somewhat of a lawless frontier town. In addition, there was no effective city government until the 1850s. However, by the 1860s, the population had grown to 1,200 and new schools and businesses were built (Long, 2020b).

2.4.4 The Study Area During the Civil War

The Civil War reached the study area in the summer of 1862, during the Battle of Corpus Christi. A part of the Texas Coast from Pass Cavallo to Corpus Christi was under blockade by United States Ship (USS) *Arthur.* Commerce, however, continued through the port at Corpus Christi because USS *Arthur* had too deep of a draft to pass through the barrier islands. Lieutenant John W. Kittredge, commander of *Arthur,* later received two vessels from New Orleans, *Corypheus,* a yacht, and *Sachem,* a steamer, both of which could pass through the shallow waters and into the interior waterways of Corpus Christi. Once inside, his shallow-drafted Union vessels captured Confederate Ship *Reindeer* and Confederate Ship *Belle Italia* and converted them into Union gunboats. On August 12, 1862, Kittredge commanded a fleet made up of *Corypheus*, *Sachem*, *Reindeer*, and *Belle Italia* into Corpus Christi Bay, and captured Confederate Ship *Breaker* (Delaney, 2020).

A conflict between the Union naval fleet and Confederate ground forces at Corpus Christi ensued after civilians fled the area. Confederate forces managed to drive back the Union fleet despite being outgunned and outmanned but keeping the city under Confederate control was hardly a celebratory victory. The years after the Battle of Corpus Christi left many of the city's residents unprotected from encroaching United States' forces and cut off from supplies. Residents were faced with starvation and constant turmoil until the war ended three years later (Delaney, 2020).

2.4.5 Post-Civil War Era

Following the Civil War, Corpus Christi, and the surrounding areas, including Port Aransas and Refugio, supported sheep and cattle ranching. Port Aransas, formerly known as Ropesville and Tarpon, is located on Mustang Island. The port town, St. Mary's of Aransas, found on Copano Bay, was the largest lumber and building-materials center in western Texas. Merchants also shipped much-needed supplies out of the port during the Civil War. The war devastated Aransas County's economy, and many towns were destroyed. However, towns such as Fulton and Rockport were founded in 1866 and 1867, respectively. Both towns supported the cattle industry, with Rockport home to several packeries. Rockport was eventually developed into a deep-water harbor, as was Aransas Pass in 1920 after several failed attempts (Long, 2020a).

Corpus Christi was used as a shipping center during a cattle boom in the 1870s, revitalizing the post-war economy. But it was not until the September 14, 1919 hurricane, which devastated the Gulf Coast, that Corpus Christi leaders implemented a plan for a deep-water port. To support its growing cattle trade, Corpus Christi dredged its main sea channel to allow access to larger steamers. Construction was completed on the port in 1926 (Long, 2020b). Its construction reduced the importance of Rockport's deep-water port (Long, 2020a).

The economy improved following the construction of the deep-water ports after being impacted by the damaging effects of the 1919 hurricane. In the years to follow, the construction of the Port of Corpus Christi, as well as the discovery of oil in Nueces County in 1930, offset the economic impact of the Great Depression (Long, 2020b). In addition, the late 19th century introduced shipbuilding and fishing into the market. The shrimping industry, introduced to the economy of Rockport by the 1930s, was prosperous, producing 51 million pounds of shrimp by the 1950s. Rockport's shipbuilding industry boomed during World War I and World War II (Long, 2020a). In 1965, the Port of Corpus Christi began dredging the navigational channels that are being upgraded as part of the current undertaking (Long, 2020b).

2.4.6 The Gulf Intracoastal Waterway

The proposed CDP crosses the Gulf Intracoastal Waterway (GIWW), a significant inland navigational and commercial waterway that parallels the Gulf coast, as it passes through the barrier Mustang and San José islands into Nueces Bay. The GIWW is a 1,100-mile-long, shallow-draft (~12 feet deep) canal system and interior waterway that runs continuously from the Port of Brownsville, Texas to Saint Marks, Florida. More than 30 percent of the entire GIWW (379 miles) follows Texas' coast (Texas Department of Transportation, 2020). Engineers and government leaders formulated the first concepts for the GIWW as an internal commercial system of interconnecting canals and roads as early as 1808, but, beyond occasional survey approvals, little physical progress was made throughout most of the 19th century. The first plans for the Texas portion of the GIWW were developed in 1875, but the dominant railroad industry successfully hindered most efforts to build it well into the 20th century (Leatherwood, 2021b). Prospectors' discovery of oil at the Spindletop field near Beaumont ushered in an oil boom that pushed canal development further, but the GIWW did not reach the study area until 1941 (Leatherwood, 2021b). Construction began in earnest when the United States entered World War II when the Gulf of Mexico became a primary hunting ground for German U-Boats (submarines). The US needed a safe transport corridor to carry supplies out of the gulf and into the open Atlantic Ocean. The GIWW was expanded and extended to its current dimensions during the War (Texas Department of Transportation, 2020; Leatherwood, 2021b).

2.4.7 Naval Aviation and Naval Air Station Corpus Christi

During the 1920s and 1930s, the U.S. Navy explored the fledgling tactic of employing aircraft in naval combat roles. These various wargaming exercises were called "Fleet Problems." By 1938, the U.S. Navy had 1,000 planes in service; however, that year, Congress authorized funds to triple naval air strength and construct new naval air stations (NAS). The Navy chose a location in Flour Bluff, fifteen miles southeast of Corpus Christi as one such NAS. The site was selected due to its favorable weather year-round and flat, undeveloped land. Corpus Christi Bay would also allow space for seaplanes to land. Construction on NAS Corpus Christi began quickly, and the station was commissioned on March 12, 1941. In early April, the first group of cadets reported for training (Coletta, 1985).

Following the Japanese attack on Pearl Harbor on December 7, 1941, NAS Corpus Christi was flooded with recruits. With its access to the ocean and port facilities, the station soon became a supply base for vessels involved in coastal patrol. In addition, the PBY *Catalinas,* used in advanced pilot training, conducted long-range patrols of the Texas Coast. In 1944, a torpedo bombing training squadron was also added to the facility. Pilots trained at NAS Corpus Christi typically joined carrier air wings or went on to fly multi-engine patrol bombers, as several types of aircraft were used to train cadets, including F6-F *Hellcats*, F8-F *Bearcats*, P2V *Neptunes*, and PBM *Mariners*.

During the 1950s, the Navy constructed more runways and navigation systems at NAS Corpus Christi. Training aircraft for primary recruits were upgraded to the T-28 *Trojan* planes while helicopters were being used at the base regularly. In 1954, the first F9F-2 *Panther* jet propelled aircraft began flying from NAS Corpus Christi; however, jet flight training quickly switched to NAS Kingsville in 1957. In 1956, USS *Antietam*, CV-36, arrived off NAS Corpus Christi, allowing pilots to become carrier qualified. By the mid-1960s, the Navy discontinued seaplane operations (Coletta, 1985), including landings in Corpus Christi Bay.

3.0 OVERVIEW OF KNOWN CULTURAL RESOURCES IN THE STUDY AREA

The following section is a summary of previously-recorded terrestrial and offshore archaeological sites, surveys, cemeteries, NRHP properties or districts, and other cultural resources within the study area that have been recorded in various databases. These include:

- THC's Online Archeological Sites Atlas (THC Atlas, 2021)
    - NRHP-listed Districts and Properties
    - Historic-age cemeteries
    - Previously conducted terrestrial and underwater archaeological investigations (locations, reports of findings)*
    - Previously recorded archaeological sites*
    - Previously recorded historic shipwrecks*
- Texas State Marine Archeologist (at the THC)
    - Various records and past investigation reports not available on the Atlas.
- National Oceanic and Atmospheric Administration (NOAA) Automated Wreck and Obstruction Information System (AWOIS) and Electronic Navigation Chart (ENC) Datasets (NOAA, 2021)
    - Recorded historic and recent shipwreck general locations and descriptions.

** Denotes datasets that contain sensitive archaeological site location information. These data are restricted from public presentation or distribution.*

3.1 TERRESTRIAL CULTURAL RESOURCES

3.1.1 National Register of Historic Places Properties and Districts in the Study Area

According to the THC's Atlas (2021), six NRHP listed Districts (Table 1) and 14 NRHP listed properties are located within the study area (Table 2). Most of these resources are individual residences, commercial buildings, and other structures that are far away from the CDP project's Area of Potential Effects (APE). Previous CDP cultural resource coordination resulted in a determination that none of these resources is likely to be affected by the proposed action. The Aransas Pass Light Station is the closest National Register-listed resource to any of the proposed project components.

Table 1
Historic Districts within the Study Area

National Register Reference #	Year Listed	Historic District	County
77001423	1977	Aransas Pass Light Station	Aransas
88001829	1988	Broadway Bluff Improvement	Nueces
6000121	2016	600 Building	Nueces
15000336	2015	Galvan Ballroom	Nueces
66000820	1966	King Ranch	Kleberg, Kenedy
96000065	1996	Seale, Wynn, Junior High School	Nueces

Source: THC Atlas (2021).

Table 2
National Register Listed Properties within the Study Area

National Register Reference #	Year Listed	County	NRHP Property Name
83003155	1983	Nueces	Guggenheim, Simon, House
75001945	1975	Aransas	Fulton, George W., Mansion
79003002	1979	Nueces	Tarpon Inn
79003003	1979	Nueces	Old St. Anthony's Catholic Church
93000129	1993	Nueces	King, Richard, House
94001016	1994	Aransas	Hoopes--Smith House
71000918	1971	Aransas	Mathis, T.H., House
76002054	1976	Nueces	Britton-Evans House
83003156	1983	Nueces	Lichtenstein, S. Julius, House
83003157	1983	Nueces	Sidbury, Charlotte, House
76002055	1976	Nueces	Nueces County Courthouse
03001043	2003	Nueces	USS *Lexington*
83003811	1983	Refugio	Wood, John Howland, House
10000863	2010	Nueces	Sherman Building

Source: THC Atlas (2021).

3.1.2 Recorded Historic-Age Cemeteries within the Study Area

According to the THC Atlas (2021), 39 previously recorded historic-age cemeteries are mapped within the study area (Table 3). San Ignacio Cemetery, near the community of Ingleside, is the closest of any of these historic-age cemeteries to the CDP project vicinity, but it is still roughly 1.6 miles away. This cemetery is briefly discussed in the Impacts chapter.

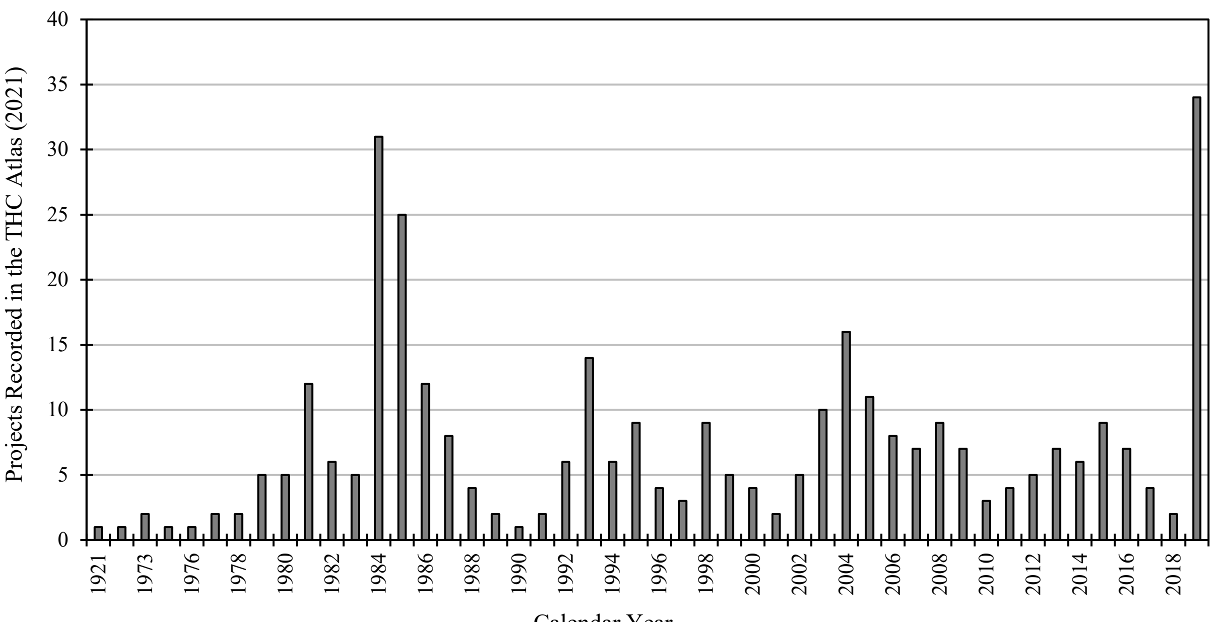
Table 3
Previously Recorded Cemeteries within the Study Area

THC Cemetery #	Cemetery Name	County
NU-C003	Memory Gardens	Nueces
RF-C004	St Bernard	Refugio
RF-C005	La Rosa	Refugio
RF-C006	Oakwood	Refugio
NU-C013	Seaside Memorial	Nueces
NU-C014	Aberdeen	Nueces
NU-C033	Rose Hill	Nueces
NU-C018	Holy Cross	Nueces
NU-C002	Old Bayview	Nueces
NU-C009	Nueces County	Nueces
NU-C031	Mercer	Nueces
NU-C022	Royal Palms	Nueces
NU-C011	Robstown	Nueces
NU-C025	Hebrew Rest	Nueces
NU-C008	St. Anthony's	Nueces
AS-C005	McLester Family	Aransas
AS-C008	Barber	Aransas
NU-C016	Sunshine	Nueces
NU-C001	Duncan	Nueces
AS-C001	Cementerio San Antonio de Padua	Aransas
AS-C002	Fulton	Aransas
AS-C003	Rockport	Aransas
AS-C004	Lamar	Aransas
AS-C006	Powell-Young	Aransas
AS-C007	Aransas Memorial Park	Aransas
SP-C001	Sinton	San Patricio
SP-C008	San Pedro	San Patricio
SP-C010	Bethel	San Patricio
SP-C012	Bellevue	San Patricio
SP-C013	San Patricio Memorial Park	San Patricio
SP-C014	Portland	San Patricio
SP-C015	Prairie View	San Patricio
SP-C016	San Ignacio	San Patricio
SP-C022	Eternal Rest	San Patricio
SP-C025	Meansville	San Patricio
RF-C003	Saint Mary's	Refugio
SP-C011	Rosita	San Patricio
SP-C020	Welder Grave	San Patricio
NU-C019	New Bayview	Nueces

Source: THC Atlas (2021).

3.1.3 Previously Conducted Terrestrial Archaeological Investigations in the Study Area

The THC's Atlas includes information regarding all recorded terrestrial archaeological field projects (that the state is informed of) conducted within the state. These projects include reconnaissance and intensive field surveys, NRHP and/or SAL-eligibility testing, and data recovery excavations. Information thoroughness and accuracy varies between the records but one can make some general interpretations from the dataset. The THC Atlas (2021) records indicate that 344 terrestrial field investigations have been conducted within the study area with the earliest dating back to 1921 (Figure 1). The USACE oversees a range of public and private development projects such as navigation improvements, oil and gas pipelines, and general infrastructure. The 109 recorded terrestrial projects in the study area attributed to the USACE – nearly five times its nearest neighbor – reflects the agency's broad oversight (Table 4). Archaeological surveys and intensive site investigations associated with road and other transportation improvement projects, sponsored by the Texas Department of Transportation (n=23; and its earlier iteration as the Texas Department of Highways and Public Transportation: n=7) or the Federal Highway Administration (n=15), make up another significant component of recorded field investigations. None of the previously conducted terrestrial projects directly overlaps the CDP APE; however approximately 33 – roughly 10 percent of the total number of recorded terrestrial field investigations – are within 3,000 feet of it. Findings from the remaining 311 recorded investigations are unlikely to contribute significant insights relevant to the CDP's potential to impact significant terrestrial archaeological resources.



Source: THC's Atlas (2021).

Figure 1. Recorded Archaeological Field Investigations Conducted within the Study Area

Table 4
Summary of Previously Conducted Terrestrial Archaeological Projects in the Study Area

Project Sponsor/Agency	Number of Projects
U.S. Army Corps of Engineers-Galveston District	109
Texas Department of Transportation	23
City of Corpus Christi	20
Environmental Protection Agency	17
Federal Highway Administration	15
U.S. Air Force	11
Texas Water Development Board	10
Texas Parks and Wildlife Department	9
Texas Department of Highways and Public Transportation	7
Port of Corpus Christi Authority	6
U.S. Navy	6
Housing and Urban Development	6
Federal Energy Regulatory Commission	5
Texas A&M University - Corpus Christi	4
Lower Colorado River Authority	4
Federal Housing Administration	3
City of Rockport	3
Nueces County	3
City of Portland	2
San Patricio Municipal Water District	2
General Services Administration	2
Aransas County	2
Veterans Administration	2
Other*	22
Null/Unknown	*51*
Total	344

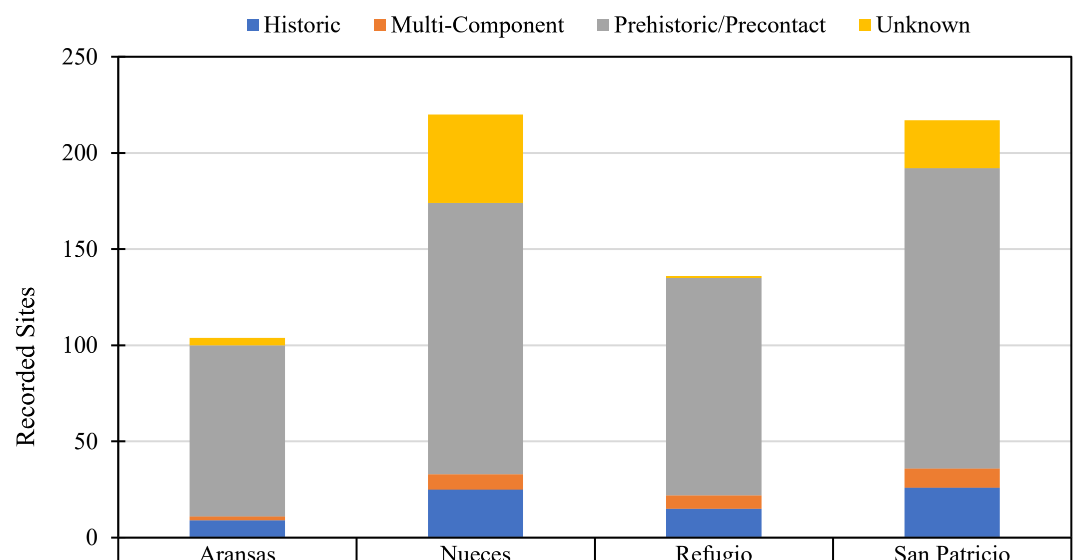
*Other: Gregory-Portland Independent School District, Bureau of Reclamation, City of Fulton, Port of Corpus Christi Authority, U.S. Fish and Wildlife Service, Private, US Fish and Wildlife, Refugio County, Texas General Land Office, San Patricio County Drainage District, Naismith Engineering, Inc., Naval Facilities Engineering Command Southeast, City of Woodsboro, U.S. Army, Voestalpine Texas LLC, Environmental Protection Agency, Bureau of Land Management, Federal Communications Commission, Witte Museum, Texas Commission on Environmental Quality, City of Port Aransas, and Nueces County Coastal Parks System (1 recorded survey each).

Source: THC Atlas (2021).

3.1.4 Previously Recorded Terrestrial Archaeological Sites in the Study Area

The THC's Atlas (2021) records indicate that there are 677 previously recorded terrestrial archaeological sites within the overall study area (Figure 2). These sites are remnants of a range of occupations from humans' earliest millennia in the region to the early-to-mid-20th century. Most of these sites dot the shorelines of the study area's major water bodies while many have been recorded farther inland. Across each of the study area counties, site age distributions are similar: most recorded sites are attributed to precontact/prehistoric periods while historic-age sites make up roughly 10 percent of a given county's site tally. The overwhelming majority of recorded prehistoric/precontact site components are of an unspecified age (Table 5). In some part, the unattributed components could be an indication of incomplete or inaccurate site records in the THC's database. With that said, many archaeological sites are small, isolated lithic flake or shell scatters with no specific types of artifacts that archaeologists know date to a certain historical period, called "diagnostics." As a result, a substantial number of these sites' ages remain unspecified.

Most of the recorded prehistoric sites date to the Late Prehistoric or Late Archaic/Late Prehistoric periods (from 3,000 to 300 years ago). Also of note, only one recorded site (41SP157 in San Patricio County) in the study area has an identified Paleoindian component. This matches the regional cultural chronology patterns discussed above. Most of the recorded prehistoric archaeological sites/site components within the study area are small, isolated lithic scatter sites like those described above (Table 6). When one includes the even more sparse scatters, these non-descript sites make up more than 60 percent of the total tally. A third of the prehistoric sites are defined as occupation sites, most often with shell middens. This is indicative of the bay systems' influence on ancient people's lives. In addition, nine site records include references to containing human remains: 41AS80, 41NU60, 41NU66, 41NU276, 41RF20, 41SP1, 41SP45, 41SP64, and 41SP203. Many of these sites were recorded decades ago in poor condition, eroded on shorelines and none are mapped in the CDP's project vicinity.



	Aransas	Nueces	Refugio	San Patricio
Unknown	4	46	1	25
Prehistoric/Precontact	89	141	113	156
Multi-Component	2	8	7	10
Historic	9	25	15	26

Source: THC Atlas (2021).

County

Figure 2. Distribution of the Ages of Terrestrial Archaeological Sites within the Study Area (Divided by Bounty and Primary Site Component Age)

Table 5
Summary of Recorded Terrestrial Archaeological Site Components in the Study Area

Prehistoric/ Precontact Period	Number of Components	Percentage of Total
Late Paleoindian/Archaic	1	10.2
Archaic	36	6.8
Early Archaic	1	0.2
Early/Middle Archaic	1	0.2
Middle/Late Archaic	1	0.2
Late Archaic	16	3.0
Late Archaic/Late Prehistoric	17	3.2
Late Prehistoric	73	13.9
Unspecified	*380*	*72.2*
Total	526	100.0

*Divided by specific component age

Source: THC Atlas (2021).

Table 6
Summary of Recorded Terrestrial Prehistoric Archaeological Sites/Site Components in the Study Area*

Recorded Prehistoric Site/ Site Component Type	Number of Recorded Sites	Percentage of Total
Scatter/campsite	244	46.4
Occupation/midden/shell midden	165	31.4
Unknown Prehistoric	95	18.1
Scatter/campsite; shell midden	13	2.5
Prehistoric burial/cemetery	8	1.5
Scatter/campsite; prehistoric burial/cemetery	1	0.2
Total	526	100.0

* Divided by Site type

Source: THC Atlas (2021).

Pre-contact archaeological sites that now lie underwater but were originally on dry land would follow similar distributional patterns of terrestrial pre-contact archaeological sites farther inland. Typically, terrestrial archaeological sites of this period are denser on terraces overlooking waterways. Periodic floods along these waterways carry mud that can bury remnants of ancient campsites, homes, and other features, preserving them in place (Davis, 2017). This preservation gives archaeologists more data from which to learn about the people who used and created the site and therefore makes them more scientifically valuable. Even though they are now underwater, many of these relict river and stream channels – and their corresponding terraces – are detectable within the study area. Bathymetric data indicates that most of the modern Corpus Christi Bay complexes were terrestrial terraces overlooking the confluence of the Nueces and Mission rivers during this period (Evans, 2016). The ancient Nueces River channel continued southward, through Redfish Bay and what is now Mustang Island State Park, where it eventually emptied into the Gulf at the Outer Continental Shelf. Because of natural siltation processes within the Gulf, prehistoric cultural deposits could be preserved under more recent Holocene deposits (Evans, 2016; Davis Jr., 2017).

As stated above, historic-age archaeological sites make up roughly 10 percent of the total study area assemblage. This is likely the result of two factors: 1) archaeologists did not typically study and formally record historic-age sites as intensively before cultural resource regulatory laws were put in place; and 2) the "historic" period lasts for only 300-400 years, roughly five percent of the full span of human occupation in the region. Not enough time has passed in the historic period to generate as many sites as the 8,000-year prehistoric period. Accordingly, when viewed in relation to their prehistoric counterparts, the density of historic-age sites is high (Table 7). Domestic and farmstead sites make up nearly half of all the historic-age sites, most dating to the late 1800s and early 1900s. Nondescript trash scatters make up another quarter of the total historic-age site tally. Other notable sites relate to military (41NU253, Zachary Taylor's Army Camp site; 41AS82, Shellbank Island Civil War Fort; and 41NU361, military housing remnants at Corpus Christi NAS), commercial (41SP35, La Quinta Mansion; 41SA95, a mid-19th-century salt production facility), and transportation (41NU289 and 41NU290, remnants of the Aransas Railroad and Ransom Island causeways) activities. Four cemeteries/burial sites are among the THC Atlas (2021) site records for the study area as well: 41NU254, 41RF143 (the Plummer's Graves Cemetery), 41SP122 (Hatch Preemption Cemetery), and 41SP276 (Portland/Georgia Cemetery). All are attributed to the late 19th century.

Table 7
Summary of Recorded Historic-Age Terrestrial Archaeological Sites/Site Components in the Study Area*

Recorded Historic-Age Site Type/Primary Age	Sites/Site Components	Percentage of Total
Agriculture	2	2
1901-1950	1	50
Unspecified	1	50
Burial/cemetery	4	3.9
1851-1900	4	100
Commerce/Transportation	5	4.9
1851-1900	2	40
1901-1950	3	60
Commercial	7	6.9
1801-1850	1	14.3
1901-1950	6	85.7
Domestic/Farmstead	44	43.1
1801-1850	1	2.3
1851-1900	15	34.1
1901-1950	17	38.6
Unspecified	11	25

Recorded Historic-Age Site Type/Primary Age	Sites/Site Components	Percentage of Total
Education	2	2
1851-1900	2	100
Engineering/Industrial	3	2.9
1901-1950	3	100
Military	6	5.9
1801-1850	1	16.7
1851-1900	3	50
1901-1950	1	16.7
Unspecified	1	16.7
Nondescript scatter/trash dump	29	28.4
1851-1900	1	3.4
1901-1950	14	48.3
Unspecified	14	48.3
Grand Total	102	100

* Divided by site type and primary age.

Source: THC Atlas (2021).

Previously recorded sites 41NU92, 41NU153, and 41NU210 are located within the proposed CDP's APE. They will be discussed in more detail in the Impacts chapter. Below is a summary of some of the other previously recorded sites within the study area but are farther away. Though they are not likely to be impacted by the undertaking, they are indicative of the types of terrestrial archaeological resources in the project vicinity.

Site 41SP28 is part of a series of shell middens that were recorded on a shoreline dune ridge on the northern shore of Corpus Christi Bay. Shell middens along the dune ridge typically hold the remains of lithic tools and fire-hardened clay in addition to the shell artifacts. Many of these sites are dateable only by projectile points; in the case of 41SP28, two dart points were recovered: one Tortugas point and the other a Plainview type, dating the site to sometime in the Middle to Late Archaic (41SP28 Site Record in THC Atlas, 2021). Evidence for long-term occupation in the study area is prevalent.

Site 41SP11 is the location of a substantial prehistoric occupation; artifacts at the site included several types of lithic dart points (Darl, Catan, Perdiz, Eddy, Starr, and Young), shell tools, stone pipe fragments, decorated and undecorated ceramics, and a glass bead. Artifacts seen at Site 41SP108 indicate a camp site and associated shell midden. In addition to the midden, artifacts included lithics, burned bone, and ceramics. Site 41SP78 was the location of a prehistoric burial that includes five to seven individuals and associated burial goods like a necklace, Ensor lithic point, and bone objects (41SP11 Site Record in THC Atlas, 2021).

While shell middens such as 41SP28 demonstrate that humans occupied the area during the Archaic Period, the ceramics at 41SP108 and 41SP11 and burials at 41SP78 indicate temporally longer occupations and possibly permanent settlements by the Late Prehistoric period (Rutherford et al., 2018).

Sites 41NU253 and 41NU351 have been identified as the locations of General Zachary Taylor's Camp during the Mexican American War. Artifacts recovered from 41NU253 included clay pipes, bottles, ammunition, and military accoutrements including buttons and belt buckles (41NU253 site record in Atlas, 2021). Site 41NU351 is also part of General Taylor's encampment at Corpus Christi, and it is located within modern-day Artesian Park. The park was named after a well that was drilled at the site to supply fresh water for the army during Taylor's encampment. The archaeological site has a subsurface layer of coal and iron slag left over from the seven-month encampment. After the Civil War, the area was presumably used as a leisure area; archaeologists encountered bottles dating from 1878 to 1882 (41NU351 site record in THC Atlas, 2021).

Finally, Site 41AS91 was initially recorded in 1995 as a potential army supply depot and camp dating to the Mexican American War and potentially re-used during the Civil War. Though informants visited the site, the high sand dunes obscured what historical records suggested might be buried features such as the quartermaster's headquarters, ordinance stores, general hospital, and more. Archaeologists did not observe any such features and based their interpretations primarily on archival records. In 2001, archaeologists returned to the site area. This time, investigators successfully interpreted that the landform on which the original 41AS91 boundary had been recorded had not developed until the 1870s, after the Aransas Lighthouse was constructed. The site recorders in 2001 did find structural features, including brick fragments and wooden posts that they attributed to a factory built in 1934. The site's original boundary is adjacent to the proposed SJI project component, but the revised site boundary is farther to the west, away from the APE. Archaeologists recommended that the site's NRHP and SAL eligibility was undetermined, pending additional investigation (41AS91 site records in THC Atlas, 2021).

Other sites associated with leisure along the bay shore include the site of the Harbor Inn (41SP199), a resort dating to the early 20th century. Structural elements and steps are located on site along with caliche-lined walkways. Artifacts recovered from the site included colorless glass, cow bone, and refrigerator and stove parts (41SP199 site record in Atlas, 2021). Historic causeways leading to the barrier islands include sites 41NU289 and 41NU290. Site 41NU289 is the remains of a 1912 railroad causeway leading to docking facilities on Harbor Island, and 41NU290 is of the remains of a causeway leading to 1930s and 1940s resorts on Ransom Island (THC Atlas, 2021).

3.2 UNDERWATER/MARITIME CULTURAL RESOURCES WITHIN THE STUDY AREA

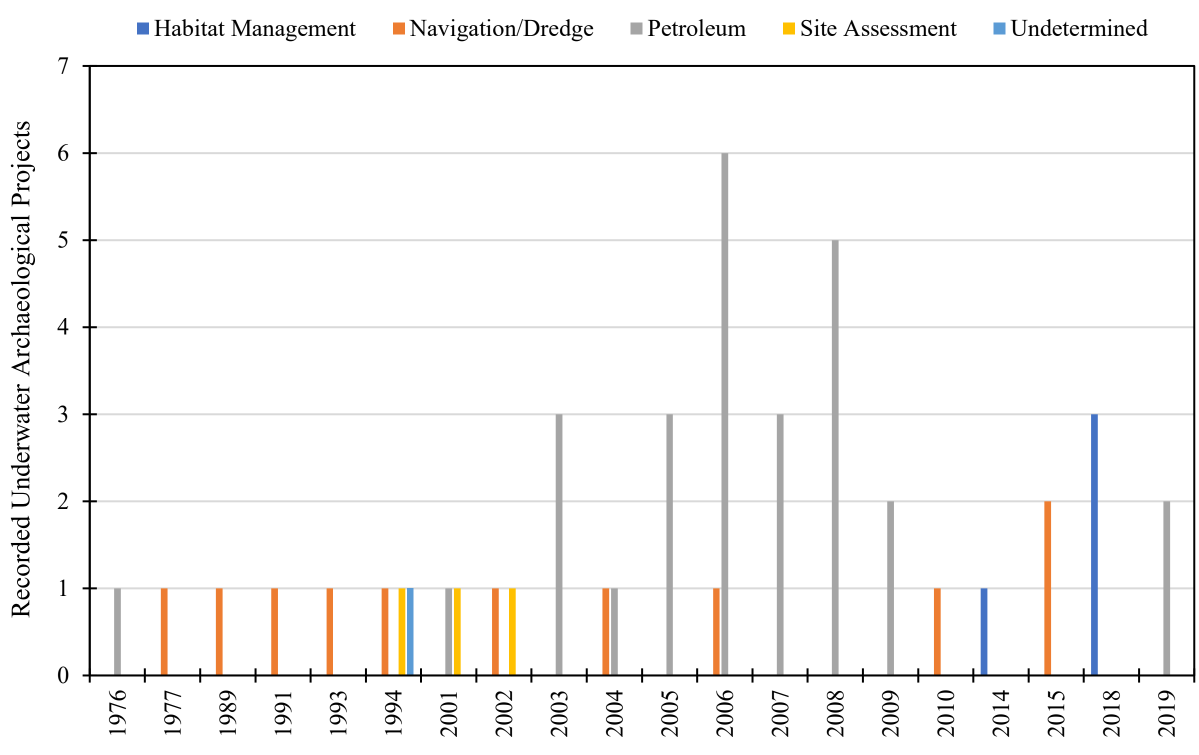
3.2.1 Previously Conducted Underwater Archaeological Surveys

According to the THC Atlas (2021), underwater archaeologists have conducted 46 surveys within the study area. These surveys cover nearly 31,000 acres of submerged lands in the study area and span more than 40 years, beginning in 1976 and extending to 2019. Investigations supporting the petroleum industry (n=27) make up nearly 60 percent of the total number of projects, while navigational, dredging, and other infrastructure improvements account for another quarter (n=11). Other surveys correspond with reef and habitat improvement projects (n=4), and specific site assessments (n=3; Table 8). Most of these projects were conducted regularly throughout the 43 years of recorded investigations, but a distinct increase in petroleum-industry-related surveys corresponds with the recent fracking boom of the mid-to-late 2000s (Figure 3). Ten of the 46 recorded investigations overlap or are located adjacent to CDP project components. Those surveys will be discussed in more detail in the Impacts chapter.

Table 8
Summary of Recorded Underwater Archaeological
Surveys Conducted in the Study Area

Proponent Industry	Number of Surveys	Percentage of Total Surveys
Petroleum	27	59.0
Navigation/Dredge	11	24.0
Habitat Management	4	9.0
Site Assessment	3	7.0
Undetermined	1	2.0
Total	46	100.0

Source: THC Atlas (2021).



(Source: THC Atlas (2021).

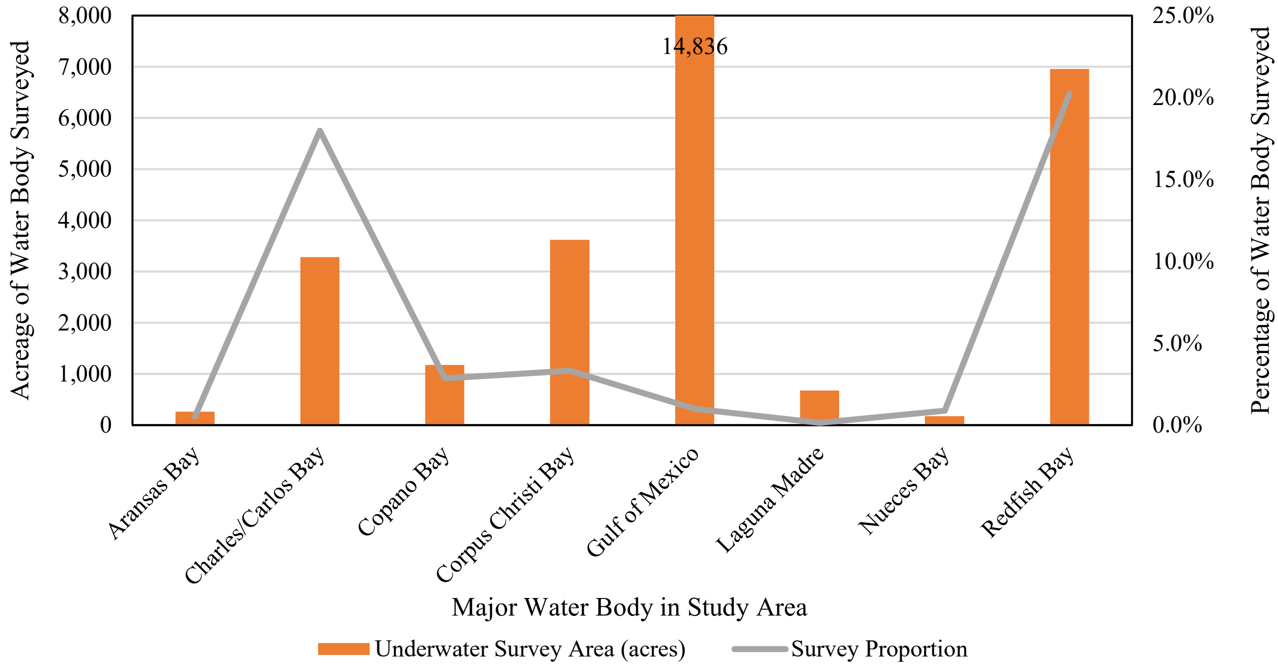
Figure 3. Recorded Archaeological Field Investigations Conducted within the Study Area

Intensive archaeological survey is necessary to determine with certainty how a proposed action (e.g., a construction project like the proposed CDP) might impact – directly or indirectly – archaeological cultural resources. Bulk geographic data from Texas Parks and Wildlife's Coastal Fisheries Division (2018) and aggregated information from underwater archaeological investigations within the PCCA CDP study area (THC Atlas, 2021) offer a preliminary glimpse of what might be affected once the project begins construction. Table 9 and Figure 4 provide breakdowns of these datasets. At the most basic level, little of the study area has been physically investigated. Collectively, more than two million acres of the study area's underwater footprint (more than 98 percent; larger than the state of Delaware) has never been subject to formal archaeological investigations. Most of the individual water bodies, though higher than the overall average, have three percent or less survey coverage. A significantly greater proportion of Charles/Carlos Bay, near the study area's eastern edge, and Redfish Bay, just inside the breakwater, have been previously surveyed. For the former, this is likely a reflection of the bay's small size, while the latter corresponds with a particularly busy part of the study area with numerous previous development projects.

Table 9
Summary of Geographic and Cultural Resource Distribution Data within the Study Area

Water Body	Total Area (acres)	Underwater Survey Area (acres)	Survey Proportion (Percent)	Recorded THC Shipwrecks	Underwater Surveys	Shipwrecks Per Surveyed Acre	Surveyed Acres Per Shipwreck
Aransas Bay	50,970	266	0.5	10	9	0.0376	26.6
Charles/Carlos Bay	18,252	3,280	18.0	0	1	0.0000	N/A
Copano Bay	41,190	1,173	2.8	3	5	0.0026	391.1
Corpus Christi Bay	108,968	3,617	3.3	18	11	0.0050	200.9
Gulf of Mexico	1,490,390	14,836	1.0	89	6	0.0060	166.7
Laguna Madre	472,615	674	0.1	1	1	0.0015	674.1
Nueces Bay	19,842	175	0.9	0	2	0.0000	N/A
Redfish Bay	34,385	6,958	20.2	28	11	0.0040	248.5
Total	2,236,610	30,980	1.4	149	46	0.0048	207.9

Source: THC Atlas (2021); Texas Parks and Wildlife Department (TPWD, 2018).



Source: THC Atlas (2021); TPWD (2018).

Figure 4. Previous Underwater Survey Coverage of the Study Area by Water Body/Bay System

Researchers can expect greater interpretive accuracy from a combination of the total survey acreage *and* the proportion of that coverage compared to the overall study area. From that perspective, data projections generated from earlier surveys in Corpus Christi and Redfish bays are likely more correct than those from, for instance, Nueces Bay or Laguna Madre. While the previous investigations do tell us a lot about the types of archaeological resources that the CDP may impact, it is essential to remember that we are basing that understanding on a tiny portion of the overall picture.

3.2.2 Previously Recorded Shipwrecks within the Study Area

THC records list 149 recorded shipwrecks within the study area (THC Atlas, 2021). Fifty-four (n=54) of those are nearest to the proposed segments of the CDP APE. Twenty-seven (n=27) of these recorded shipwrecks correspond with entries in NOAA's AWOIS/ENC databases. An additional 31 AWOIS shipwreck records are mapped in the study area but do not correspond with THC shipwrecks. This brings the total number of recorded shipwrecks in the study area to 180. Table 10 includes the list of known shipwrecks inside the study area, as well as their THC Shipwreck Number and/or AWOIS Record Number, the year each was lost, a trinomial (if the shipwreck is also an archaeological site), each shipwreck's SAL status, what type of vessel (if known), and its estimated position accuracy (THC Atlas, 2021; NOAA, 2021).

Table 10
Reported Shipwrecks within the Study Area

THC Shipwreck Number	AWOIS Record #	Name	Year Lost	Trinomial	SAL	Vessel Type	Position Accuracy	Dataset
5	–	*Henrietta*	1888	–	yes	sailing ship, merchant	1.0 mile	–
31	182	*Empress*	1955	–	no	trawler	1.0 mile	THC, AWOIS, ENC
41	–	Unknown	pre–1943	–	no	barge	"excellent"	–
51	4175	*Mary*	1876	41NU252	yes	sail–steam, merchant	"exact"	THC, AWOIS
113	–	Unknown	1834	–	yes	sailing ship	15.0 miles	–
114	–	*Wildcat*	1834	–	yes	sail	5.0 miles	–
115	–	*Cardena*	1834	–	yes	sailing ship, merchant	3.0 miles	THC
137	191	*Atlanta*	1957	–	no	unknown	1.0 mile	THC, AWOIS, ENC
141	–	*Baddacock*	1920	41NU282	no	sail tug	–	–
153	–	*Bertha*	1917	–	no	unknown	5.0 miles	–
156	–	*Betty Sca*	1966	–	no	oil screw	–	–
165	–	*Captiva II*	1942	–	no	yacht	3.0 miles	–
175	–	*Chuckadee*	1963	–	no	shrimp boat	1.0 mile	–
192	–	*Colonel Yell*	1847	–	yes	sail–steam, merchant	2.0 miles	THC
197	–	*Coral Sands*	1955	–	no	unknown	–	THC
208	–	*Dayton*	1845	–	yes	sail–steam, merchant	–	–
214	–	*Desco*	1966	–	no	oil screw	–	–
215	–	*Dixie Dandy*	1957	–	no	oil screw	–	–
235	–	*Electra*	1955	–	no	unknown	5.0 miles	–
256	–	*40 Fathom No. 12*	1955	–	no	unknown	0.5 miles	THC
260	–	*Florette*	1938	–	no	unknown	20.0 miles	–
286	–	*Guyton No. 1*	1916	–	no	barge	1.0 mile	THC
287	–	*Guyton No. 10*	1911	–	no	barge	5.0 miles	THC, ENC
307	–	Unknown	1865	41NU153	yes	anti–torpedo raft; naval vessel	0.10 miles	–
315	–	*Japonica*	1941	–	no	oil screw	5.0 miles	–
316	–	*Jesse C. Barbour*	1922	–	no	sailing ship, merchant	20 miles	–

THC Shipwreck Number	AWOIS Record #	Name	Year Lost	Trinomial	SAL	Vessel Type	Position Accuracy	Dataset
343	–	*Libbie Shearn*	1911	–	no	sailing ship, merchant	3.0 miles	–
423	–	*Philidelphia*	1868	–	yes	sail–steam, merchant	1.0 mile	–
469	–	*San Jacinto*	1960	–	no	oil screw	5.0 miles	–
512	–	*Umpire*	1852	–	yes	sail–steam, merchant	0.5 miles	THC
513	11022(?)	Unknown (*Utina*?)	–	41NU264	no	–	–	THC, AWOIS
609	–	*Mary E. Lynch*	1902	–	no	sailing ship, merchant	1.5 miles	–
623	–	*Mystery*	1899	–	yes	sailing ship, merchant	–	–
637	–	*Hannah*	1862	–	yes	sailing ship, merchant	–	–
653	–	*Mattie*	1873	–	yes	sailing ship, merchant	0.5 miles	THC
655	–	*Mary Agnes*	1862	–	yes	sailing ship, merchant	5.0 miles	THC
658	–	*Lottie Mayo*	1886	–	yes	sailing ship, merchant	3.0 miles	–
659	–	*Louisa*	1865	–	yes	sailing ship, merchant	5.0 miles	–
853	176(?)	Unknown	1954	–	no	unknown	–	THC, AWOIS, ENC
854	–	*Tarambana*	1967	–	no	unknown	–	–
855	185(?)	Unknown	1960	–	no	trawler	0.5 miles	THC, AWOIS, ENC
858	4162	*Hill Tide*	1967	–	no	–	1.0–3.0 miles	THC, AWOIS, ENC
860	–	*Liboria C.*	1954	–	no	trawler	1.0 mile	–
861	201	*Blue Bonnet*	1967	–	no	trawler	–	THC, AWOIS
992	–	*Lake Austin*	1903	–	yes	trading scow	3.0 miles	THC
1019	–	Unknown	pre–1928	–	no	unknown	0.25 miles	THC
1024	4190	Unknown	–	–	no	unknown	–	THC, AWOIS, ENC
1025	4193	*Lisa Gail*	1972	–	no	unknown	–	THC, AWOIS, ENC
1027	–	Unknown	pre–1968	–	no	unknown	0.25 miles	THC
1028	195	*De Rail*	1972	–	no	cabin cruiser	0.25 miles	THC, AWOIS

THC Shipwreck Number	AWOIS Record #	Name	Year Lost	Trinomial	SAL	Vessel Type	Position Accuracy	Dataset
1030	–	Unknown	pre–1950	–	no	unknown	0.25 miles	THC
1031	4175	*Jimbo*	1965	–	no	fishing boat	0.35 miles	THC, AWOIS
1032	5020	*John Worthington*	1944	41AS88	no	oil tanker	"exact"	THC, AWOIS, ENC
1045	–	*William Bagley*	1863	–	yes	sail–steam, merchant	3.0 miles	THC
1047	–	Unknown	pre–1935	–	no	unknown	0.25 miles	THC
1049	–	*Ramyrez*	1882	–	yes	unknown	0.25 miles	THC
1056	–	Unknown	pre–1853	–	yes	schooner	0.5 miles	THC
1086	–	Unknown	pre–1971	–	no	unknown	–	THC
1087	–	Unknown	pre–1973	–	no	unknown	0.25 miles	THC
1088	–	Unknown	pre–1975	–	no	unknown	0.5 miles	THC
1089	–	Unknown	pre–1966	–	no	unknown	0.5 miles	THC
1090	–	Unknown	1977	–	no	unknown	–	THC, ENC
1091	–	Unknown	pre–1977	–	–	unknown	–	THC
1092	–	Unknown	pre–1967	–	no	fishing vessel	0.5 miles	THC
1180	–	Unknown	pre–1971	–	no	unknown	0.25 miles	THC
1181	–	Unknown	pre–1971	–	no	unknown	0.25 miles	THC
1218	5166(?)	Unknown	pre–1975	–	no	unknown	0.25 miles	THC, AWOIS
1219	–	Unknown	pre–1975	–	no	unknown	0.25 miles	THC
1220	–	Unknown	pre–1970	–	no	unknown	0.25 miles	THC
1221	5101(?)	Unknown	pre–1972	–	no	unknown	0.25 miles	THC, AWOIS
1222	–	Unknown	pre–1959	–	no	unknown	0.25 miles	THC
1223	10439(?)	Unknown	pre–1959	–	no	unknown	0.25 miles	THC, AWOIS, ENC
1224	5047(?)	Unknown	pre–1959	–	no	unknown	0.25 miles	THC, AWOIS, ENC
1225	5051(?)	Unknown	pre–1970	–	no	unknown	0.25 miles	THC, AWOIS, ENC
1226	–	Unknown	pre–1975	–	no	unknown	0.25 miles	THC

THC Shipwreck Number	AWOIS Record #	Name	Year Lost	Trinomial	SAL	Vessel Type	Position Accuracy	Dataset
1227	–	Unknown	pre–1968	–	no	unknown	0.25 miles	THC
1228	5967	Unknown	pre–1972	–	no	unknown	0.25 miles	THC, AWOIS
1229	–	Unknown	pre–1971	–	no	unknown	1.0 mile	THC
1230	–	Unknown	pre–1971	–	no	unknown	–	THC
1231	–	Unknown	pre–1975	–	no	unknown	–	THC
1232	4998	*Bahia Honda*	pre–1968	–	no	shrimp boat	0.25 miles	THC, AWOIS, ENC
1233	–	Unknown	pre–1970	–	no	unknown	–	THC, ENC
1234	10436	Unknown	pre–1959	–	no	unknown	0.25 miles	THC, ENC
1272	–	*L'éclair*	1866	–	yes	sailing ship, merchant	5.0 miles	THC
1289	–	Unknown	pre–1971	–	no	unknown	0.5 miles	THC
1411	–	*Two Marys*	1882	–	yes	sailing ship, merchant	0.5 miles	THC
1412	–	*Tex Mex*	1882	–	yes	sailing ship, merchant	0.5 miles	THC
1417	–	*Silas*	1902	–	no	sailing ship, merchant	2.0 miles	THC
1420	–	*Ellen*	1901	–	no	sailing ship, merchant	0.25 miles	THC
1422	–	*Mary Lorena*	1900	–	yes	sailing ship, merchant	1.0 mile	THC
1449	–	*Reindeer*	1870	–	yes	sailing ship, merchant	0.5 miles	THC
1450	–	*Sea Bird*	1870	–	yes	sailing ship, merchant	3.0 miles	THC
1457	–	*Surprise*	1871	–	yes	sailing ship, merchant	1.0 mile	THC
1459	–	*Mary Hanson*	1870	–	yes	sailing ship, merchant	3.0 miles	THC
1476	–	*Nonesuch*	1880	–	yes	sailing ship, merchant	5.0 miles	THC
1528	–	Unknown	pre–1900	–	yes	unknown	0.25 miles	THC
1532	4817	Unknown	pre–1971	–	no	unknown	–	THC, AWOIS, ENC
1533	–	Unknown	1970	–	no	unknown	–	THC
1534	–	Unknown	pre–1966	–	no	unknown	0.1.0 miles	THC

THC Shipwreck Number	AWOIS Record #	Name	Year Lost	Trinomial	SAL	Vessel Type	Position Accuracy	Dataset
1535	–	Unknown	pre–1950	–	no	unknown	0.25 miles	THC
1536	–	Unknown	pre–1971	–	no	unknown	0.25 miles	THC
1537	–	Unknown	pre–1950	–	no	unknown	0.25 miles	THC
1538	4816(?)	Unknown, *Donna Marie* (AWOIS)	pre–1976	–	no	unknown	–	THC
1539	–	Unknown	1976	–	no	unknown	–	THC
1690	–	*Leeway II*	1975	–	no	fishing vessel	"poor"	THC
1727	–	*Pilot Boy*	1916	–	no	steamship	20 miles	THC
1938	4183	*Eagle's Cliff*	1981	–	no	freighter	10.0 miles	THC, AWOIS
1939	–	*Jane and Julie*	1981	–	no	trawler	5.0 miles	THC
1940	–	*De Rail*	1972	–	no	yacht	3.0 miles	THC
1941	–	*Liberia C*	1964	–	no	–	5.0 miles	THC
1942	–	*Cabezon*	1959	–	no	–	5.0 miles	THC
1943	–	*Princess Pat*	1958	–	no	–	2.0 miles	THC
1944	–	*Jiffie*	1955	–	no	–	5.0 miles	THC
2186	–	*Tramp*	1919	–	no	–	5.0 miles	THC
2187	–	*Ring Dove*	1919	–	no	–	5.0 miles	THC
2190	–	*Texas No. 2*	1960	–	no	–	–	THC
2209	–	*American Star*	1970	–	no	–	5.0 miles	THC
2215	–	*Baetty Sca*	1966	–	no	–	5.0 miles	THC
2218	–	*Bill Hollis*	1970	–	no	–	3.0 miles	THC
2224	–	*Buckroy*	1959	–	no	–	–	THC
2231	–	*Captain Jimmie*	1962	–	no	–	–	THC
2236	–	*Claudia Eliza G.*	1976	–	no	–	–	THC
2240	–	*Corpus Lady*	1969	–	no	–	–	THC
2260	–	*Georgiana*	1951	–	no	–	5.0 miles	THC
2271	–	*Irvin*	1948	–	no	–	–	THC
2281	4191	*Lionel Hodgson*	1977	–	no	–	–	THC, AWOIS, ENC
2282	–	*Little Saran*	1959	–	no	–	–	THC
2287	–	*Mert*	1970	–	no	–	–	THC
2289	–	*Coral Chipper*	1961	–	no	–	–	THC

THC Shipwreck Number	AWOIS Record #	Name	Year Lost	Trinomial	SAL	Vessel Type	Position Accuracy	Dataset
2291	–	*Miss Anita Bryant*	1971	–	no	–	–	THC
2292	–	*Miss Aransas*	1974	–	no	–	–	THC
2302	–	*Mr. Murphy*	1968	–	–	–	–	THC
2306	–	*Ocean Bride*	1958	–	no	–	–	THC
2311	–	*Powhatton*	1969	–	no	–	–	THC
2323	–	*Scorpion*	1984	–	no	–	–	THC
2334	–	*Taasinge*	1970	–	no	–	–	THC
2369	–	Unknown	–	41NU291	no	–	"exact"	THC
2373	186(?)	Unknown	pre–1973	–	no	–	0.25 miles	THC, AWOIS, ENC
2374	–	Unknown	pre–1991	–	no	–	"high"	THC
2408	5016	"Fire Brick" Wreck	post–1915	41AS117	no	steamship	"exact"	THC, AWOIS, ENC
2414	–	*Waco*	–	–	–	–	"exact"	THC
2430	–	*Utina* (Hull 1)	–	41NU292	no	–	"exact"	THC, ENC
2459	–	"Bob Hall Pier Wreck"	1800s?	41KL108	no	unknown	1.0 mile	THC
2473	–	*Breaker*	1862	–	–	schooner	5.0 miles	THC
2479	–	*Lizzie Baron*	–	–	–	steamer	5.0 miles	THC
2488	–	*America*	1863	–	–	schooner	5.0 miles	THC
2545	–	Unknown	pre–1900	41AS119	–	steamship	"exact"	THC
2561	–	Unknown	pre–1908	–	–	–	0.25 miles	THC
2562	–	Unknown	–	TBA	–	–	"exact"	THC
–	190	Unknown	–	–	–	–	–	AWOIS, ENC
–	279	Unknown	–	–	–	–	–	AWOIS, ENC
–	4159	*Gypsy Girl*	–	–	–	–	–	AWOIS, ENC
–	4172	"Blue Hull Airboat"	1984	–	–	airboat	–	AWOIS
–	4186	*Margie B*	–	–	–	–	–	AWOIS, ENC
–	4807	Unknown	–	–	–	–	–	AWOIS, ENC
–	4838	Unknown	–	–	–	–	–	AWOIS, ENC
–	4839	*Sir John*	–	–	–	–	–	AWOIS, ENC
–	4846	Unknown	–	–	–	–	–	AWOIS, ENC

THC Shipwreck Number	AWOIS Record #	Name	Year Lost	Trinomial	SAL	Vessel Type	Position Accuracy	Dataset
–	5014	*Moon Glow*	–	–	–	–	–	AWOIS, ENC
–	5087	Unknown	–	–	–	–	–	AWOIS, ENC
–	5110	Unknown	–	–	–	–	–	AWOIS, ENC
–	5117	Unknown	–	–	–	–	–	AWOIS, ENC
–	5155	Unknown	–	–	–	–	–	AWOIS, ENC
–	5190	Unknown	–	–	–	–	–	AWOIS, ENC
–	7856	Unknown	–	–	–	–	–	AWOIS, ENC
–	7857	*First Boy*	–	–	–	–	–	AWOIS, ENC
–	8209	Unknown	–	–	–	–	–	AWOIS, ENC
–	8877	*Vilco 22*	–	–	–	–	–	AWOIS, ENC
–	10427	Unknown	–	–	–	–	–	AWOIS, ENC
–	10428	Unknown	–	–	–	–	–	AWOIS, ENC
–	10429	Unknown	–	–	–	–	–	AWOIS, ENC
–	10431	Unknown	–	–	–	–	–	AWOIS, ENC
–	10432	Unknown	–	–	–	–	–	AWOIS, ENC
–	10434	Unknown	–	–	–	–	–	AWOIS, ENC
–	10435	*Rose Mist*	–	–	–	–	–	AWOIS, ENC
–	10961	*Teachers Pet*	–	–	–	–	–	AWOIS, ENC
–	11022	Unknown	–	–	–	shipwreck	–	AWOIS
–	13346	Unknown	–	–	–	fishing vessel	–	AWOIS, ENC
–	13347	*Bertram*	1992	–	–	fishing vessel	–	AWOIS, ENC
–	13348	Unknown	–	–	–	–	–	AWOIS, ENC

Figure 5 presents the overall number of shipwrecks in the THC's shipwreck database within each of the study area's major water bodies/bay systems while Figure 6 depicts the general density of recorded shipwrecks within each of the study area's major water bodies in surveyed acres per recorded shipwreck (THC Atlas, 2021; TPWD, 2018). On this chart, higher bars correspond with less frequent recorded wrecks and lower site density. (Charles/Carlos and Nueces bays had no recorded shipwrecks, so their corresponding wreck densities cannot be calculated). Overall, shipwrecks are distributed across the Corpus Christi Bay system at an average of one every 203.8 surveyed acres (see Table 7). Recorded shipwrecks are more frequent within Aransas and Corpus Christi bays and within the Gulf study area portions. The greatest density of recorded shipwrecks in the study area are in the vicinity of the bay entrance at Aransas Pass. This is due to the intense vessel traffic through the pass as well as the navigational hazards that endangered those ships prior to more permanent jetties being constructed (USACE, 2003). They are less common in Copano and Redfish bays. Shipwrecks are least common within Laguna Madre. This should not be interpreted as a direct representation of actual shipwreck density. The survey coverage is much lower there than in other water bodies. It is likely that more investigations within the Laguna Madre could significantly change this projection. The CDP components correspond with higher-shipwreck-density major water bodies (the Gulf and Corpus Christ Bay), suggesting a higher likelihood that construction could affect previously unrecorded shipwrecks and cultural resources.

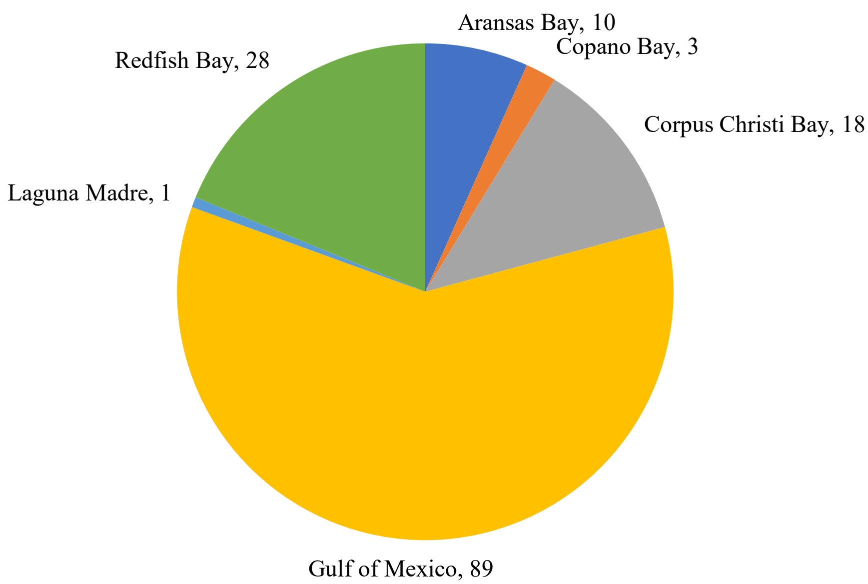
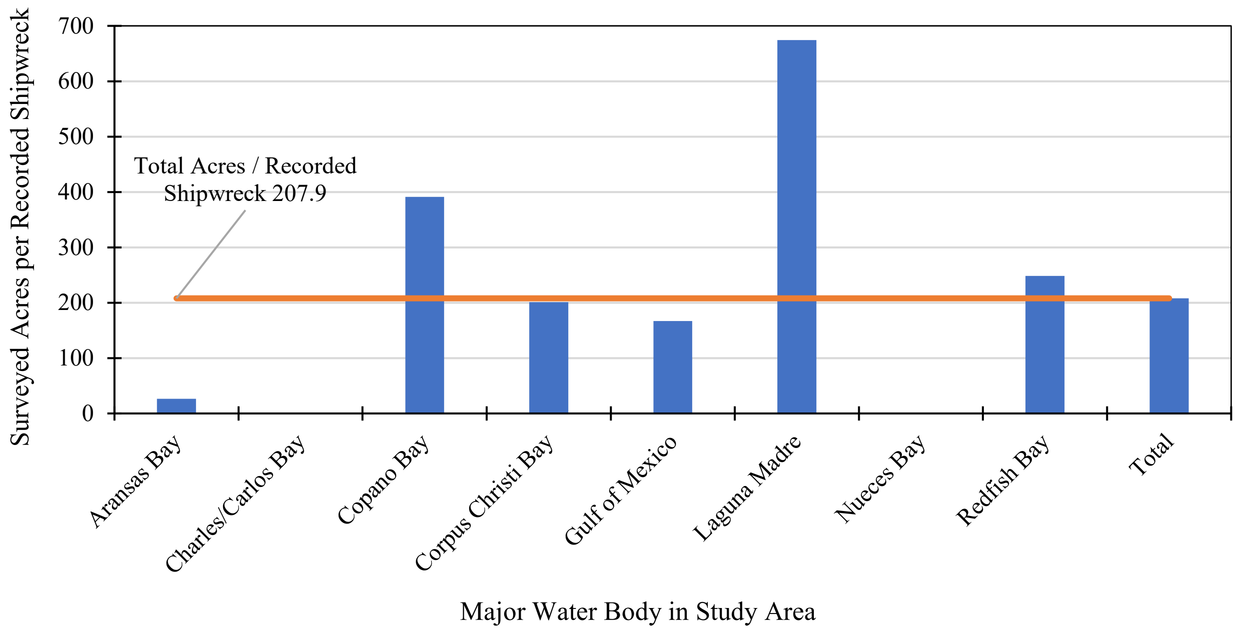


Figure 5. Number of Recorded Shipwrecks within the Study Area

Estimated shipwreck age information included with previously recorded shipwreck datasets supplies another opportunity for basic analysis and interpretation. Most previously recorded shipwrecks within the study area wrecked sometime after 1950 (n=84, 55; Figure 7). Only six recorded shipwrecks (four percent) date to 1850 or earlier (THC Atlas, 2021). In general, this data suggests that previously unknown and unrecorded shipwrecks within the study area are more likely going to have wrecked in the last 70 years. Figures 8 and 9 show a consistent distribution of the different shipwreck age groups across each of the major water bodies. With that said, Redfish Bay shipwrecks are more often older than those in Corpus Christi Bay or the Gulf. Unrecorded shipwrecks within Redfish Bay could more likely be older as well.

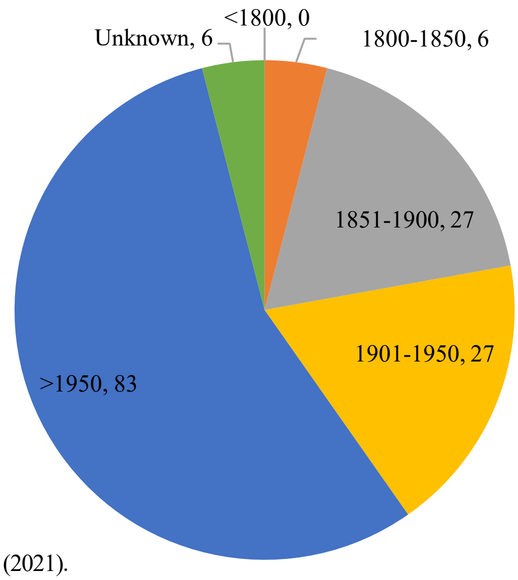


Source: THC Atlas (2021); TPWD (2018).

Figure 6. Density of Recorded Shipwrecks within the Major Water Bodies of the Study Area

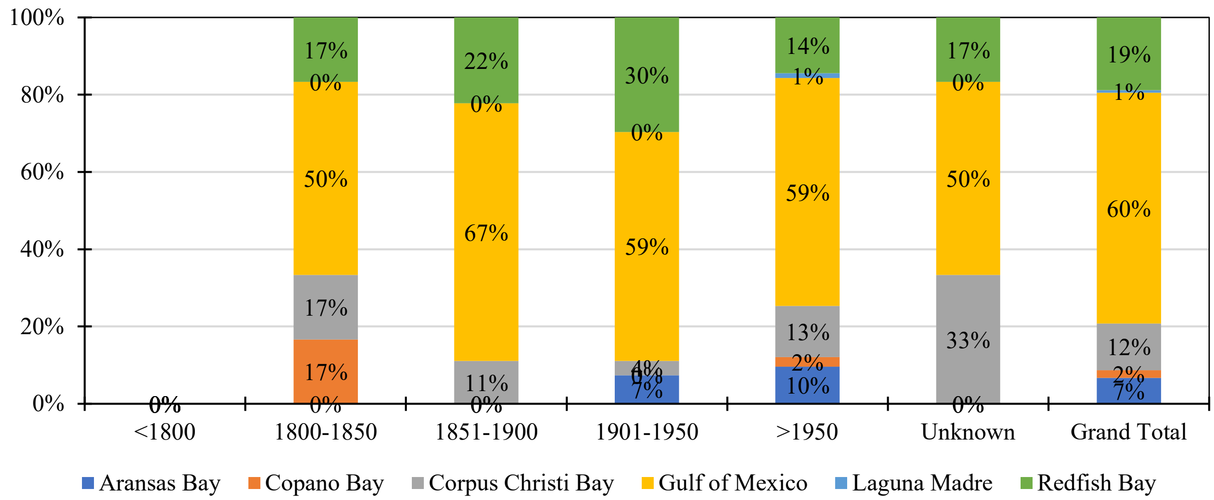
3.2.3 Potential for Submerged Aircraft

It is important to highlight the history of NAS Corpus Christi when evaluating submerged cultural resources within the study area. Following numerous reports of salvage events, the United States Navy Naval History and Heritage Command's Underwater Archaeology Branch, expanded their purpose to the protection of submerged naval aircraft in addition to naval shipwrecks during the late 1990s (Neyland and Grant, 1999; Coble, 2001). At domestic NAS locations, the greatest potential for losses comes from operational flights (such as ferry flights) or training flights. This has been demonstrated at coastal NAS locations throughout the country (Schwarz et al., 2017; Bleichner et al., 2018). It is currently unknown where dive bombing ranges for NAS Corpus Christi were located, but it can be assumed that at least some were in the surrounding bays, as pilots would have needed to be proficient at bombing targets on the water's surface. Additionally, the introduction of the torpedo bombing training schedule for pilots in 1944 suggested another bombing range in the bays specifically for torpedo bombing practice. Following the arrival of USS *Antietam* in 1956, potential for training accidents grew larger as pilots could gain carrier qualifications. It is currently unknown if any training losses occurred; however, as demonstrated by similar accidents aboard USS *Wolverine* (IX-64) and USS *Sable* (IX-81) off Chicago during World War II, potential for losses cannot be ruled out (Naval History and Heritage Command, 2020).



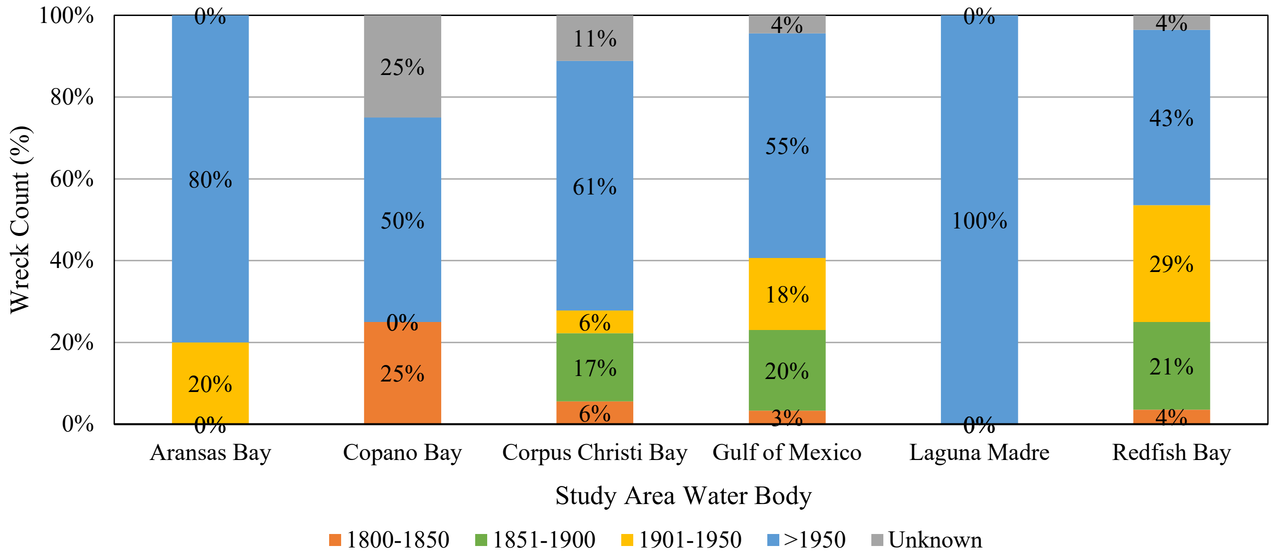
Source: THC Atlas (2021).

Figure 7. General Age Distribution of Recorded Shipwrecks within the Study Area



Source: THC Atlas (2021); TPWD (2018).

Figure 8. Percentage of Age Distribution of Recorded Shipwrecks within the Study Area



Source: THC Atlas (2021); TPWD (2018).

Figure 9. Percentage of Water Body Distribution of Recorded Shipwrecks within the Study Area, By Age Group

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Appendix G

Sediment Transport Modeling Study

Note: The Section 508 amendment of the Rehabilitation Act of 1973 requires that the information in Federal documents be accessible to individuals with disabilities. The USACE has made every effort to ensure that the information in this appendix is accessible. However, this appendix is not fully compliant with Section 508, and readers with disabilities are encouraged to contact Mr. Jayson Hudson at the USACE at (409) 766-3108 or at SWG201900067@usace.army.mil if they would like access to the information.

Environmental Impact Assessment for Channel Deepening, Port of Corpus Christi

Sediment Transport Modelling Study

April 1, 2022 | 13242.102

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Environmental Impact Assessment for Channel Deepening, Port of Corpus Christi

Sediment Transport Modelling Study

Prepared for:

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Revision	Date	Status	Comments	Prepared	Reviewed	Approved
RevA	2022-04-01	Draft	For Client Review	YT/RQ	MD/LAW	LAW

Executive Summary

W.F. Baird & Associates Ltd. (Baird) was retained by Freese & Nichols, Inc. (FNI) to provide modeling studies in support of the third-party environmental impact study (EIS) for the Corpus Christi Ship Channel Deepening Project (CDP). The project is the proposed deepening of the offshore channel, entrance channel, and seaward most portion of the Corpus Christi Ship Channel to a nominal depth of 75 ft. Baird has provided consulting services for the past 11 months on the project to FNI as part of the 3rd Party EIS contract with the Port of Corpus Christi Authority (PCCA). The work has been coordinated with the US Army Corps of Engineers (USACE) Galveston District Regulatory Branch. The main purpose of this sediment transport modeling study is to provide a direct response to the data gaps identified in the PCCA CDP Recommended Actions Plan developed by FNI on 30 September 2020 (Freese and Nichols, Inc., 2020).

Corpus Christi Bay connects to several subtropical bays, such as Nueces Bay to northwest, Aransas Bay and Copano Bay on the northeast side, and Baffin Bay on the southwest side. It is separated from the GOM by the longshore barrier islands, such as Mustang Island, Padre Island, and San Jose Island. These bays are connected to the GOM by a narrow entrance channel, Aransas Pass, where the navigation channel will be deepened in the CDP. There is a secondary pass, Packery Channel.

MIKE21 and MIKE3 models were used to develop a model to predict the sedimentation in the channel. The model was calibrated and validated against the shoaling rates obtained from the Corps Shoaling Analysis Tool (CSAT) for the periods of 2011-2015 and 2016-2020, respectively. The impact of sedimentation in the channel was evaluated using three scenarios: existing, Future Without Project (FWOP) and Future With Project (FWP). Additional features such as the offshore berms, beach nourishment and Berms and Offshore Dredged Material Disposal Area (ODMS) were also evaluated.

Predicted FWOP and FWP shoaling rates were comparable to the existing condition. Overall, both 2D and 3D model results indicate that the project impact on sedimentation rates in the inner channels is limited to less than 10%. The model predicted that sedimentation in the outer channel increases from approximately 95,000 yd^3/year (73,000 m^3/year) for the FWOP to approximately 214,000 yd^3/year (164,000 m^3/year) for the FWP scenario, approximately 2.25 times higher. This is primarily due to that fact that the FWP has a deeper and longer channel comparted to FWOP. The beach nourishment and offshore berms make small contributions to channel sedimentation with less than 600 yd^3 (459 m^3) of total sedimentation predicted by the model. On the other hand, the model predicted that sedimentation in the outer channel under FWP conditions increases from approximately 214,000 yd^3/year (164,000 m^3/year) in the absence of the ODMDS mound to approximately 342,000 yd^3/year (262,000 m^3) (approximately 1.6 times greater) when the ODMDS mound is present. Individual hurricane events could result in sedimentation volumes in the outer channel that are several times higher than the average annual sedimentation. In contrast, the impact of hurricanes on the inner channel sedimentation is small.

The stability of the designed offshore berm and beach nourishment was assessed using two 1D cross-shore transport numerical models: XBeach by Deltares and CSHORE by the USACE. Assessment of the cross-shore profile response to long-term wave conditions and short-term storm conditions found it is unlikely that significant sediment movement will occur at the designed placement depth of -25 to -30 ft NAVD88 as it is placed beyond the depth of closure. As for the beach nourishment, XBeach predicted significant overtopping of the dune during stronger storms (e.g., Hurricane Allen and Hurricane Harvey). XBeach storm response predictions were validated using pre- and post-Hurricane Harvey imagery and surveys. Model results indicated that the offshore berm does not provide meaningful protection for beach nourishment, except during smaller storms with longer wave periods.

A sediment budget model to assess the fate of the placed beach nourishment was developed by Baird. Cross-shore and longshore transport processes were incorporated in the model using XBeach (cross-shore) and Baird's COSMOS model (longshore). In the Mustang Island domain, the average nourishment loss rate is approximately 29k to 112k yd^3 (22k to 86k m^3) per year (1 to 5% of the total volume per year); the lost sediment is generally transported to the northeast towards the jetties. In the San Jose Island domain, the average nourishment erosion rate is approximately 0 to 80k yd^3 (0 to 62k m^3) per year (0 to 2% of the total volume per year); the lost sediment is generally redistributed over the model domain.

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Figures

1. Introduction

W.F. Baird & Associates Ltd. (Baird) was retained by Freese & Nichols, Inc. (FNI) to provide modeling studies in support of the third-party environmental impact study (EIS) for the Corpus Christi Ship Channel Deepening Project (CDP). The project is the proposed deepening of the offshore channel, entrance channel, and seaward most portion of the Corpus Christi Ship Channel to a nominal depth of 75 ft. Baird has provided consulting services on the project to FNI as part of the 3rd Party EIS contract with the Port of Corpus Christi Authority (PCCA). The work has been coordinated with the US Army Corps of Engineers (USACE) Galveston District Regulatory Branch. The main purpose of this sediment transport modeling study is to provide a direct response to the data gaps identified in the PCCA CDP Recommended Actions Plan developed by FNI on 30 September 2020 (Freese and Nichols, Inc., 2020).

The objectives for this modeling study are:

- To address Data Gap Analysis Section 2.20.5 with Recommended Action “Option 2 for 408/TPC to perform sediment transport modeling to assess channel shoaling rates. For both options sedimentation analysis to cover full extents of project including areas within Corpus Christi Bay and the Jetty Channel. For both options consider CSAT data to provide historic shoaling analysis validation.”
- To address Data Gap Analysis Section 2.20.7 with Recommended Action “USACE408/TPC Team to support EPA in performing FATE (DELFT 3D) modeling for the proposed expanded ODMDS.”
- To better understand sedimentation processes in turning basin and Inshore Channel using a physics-based modeling approach
- To better understand sedimentation processes in channel outside of jetties using a physics-based modeling approach
- To assess potential impacts of channel deepening on sedimentation rates using a physics-based modeling approach

This report documents the data collected and used for the study, the model development, and the assessment on the impacts of CDP on sediment transport. The report consists of:

Section 1. Introduction (this section)

Section 2. Data collection and analysis – to document all data used in this study, including data sources, data gaps, data processing, and the understandings of physical processes from the data analysis

Section 3. Sedimentation Model Description: - to describe the model development and set up

Section 4. Model Calibration and Validation: - to describe the process of calibrating and validating the model against CSAT data

Section 5. Modeling Assessment of Potential Project Impacts: - to present and compare model results and assess potential project impacts on channel sedimentation rates

Section 6. Modeling Assessment of Beach Nourishment, Offshore Berms and Offshore Dredged Material Disposal Area (ODMDS): - to present simulation results with beach nourishment, offshore berms and ODMDS in place and assess their potential impacts on channel sedimentation

Section 7. Stability of Offshore Berms and Beach Nourishment – to present simulation results of profile response to short-term storm events and long-term annual wave climate and assess the stability of the placed sediment using cross-shore profile change models

Section 8. Fate of Beach Nourishment – to assess beach nourishment longevity using a sediment budget approach

Section 9. Conclusion, Uncertainties, and Recommendation: - to document the conclusions made from this study

2. Data Collection and Analysis

2.1 Relevant Data Collection

2.1.1 Geospatial Data

Several geospatial datasets were acquired in support of the numerical modelling of the Port of Corpus Christi. Elevation datasets were downloaded to cover the model domain as well as navigation channel boundaries in the study area.

2.1.1.1 Elevation Data

Four elevation datasets were acquired for use in the model grid, listed in hierarchical order within the model domain below. Figure 1 shows the spatial coverage within the model domain of each elevation source.

- United States Army Corps of Engineers (USACE), Galveston District, Sea Bar Channel Survey, 2018/07/17
- Continuously Updated Digital Elevation Model (CUDEM) - 1/3 Arc-Second Resolution Bathymetric-Topographic Tiles (v2020)
- Corpus Christi, Texas 1/3 arc-second MHW Coastal Digital Elevation Model
- U.S. Coastal Relief Model Vol.5 - Western Gulf of Mexico

Elevation data in Nueces Bay was estimated based on discussions with a surveyor familiar with the bay and interpretation of aerial images from Google Earth.

All elevations were converted to the North American Vertical Datum of 1988 (NAVD 88) at Port Aransas. The horizontal coordinate system of Universal Transverse Mercator 14-North (UTM-14N) was used for all bathymetry data.

The model was validated against the Corps Shoaling Analysis Tool CSAT data for the period of 2016 to 2020 and therefore the use of the channel bathymetry in 2018 is appropriate for this study.

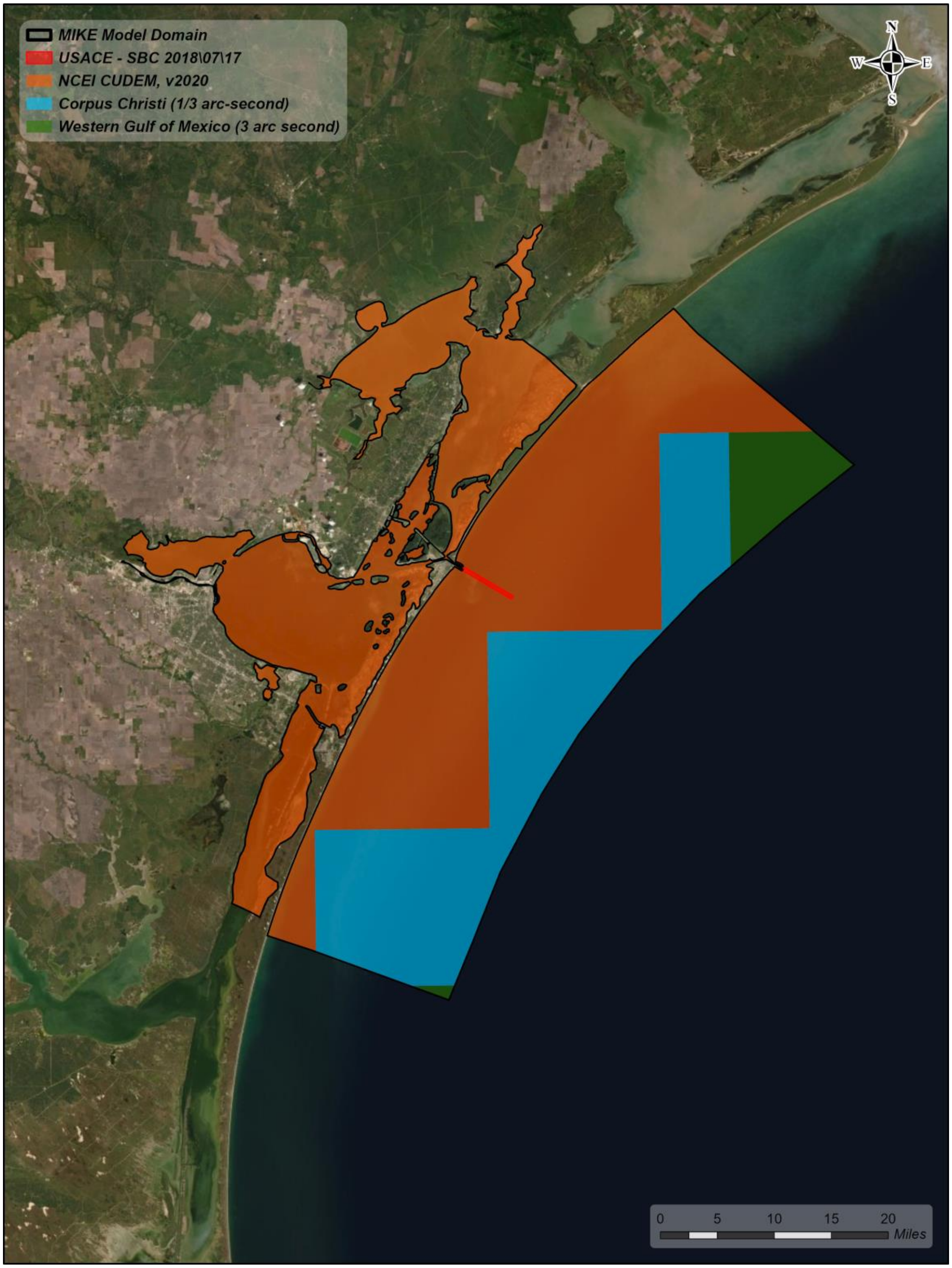


Figure 2.1: Bathymetry data collected for this modeling study

2.1.1.2 Navigation Channel Data

The extents of the navigation channels within the study area were downloaded from the USACE Geospatial National Channel Framework (NCF) portal (USACE, 2017). These data included channel areas, reaches and lines.

2.1.2 Forcing Data

2.1.2.1 Water Levels

Water levels from 10 stations was obtained in Corpus Christi's Bay and in Aransas Bay from the National Oceanic and Atmospheric Administration's Tides & Currents database (NOAA, https://tidesandcurrents.noaa.gov/map/index.html). Data availability at the stations is summarized in Table 2.1, and the locations are illustrated in Figure 2.7. Data gaps exist for four stations during the period of interest: Aransas Wildlife Refuge, Rockport, USS Lexington, and South Bird Island. Of these stations, Rockport has the greatest number of data gaps, representing approximately 14% of the available data. The other three stations have data gaps representing less than 2% of the available data for the period of interest. Some stations provide 6-min data instead of hourly data for certain time period. In these cases, the data was interpolated to hourly data.

Table 2.1: Summary of hourly data available from NOAA stations

Name	Station ID	Start Date	End Date
Aransas Wildlife Refuge	8774230	2012-11-01	Present
Rockport	8774770	1937-03-01	Present
Aransas Pass	8775241	2016-12-20	Present
Port Aransas	8775237	2002-06-26	Present
Nueces Bay	8775244	2012-01-01	2012-12-31
USS Lexington	8775296	2012-01-01	Present
Packery Channel	8775792	1996-01-01	Present
Bob Hall Pier	8775870	1983-11-30	Present
South Bird Island	8776139	2012-10-01	Present
Baffin Bay	8776604	2012-10-01	Present

Figure 2.2: Water level stations on Corpus Christi Bay

2.1.2.2 River Flows

River flows draining into Corpus Christi Bay and Aransas Bay were retrieved from seven USGS gages (https://maps.waterdata.usgs.gov/mapper/index.html). Four of the gages drain into Corpus Christi Bay, three of which are located along the Nueces River, and one along Oso Creek. The remaining gage stations drain into Copano Bay. The data availability for each gage is summarized in Table 2.2. Figure 2.3 shows the location for each gage.

Table 2.2: Summary of river flow gages from USGS

Name	Gage ID	Start Date	End Date
Nueces Rv nr Mathis	08211000	1987-09-01	Present
Nueces Rv at Bluntzer	08211200	1992-04-01	Present
Nueces Rv at Calallen	08211500	1989-10-02	Present
Oso Ck at Corpus Christi	08211520	1995-10-01	Present
Aransas Rv nr Skidmore	08189700	1964-03-27	Present
Mission Rv at Refugio	08189500	1939-07-01	Present
Copano Ck nr Refugio	08189200	1970-06-17	Present

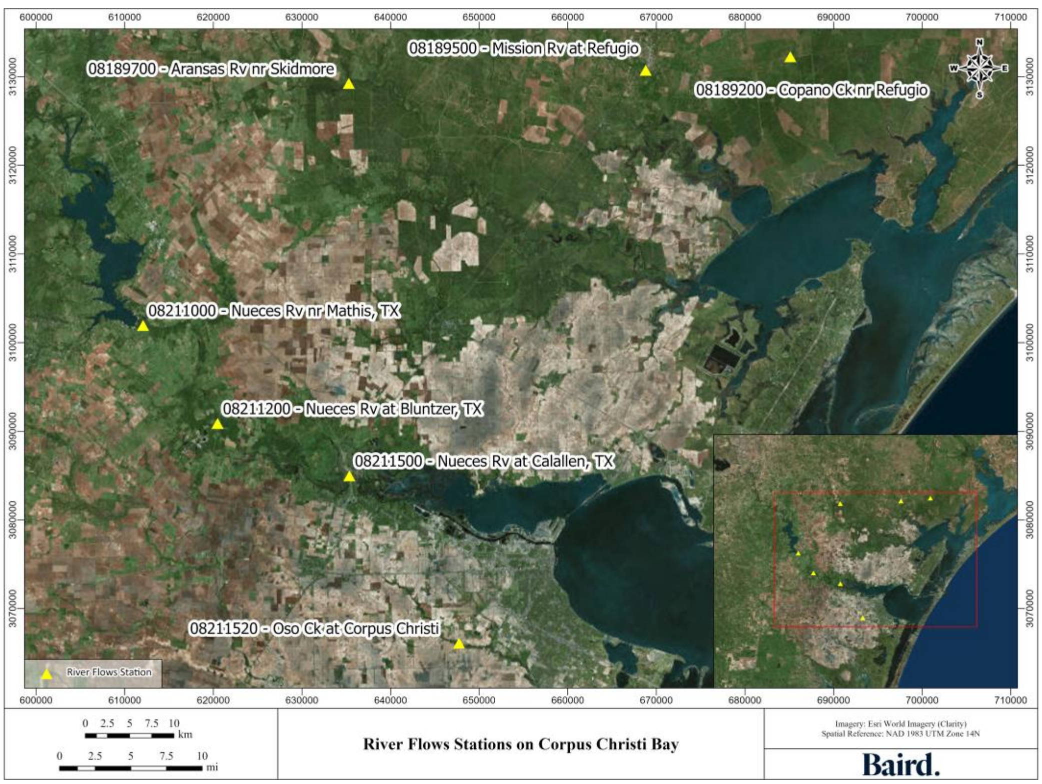


Figure 2.3: Location of USGS gages

More details about the river inflows to the Corpus Christi Bay can be found in the hydrodynamic and salinity study conducted by Baird (Baird, 2020).

2.1.2.3 HYCOM Model

The HYCOM (Hybrid Coordinate Ocean Model) ocean circulation model results were used to obtain surface elevation and fluxes at the model boundary (https://www.hycom.org/). Figure 2.4 shows in black dots the HYCOM model nodes, in yellow dots the offshore boundary of the mesh, in purple dots the northeast offshore boundary, in orange dots the southwest offshore boundary and in blue lines the mesh elements used. At the offshore boundary (yellow) the interpolated surface elevation was extracted from the HYCOM nodes, while velocities were extracted at the northeast and southwest offshore boundary.

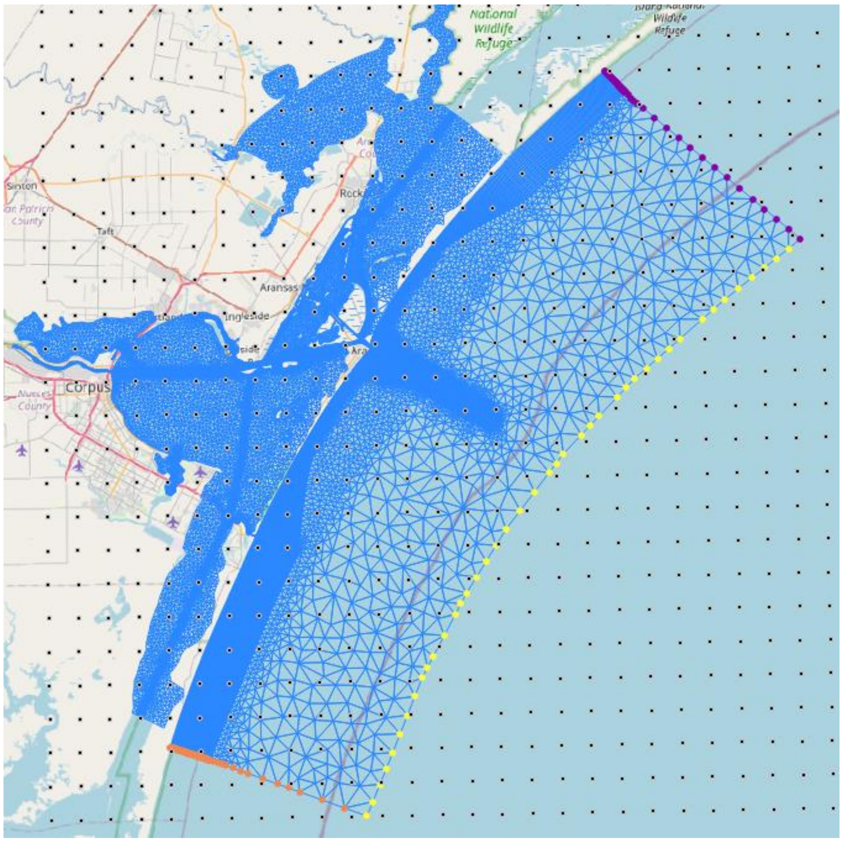


Figure 2.4: HYCOM model nodes and boundary of the computational mesh.

2.1.2.4 Offshore Wave Data

Offshore wave conditions in the Corpus Christi Bay and Gulf of Mexico were extracted from the U.S. Army Corps of Engineers (USACE) Wave Information Studies (WIS) hindcast station ST73040 for 2011 and 2019. The station is located approximately 25 km offshore of Port Aransas, where the water depth is approximately 30 m. The WIS hindcast data was not available for 2020 therefore wave data from NOAA buoy 42020 (see Figure 2.5) was used in this case. The wave rose in Figure 2.6 presents offshore wave heights by direction at the WIS station from 1980 to 2019; the waves at this location are predominately from the southeast direction.

Figure 2.5: Location of WIS data point

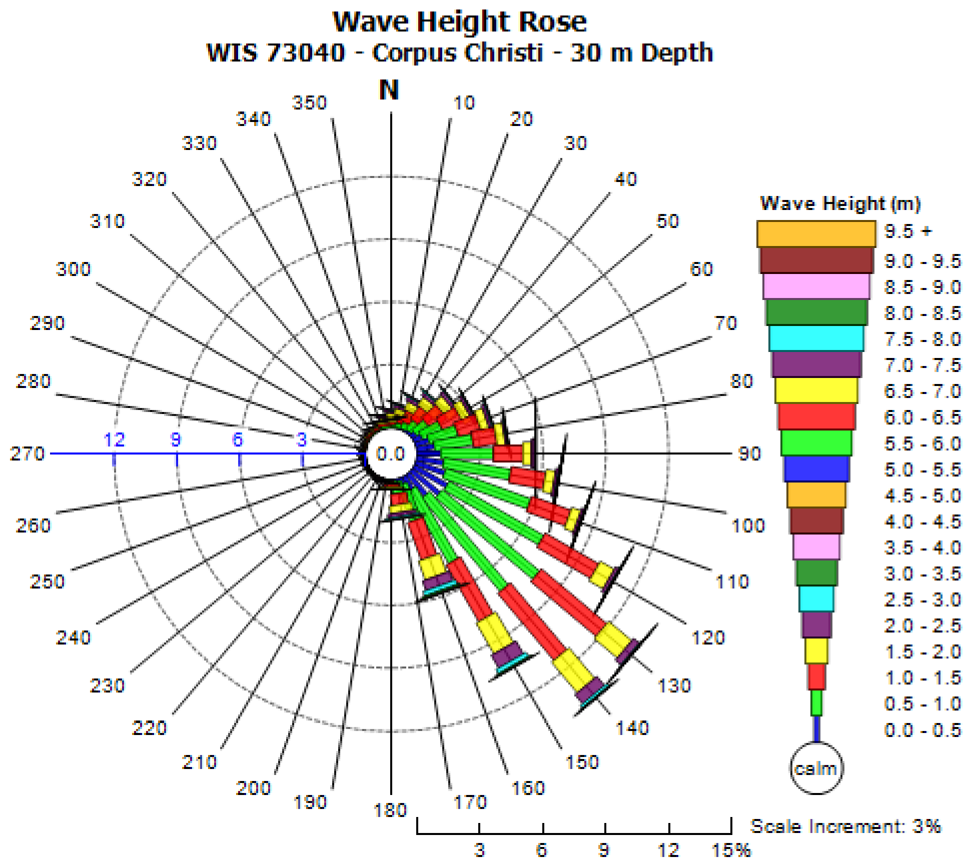


Figure 2.6: Wave Height Rose at WIS Station 73040 (1980 to 2019)

2.1.2.5 Wind Data

Wind data used in the sediment transport model was obtained from the Bob Hall Pier in-situ observation station operated by the National Oceanic and Atmospheric Administration (NOAA) with hourly data available online: https://tidesandcurrents.noaa.gov. Wind speed and direction was collected in hourly increments for 2011, 2017 and 2020. The wind sensor is 46.87 ft (14.29 m) above MSL. Observed wind speeds were converted to 33 ft (10 m) wind speeds using the log law shown below:

$$u_2 = u_1 * \left(\frac{ln \frac{z_2}{z_0}}{ln \frac{z_1}{z_0}} \right)$$

Where u_2 is the wind speed at the desired elevation, u_1 is the observed wind speed at the station elevation, z_2 is the desired elevation (33 ft/10 m), z_1 is the station instrument elevation and z_0 is the roughness length coefficient. Figure 2.7 displays an example 33 ft (10 m) wind speed plot for Bob Hall Pier.

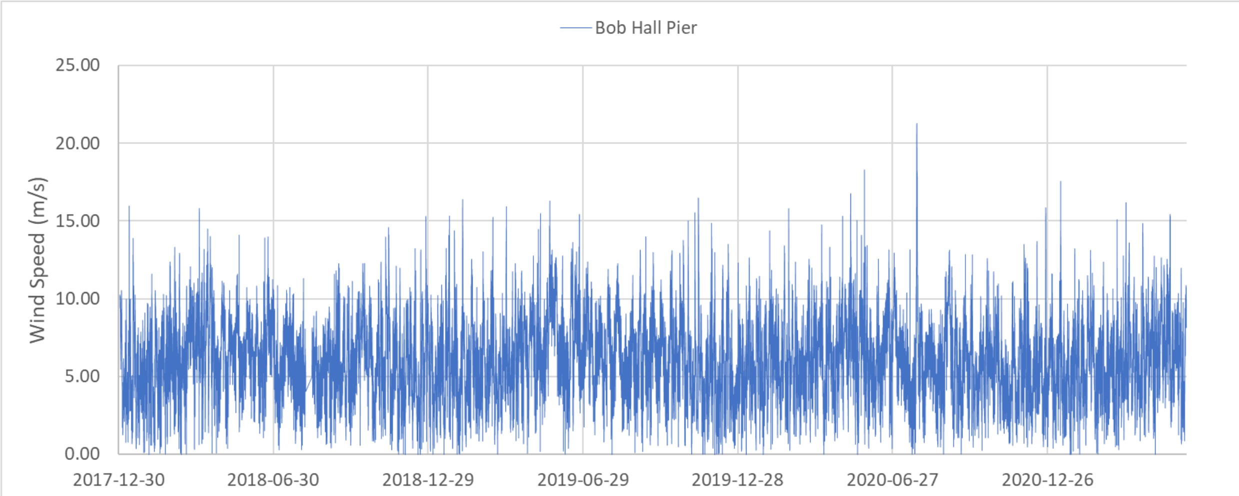


Figure 2.7: Wind Speed at Bob Hall Pier

Wind data from Bob Hall Pier was usable with small data gaps. However, larger data gaps of up to 1 month were present in 2011. Thus, for the year 2011, the wind data obtained from the WIS data station mentioned in section 2.1.2.4 was used.

2.1.3 Sediment Data

2.1.3.1 Sediment Fraction Distribution

Baird received from the USACE Galveston District historical sediment grain size and fraction distribution data along the Corpus Christi channel collected between 1977 and 2015. An example figure showing the spatial and temporal distribution of the sediment data is provided in Figure 2.8. The data is plotted with respect to the station numbers going from the Jetty Channel to the Viola Turning Basin, as shown in Figure 2.9, featuring a wide scatter. The trend lines in this figure indicate that, on average, the sediment composition is made up of higher sand content (~60%) in the Jetty Channel in the Gulf of Mexico. The fraction of sand decreases in the Corpus Christi Bay (~20%) and increases again slightly (~30%) toward the Viola Turning Basin in the inner harbor. Silt and clay content is higher in the Corpus Christi Bay (~80%). While silt was generally present everywhere along the channel, clay content was down to 10% in the jetty channel.

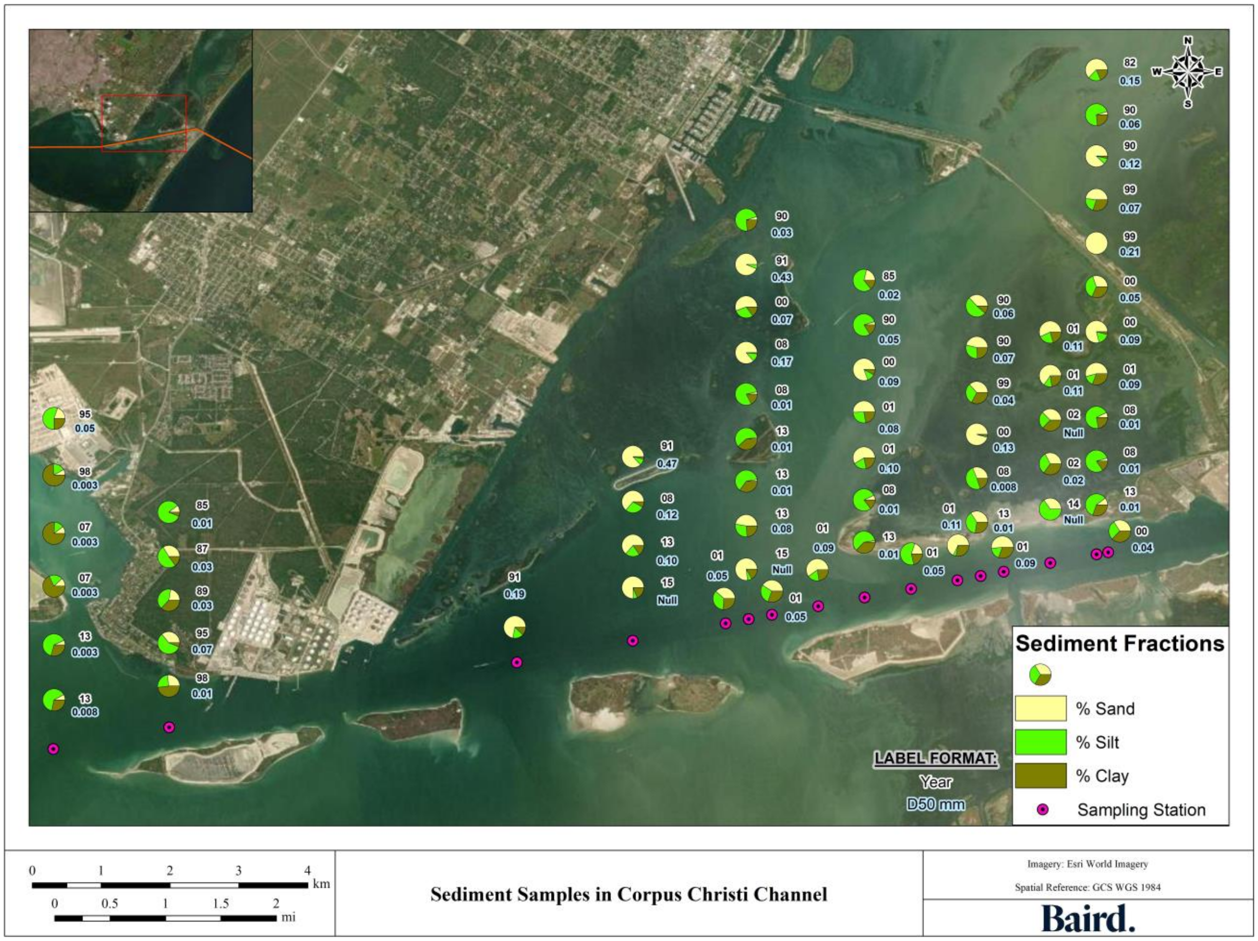


Figure 2.8: Sediment fraction distribution along the channel

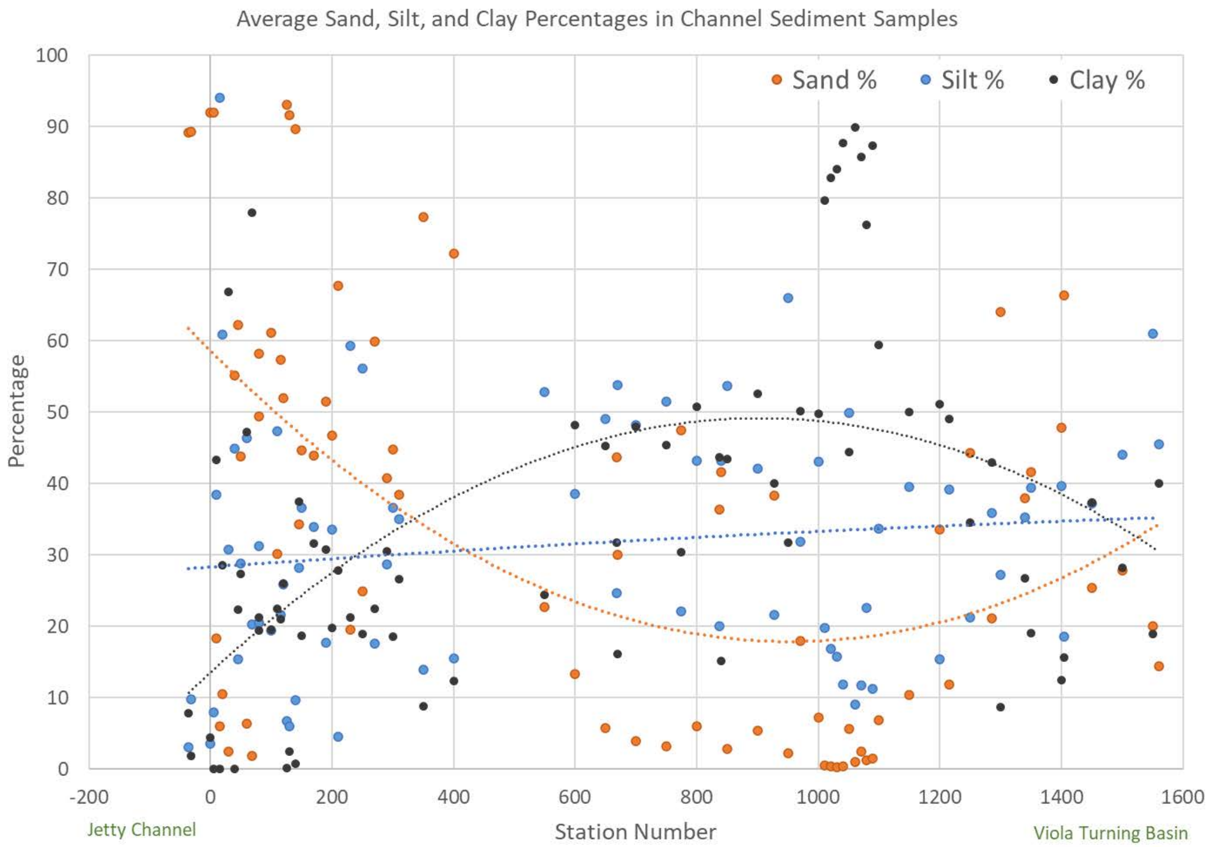


Figure 2.9: Sediment fraction distribution along the Corpus Christi channel

Sediment fraction data on the seabed outside of the Corpus Christi channel was acquired from the Texas Sediment Geodatabase by the Texas General Land Office (https://cgis.glo.texas.gov/txsed/index.html). The data comes from surface grab samples taken at different times ranging from 1976 to 2006. Figure 2.10 shows the sample locations and the sediment fraction distribution from each sample. Based on this data, interpolated maps of sediment type and grain size were developed for model input. The interpolation for silt is shown in Figure 2.11.

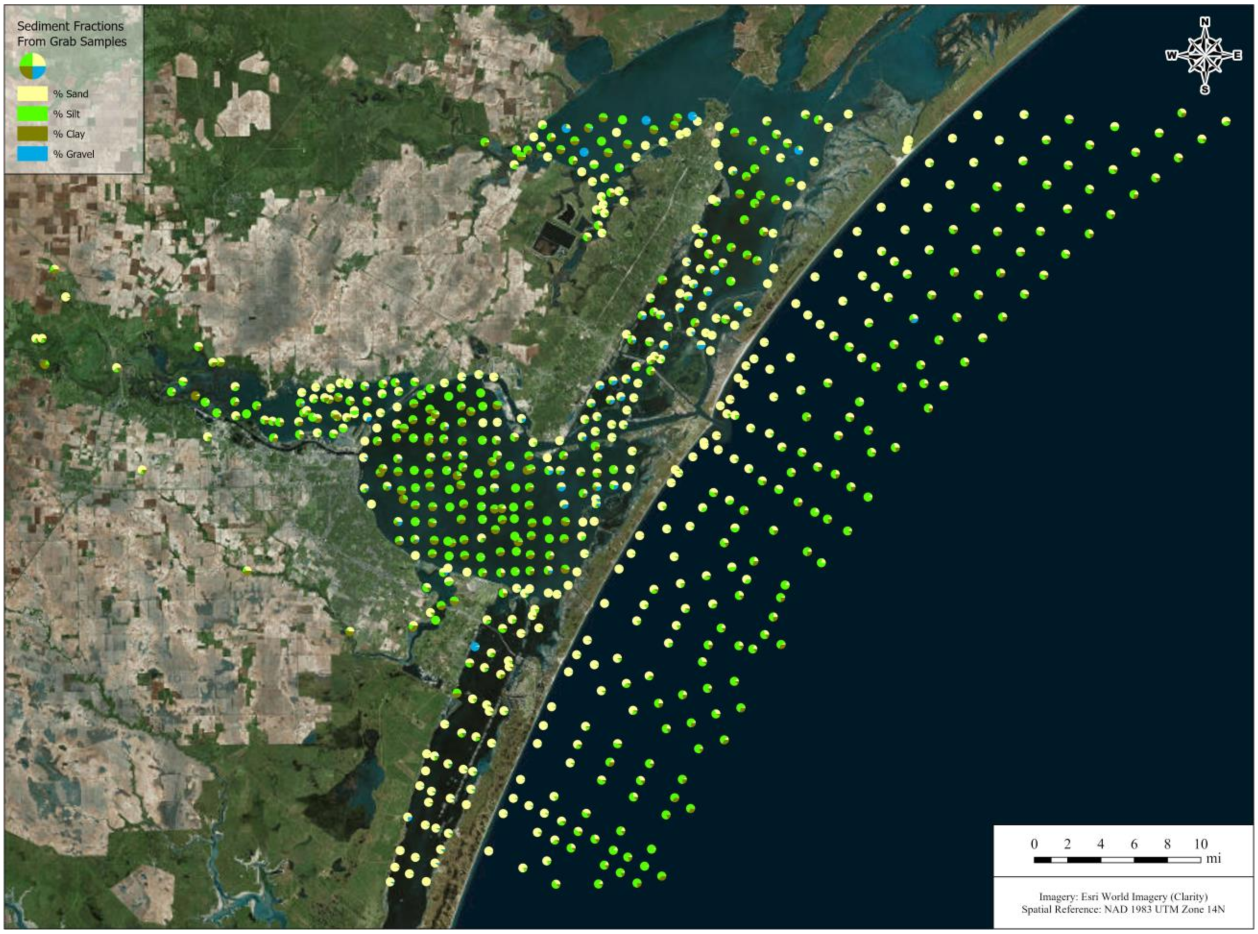


Figure 2.10: Sediment fraction distribution in the Corpus Christi Bay and adjacent water bodies (TGLO)

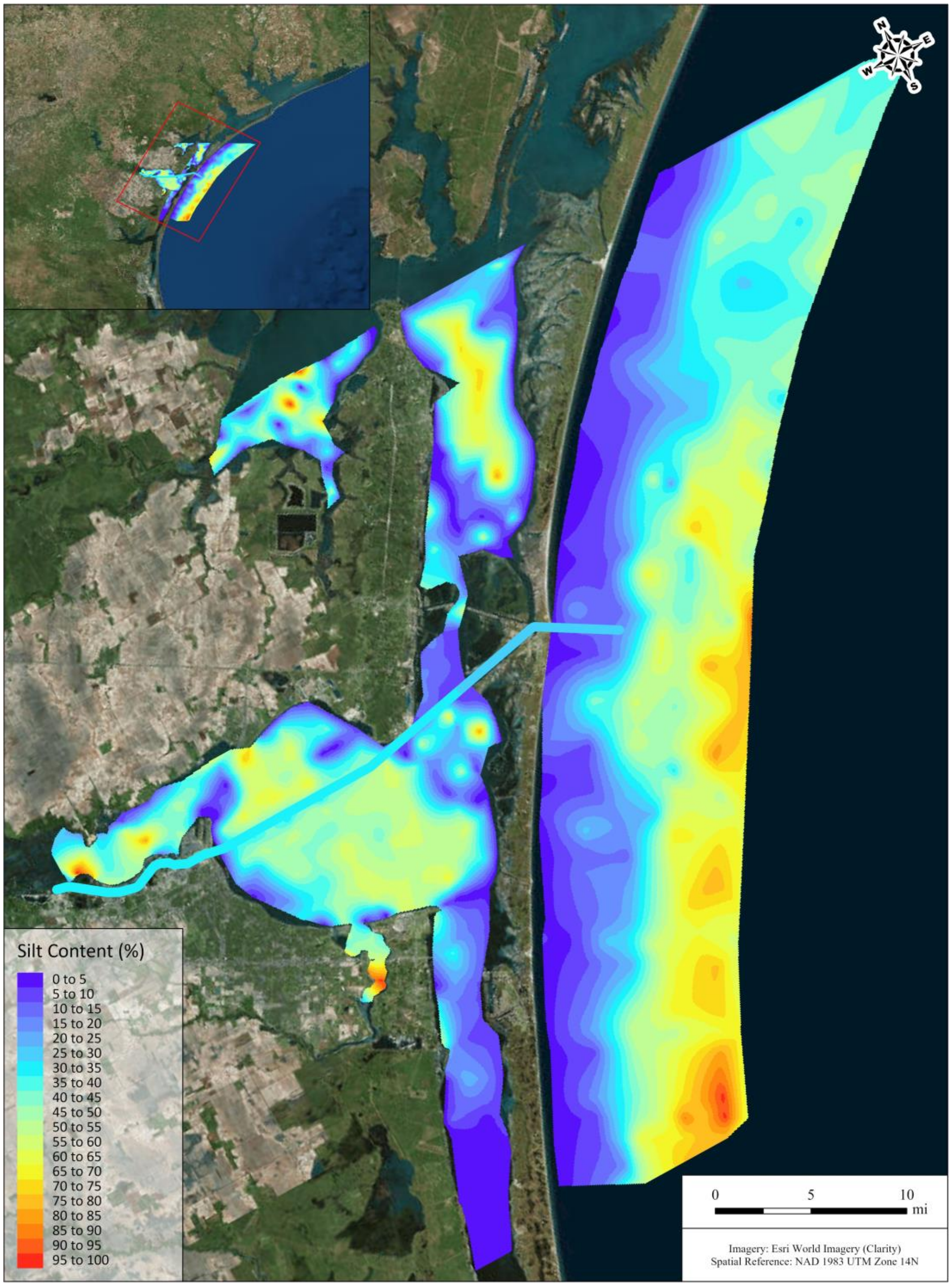


Figure 2.11: Silt content in the Corpus Christi Bay

2.1.3.2 River Sediment Rating Curves

To evaluate the sediment concentration coming in from the rivers, sediment rating curves were developed. Suspended sediment concentration data was available at three USGS stations. The summary of the available suspended sediment data is shown in Table 2.3.

Table 2.3: Summary of suspended sediment data available from USGS

Name	Station ID	Start Date	End Date	Number of Data Points
Nueces River at Calallen	08211500	2006-05-16	2018-04-11	12
Aransas River near Skidmore	08189700	1966-02-15	1975-05-23	36
Mission River at Refugio	08189500	1973-08-09	1993-08-17	89

The sediment concentration data and the corresponding flow rate was used to develop the sediment rating curves. The rating curves are plotted on the log scale and is shown in Figure 2.12, Figure 2.13, and Figure 2.14.

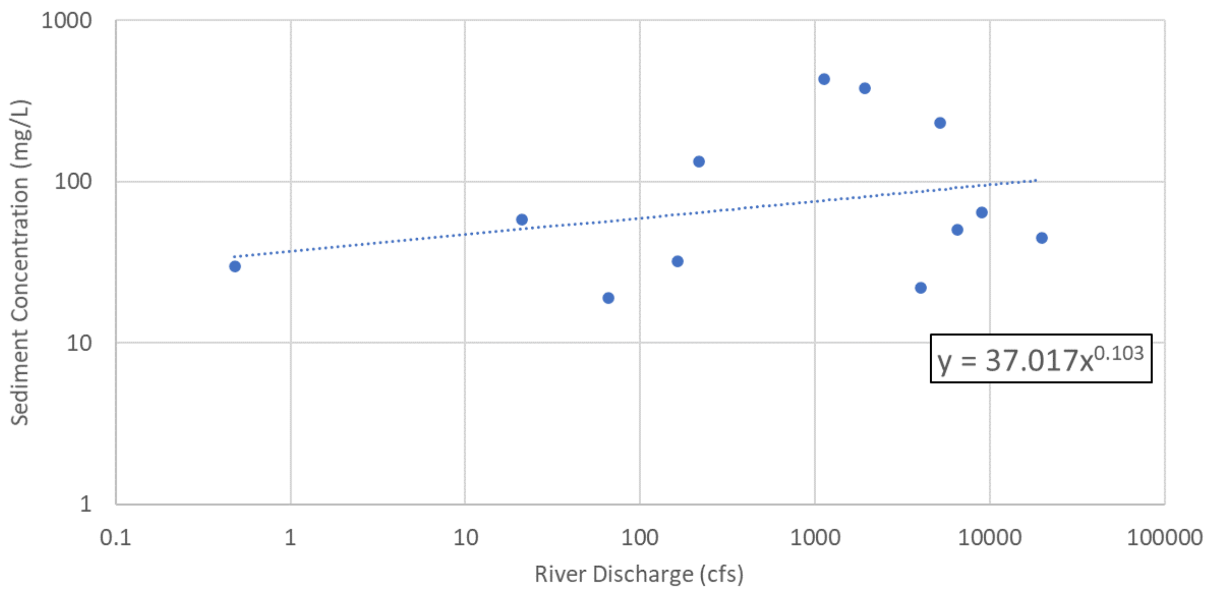


Figure 2.12: Sediment rating curve at 8211500 (Nueces River at Calallen)

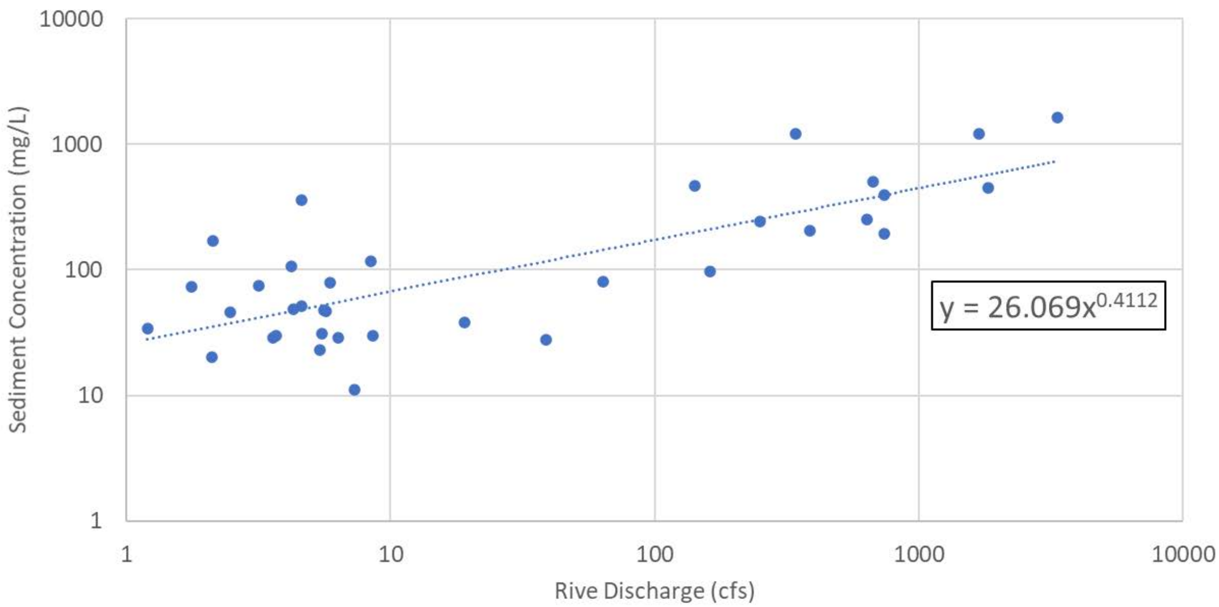


Figure 2.13: Sediment rating curve at 8189700 (Aransas River near Skidmore)

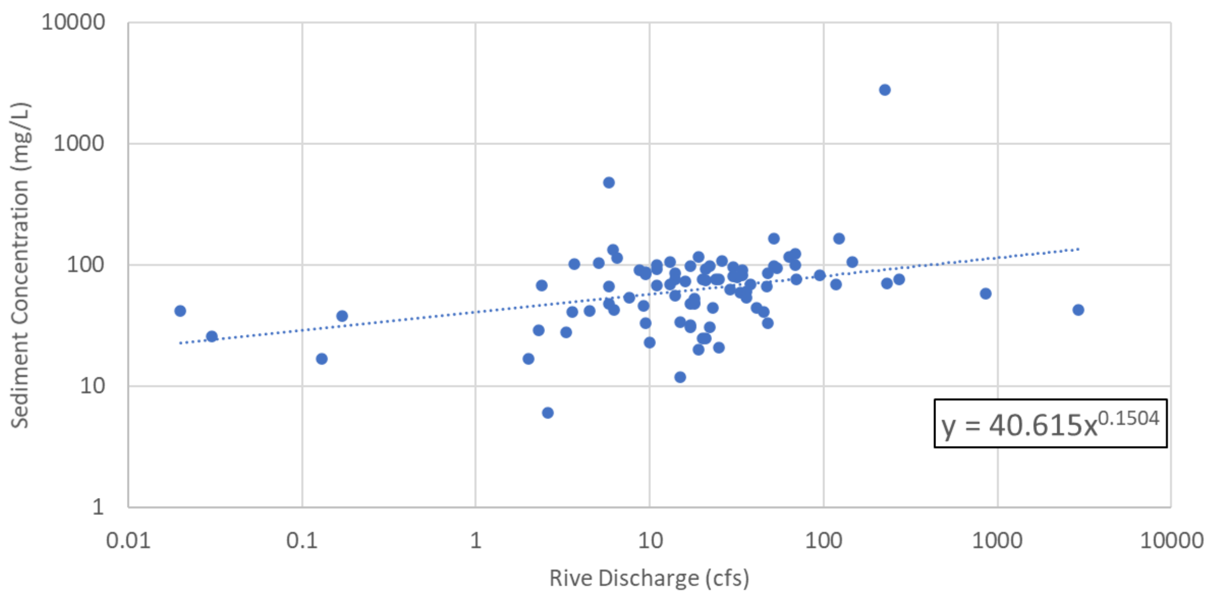


Figure 2.14: Sediment rating curve at 8189500 (Mission River at Refugio)

2.1.3.3 CSAT Dredging Data

The Corps Shoaling Analysis Tool (CSAT) is a tool developed by USACE that calculates channel shoaling volumes using historical channel survey. CSAT can predict future dredging volumes base on the shoaling rates. CSAT can also generate shoaling rate maps to identify hotspots or areas of increased sedimentation.

The data for CSAT tool at Corpus Christi can be divided into two periods based on the vertical datum used in the surveys. The period from 2011 to 2015 is based on the mean low tide datum and the period from 2016 to 2020 is based on the mean lower low water datum. CSAT uses the reaches defined by the natural channel network, according to which, the Corpus Christi shipping channel has 15 reaches (Figure 2.15). The period from 2011-2015 was used for model calibration and the period from 2016-2020 was used for model validation. The average annual shoaling rates calculated by CSAT for the two periods is shown in

Table 2.4. CSAT data indicates that most of the sedimentation occurs in Reach 1, Reach 6, Reach 7, and Reach 8.

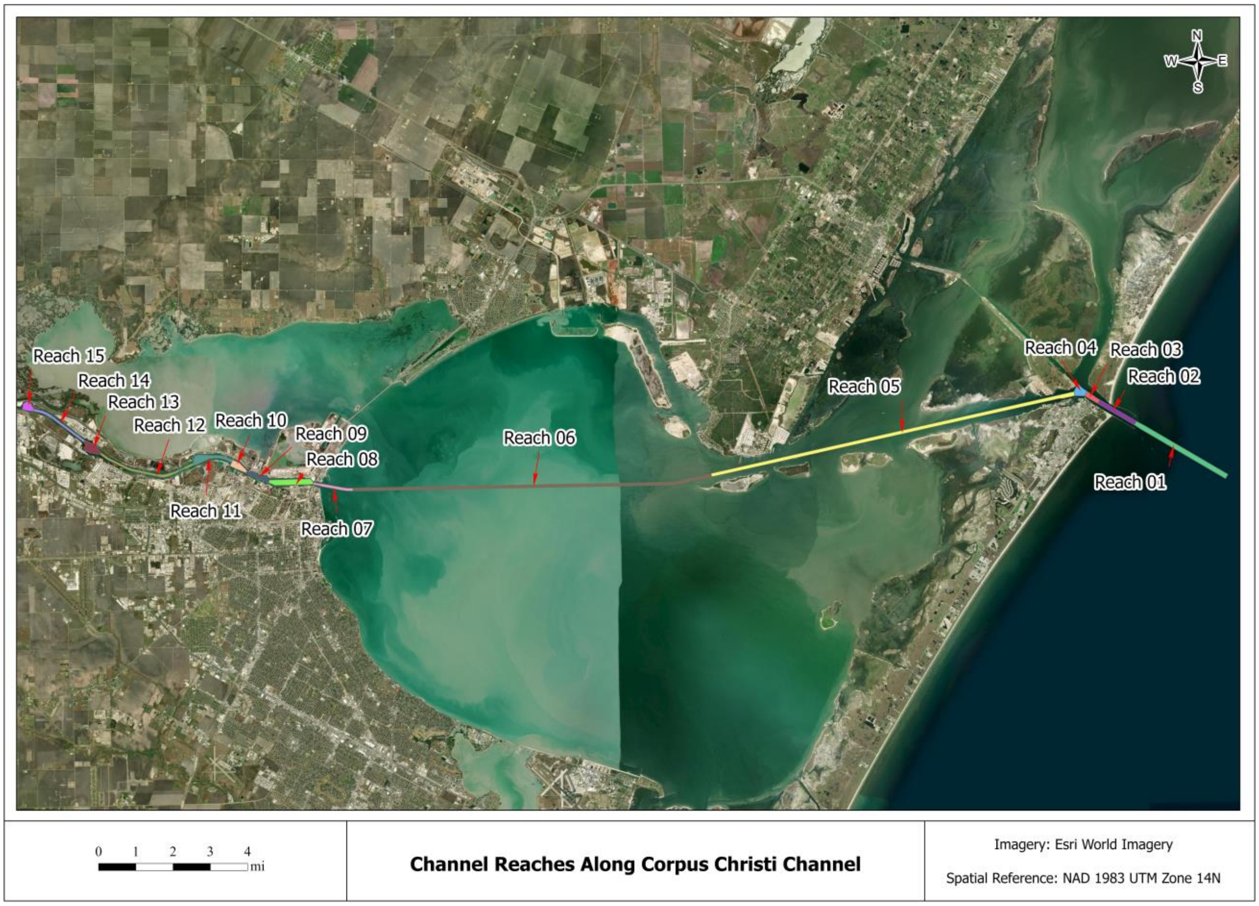


Figure 2.15: National channel network reach numbers for Corpus Christi channel

Table 2.4: Average annual shoaling rates from CSAT

Reach Number	Reach ID	Reach Name	Average Annual Shoaling Rate [ft/yr (m/yr)]	
			2011-2015	2016-2020
01	CESWG_CC_01_SBC_1	Sea bar channel	0.097 (0.03)	1.029 (0.314)
02	CESWG_CC_02_JEC_2	Jetty channel	0	0
03	CESWG_CC_03_IMC_3	Inner Basin at Main Channel	0	0
04	CESWG_CC_04_IHI_4	Inner Basin at Harbor Island	0.184 (0.056)	0
05	CESWG_CC_05_HLQ_5	Humble Basin to Junction at La Quinta Channel	0.022 (0.007)	0
06	CESWG_CC_06_LQB_6	La Quinta Channel Junction to Bcn. 82	0.782 (0.238)	1.585 (0.483)
07	CESWG_CC_07_BTB_7	Bcn. 82 to Main Turning Basin	1.419 (0.432)	1.523 (0.464)
08	CESWG_CC_08_MTB_8	Main turning basin	0.945 (0.288)	1.090 (0.332)
09	CESWG_CC_09_INC_9	Industrial canal	0.186 (0.057)	0.246 (0.075)
10	CESWG_CC_10_ATB_10	Avery point turning basin	0.497 (0.151)	0.384 (0.117)
11	CESWG_CC_11_CTB_11	Chemical turning basin	0.432 (0.132)	0
12	CESWG_CC_12_TLC_12	Tule lake channel	0.203 (0.062)	0.026 (0.008)
13	CESWG_CC_13_TTB_13	Tule lake turning basin	0.281 (0.086)	0
14	CESWG_CC_14_VCH_14	Viola channel	0.425 (0.130)	0
15	CESWG_CC_15_VTB_15	Viola turning basin	0.260 (0.079)	0.004 (0.001)

3. Sedimentation Model Description

3.1 Model Development

Baird developed MIKE21 and MIKE3 models to simulate sedimentation/shoaling rates for the Port of Corpus Christi Channel Deepening Project 3rd Party study. Developed by the Danish Hydraulic Institute (DHI), MIKE21 Flow Model FM is a two-dimensional modeling system capable of simulating free surface flows where stratification is not of concern. MIKE3 Flow Model FM is three-dimensional modelling system unlike MIKE21 Flow Model FM, the free surface is taken into account using sigma-coordinate transformation approach or using a combination of a sigma and z-level coordinate system. Both MIKE21 and MIKE3 hydrodynamic models were calibrated and validated under the hydrodynamic and salinity modeling task (Baird, 2022). The sedimentation model is described in this report.

The model domain includes two major inner bays, i.e., Corpus Christi Bay and Nueces Bay,) in which the sediment is mainly clay. The shorelines of Mustang and San José islands in the Gulf of Mexico, on the other hand, are predominantly sandy out to approximately the 15 m depth contour in the Gulf. Therefore, a combination of the Mud Transport module (MT) and the Sand Transport module (ST) was used in the sedimentation. Model Domain and Grid

The model domain includes Nueces Bay, Corpus Christi Bay, and several linked bays on the north and south sides of it separated from the Gulf of Mexico (GOM) by Mustang Island, North Padre Island, and San José Island. These bays are connected to the GOM by a narrow entrance channel, Aransas Pass, and a secondary inlet, Packery Channel. River inflows come from the Nueces River and Oso Creek at the domain's western and southern extensions. The open boundaries for the model were selected sufficiently far from the navigation channel to avoid boundary effects on the study area. Figure 3.1 shows the model domain.

Mesh generation is one of the most important parts of the modeling strategy, since it defines the level of detail included in the model and the computation time required. An unstructured flexible mesh with triangular and quadrangular elements of different sizes was used to provide greater accuracy in and around the channels and nearshore areas.

Model bathymetry was obtained as mentioned in Section 2.1.1. The horizontal coordinates are located at UTM14N, while all bed elevations were adjusted to the datum of NAVD88. This mesh is shown in Figure 3.1. Figure 3.2 shows an example of the finer mesh resolution area around the channel where the different sizes and transitions to smaller elements can be seen. As waves are believed to be an important driving factor in movement of sediments around the outer channel in the GOM, the offshore boundary was set at 98ft (30 m) depth to match with the location of WIS hindcast wave data.

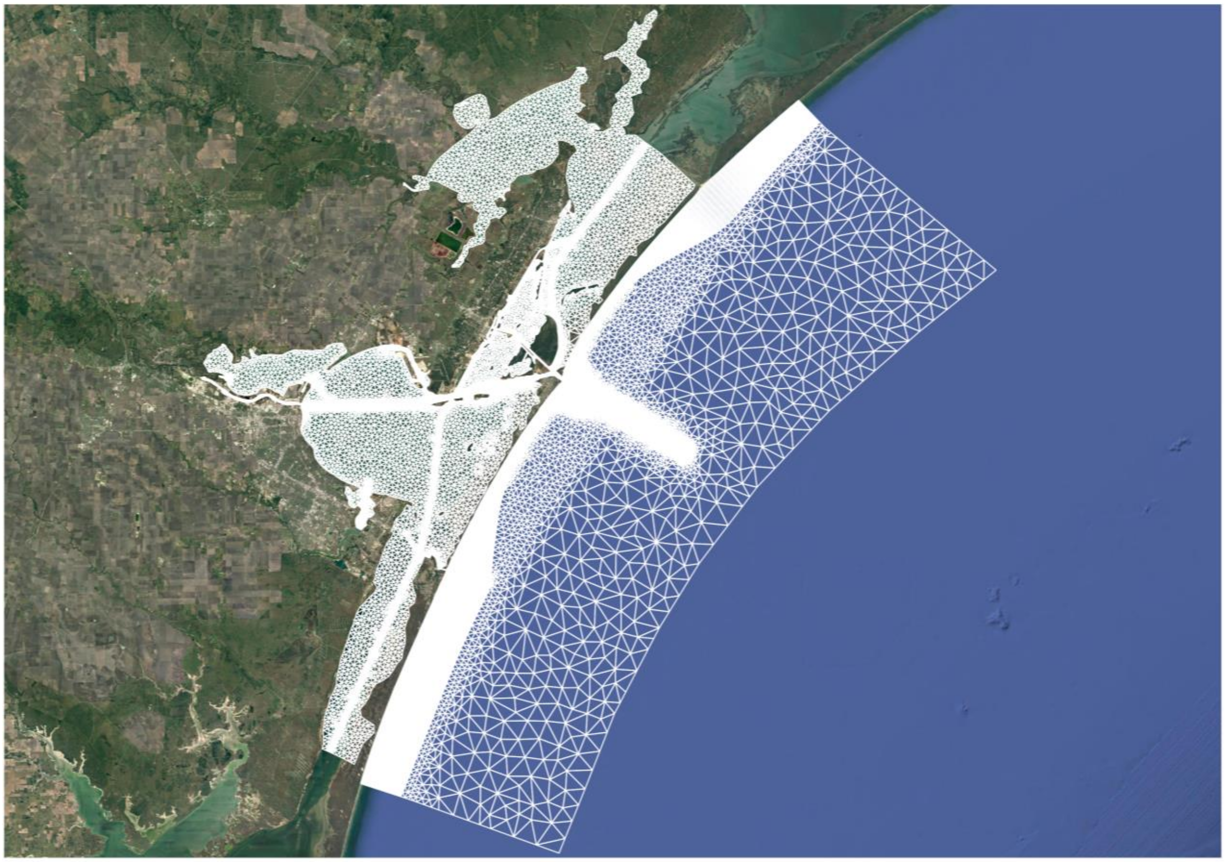


Figure 3.1: Computational mesh for the MIKE sedimentation model

Figure 3.2: Computational mesh for the MIKE sedimentation model showing the grid cells in the channel

3.1.1 Model Setup

The boundary conditions used by the model are surface elevation from the HYCOM model along the offshore boundary, and fluxes at the northeastern and southwestern lateral boundaries in the GOM. The open inland boundaries use measurements of water levels from nearby stations (Rockport to the northeast and Baffin Bay to the southwest). At river boundaries, measured discharge from stations upstream of the boundary, such as Nueces River, Aransas River, Mission River, Oso Creek, and Copano Creek were applied. The intake at the Nueces Bay power plant is located in the inner harbour portion of the channel (Reach 9). From the permitting documentation, the intake rate is 500 mgd, which is incorporated into the model as a sink term.

Sensitivity tests were performed with bed roughness to observe changes in surface elevation and current velocity. It was determined to use spatially variable roughness values in the domain to properly reproduce desired flow conditions. For the 2D model, Manning values in the range of 43 to 67 were used, which are equivalent to Manning's “n” values in the range of 0.023 to 0.015.   For the 3D model, Nikuradse roughness values of 0.003 to 0.039 were used. These values represent a range of roughness from natural streams to excavated or dredged channels, as occurs in the main channels. See the Hydrodynamic and Salinity modeling report (Baird, 2022) for more details.

Three sediment fractions were included in the model: clay, silt, and sand. The fraction of available sediment in the bed was generated by spatial interpolation of the sediment fraction data mentioned in Section 2.1.3.1. The sediment contribution from the rivers and creeks was calculated using the sediment rating curves mentioned in section 2.1.3.2. Data was not available for Oso Creek and Copano Creek and therefore, the rating curves for Nueces River and Mission River were used respectively since they are close by. Settling velocities for mud fractions were set assuming medium silt and medium clay.

3.1.2 Spectral wave model

Baird used the Danish Hydraulic Institute (DHI) MIKE21 Spectral Wave (SW) model to transform the offshore wave climate, from the WIS station to the nearshore region in front of the project shoreline. The same model domain, including the model mesh and bathymetry mentioned above were used for the SW model. The offshore wave data and wind data from the WIS station and NOAA buoy were used as boundary conditions for the spectral wave model. The same model was used to simulate wind generated waves over Corpus Christi Bay and other inland water bodies.

4. Model Calibration and Validation

The sedimentation model was calibrated and validated against the CSAT data. For the calibration, one-year two-dimensional simulations were completed for 2011 and model results were compared to CSAT data for period of 2011 to 2015. Similarly, the validation runs were conducted for 2020 and compared to CSAT data for 2016 to 2020. The above simulation periods were selected based on availability of HYCOM data for boundary conditions.

4.1 Scaling Factor due to Wind

The sedimentation model was calibrated to the CSAT data representing average sedimentation rates for the period of 2011 to 2015. Due to data availability, one year of model runs were done for 2011. However, wind conditions were above average in 2011 resulting in higher-than-average sedimentation in the Northern part of the channel in Corpus Christi Bay. A scaling factor was thus used to adjust the result to represent a typical year.

Most sedimentation in Corpus Christi Bay occurs between the months of April and July. The predominant wind direction in the area is from 130 degrees (or southeast) as shown in the wind rose in Figure 4.1. As shown in this figure, southeasterly winds and associated waves generated within Corpus Christi Bay are in the key contributing factor to sediment resuspension in the northeastern part of Corpus Christi Bay and in Nueces Bay. It is mainly the resuspended sediment from this area that ends up in Reaches 6 and 7 of the channel causing sedimentation. Therefore, the effective wind energy was calculated from the wind speeds projected onto the 130-degree direction (Figure 4.2). A scaling factor was defined as the ratio of the excess wind energy in a certain year to the long-term average annual wind energy. Model results indicated that the critical wind speed for sediment resuspension is around 21.3 ft/s (6.5 m/s), resulting in a threshold wind energy of 35,000 J/kg. The final scaling factor for the calibration runs (2011) was calculated to be 1.39 and that of the validation runs (2020) was 0.55.

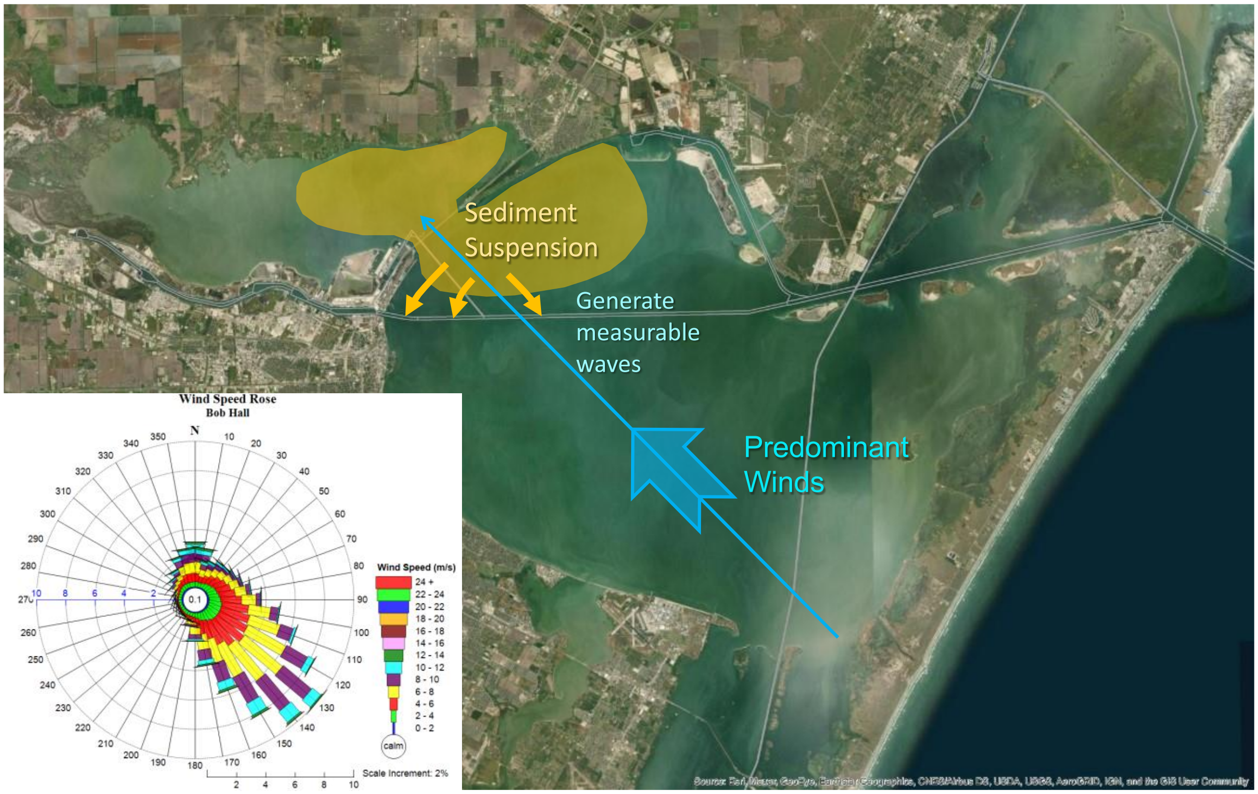


Figure 4.1: Wind rose and schematics of channel sedimentation processes inside Corpus Christi Bay

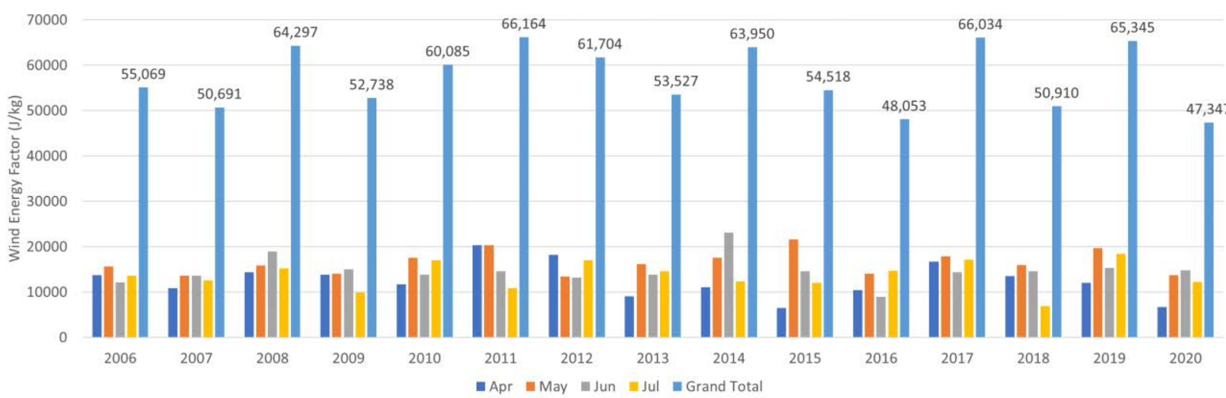


Figure 4.2: Variation of wind energy between April and July from 2006 to 2020

4.2 Erosion in the Inner Harbor

Examination of historic shorelines in the Inner Harbor determined shoreline erosion as the source of sediment causing sedimentation in Reaches 9 to 15 of the channel. Bank erosion and sediment transport processes are not included in the sedimentation model. Sedimentation volume was thus calculated using aerial images between 1995 to 2020 (Figure 4.3 and Figure 4.4). Using the areas shown in Table 4.1 and assuming a depth of 48 ft (15 m), the average shoaling rate in the inner harbor was calculated to be around 0.325 ft/year (0.099 m/year). It is expected that this rate will decrease as/if the shoreline becomes more stable into the future.

Table 4.1: Erosion area in the inner harbor

Year	Erosion Area (yd^2)
2004-2020	152,690
1995-2004	274,710

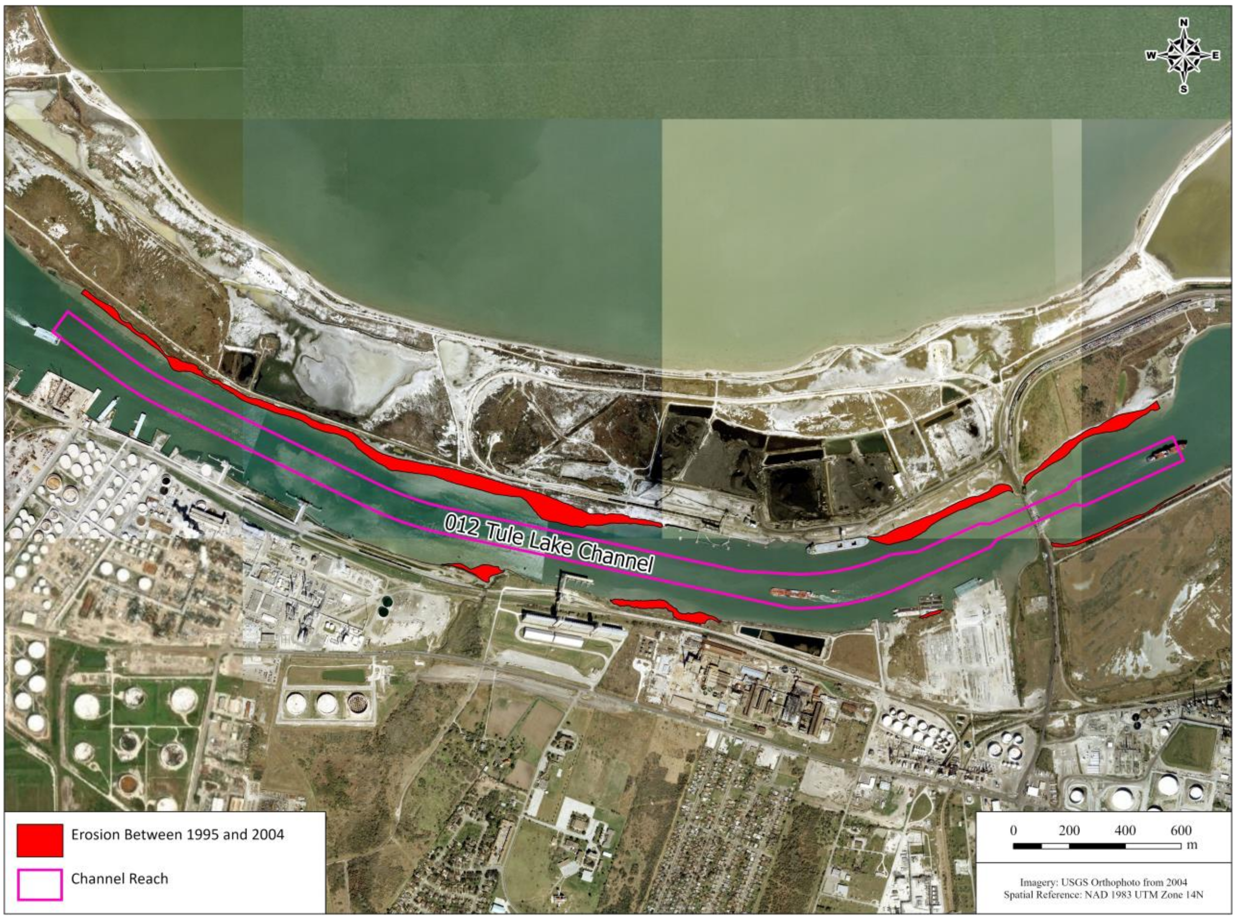


Figure 4.3: Erosion in the Inner Harbor (Reach 12) between 1995 and 2004

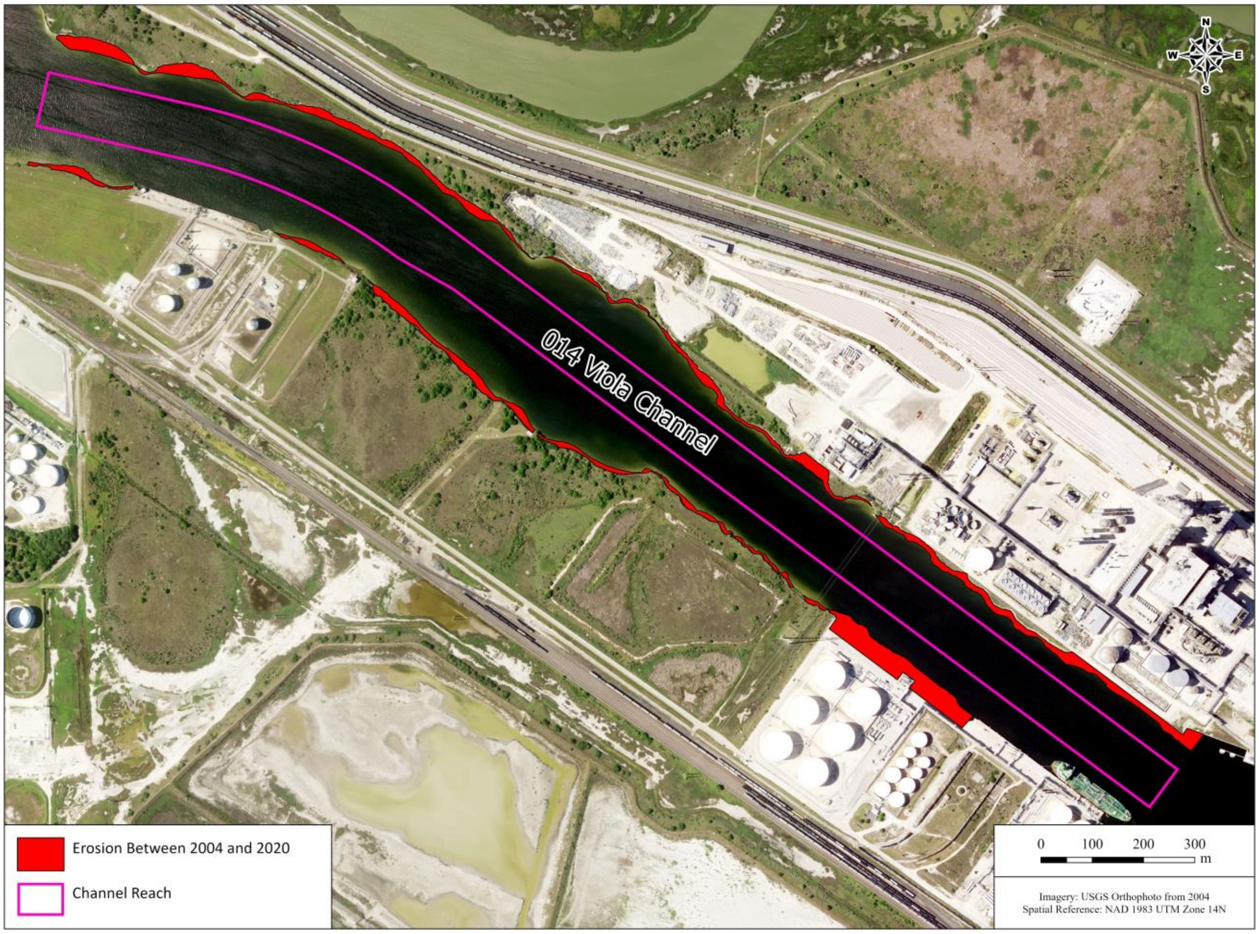


Figure 4.4: Erosion in the Inner Harbor (Reach 12) between 2004 and 2020

4.3 Two-dimensional model

Shoaling rates were calculated from predicted sedimentation for 2011 using the national channel database polygons which includes the channel bottom and have 15 reaches as described in Section 2.1.3.3. Figure 4.5 shows the predicted average annual shoaling rate in the different reaches of the channel compared to the CSAT data. Most of the sedimentation in the Corpus Christi Bay is predicted to occur at the northern end of the shipping channel (i.e., Reaches 6, 7, and 8) which is consistent with CSAT. Predicted sedimentation rates for Reaches 9 to 15 include average shoreline erosion volumes discussed in the previous section. Predicted sedimentation rates are in reasonable agreement with CSAT data despite some overprediction in Reach 6 and underestimation in Reach 8.

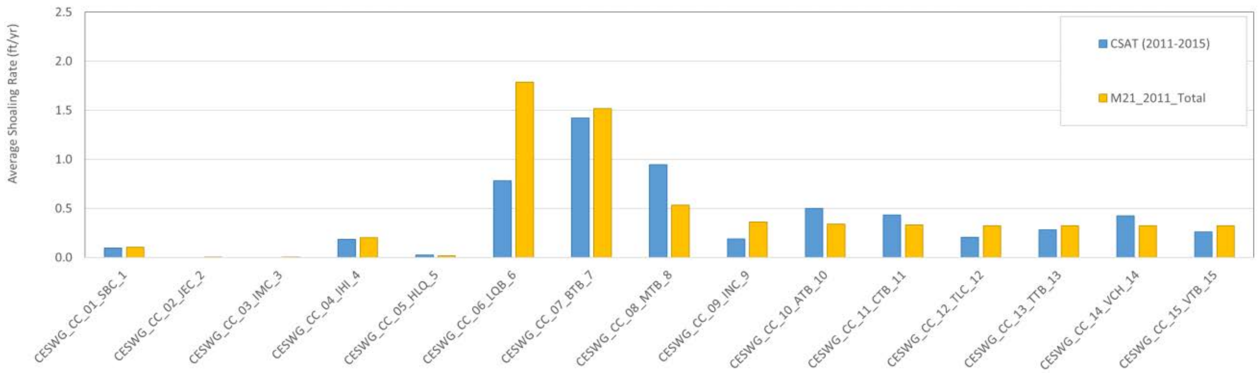


Figure 4.5: Comparison of CSAT shoaling rates (2011-2015) and model predictions (2011)

Subsequently, channel sedimentations in 2020 were predicted and compared with the CSAT data to validate the model. The 2020 predicted rates were first normalized by a factor of 0.55 as discussed in the prior section. The 2016-2020 CSAT data shows significantly higher sedimentation in the outer channel (Reach 1) because of Hurricane Harvey which occurred in 2017. Therefore, wind and wave conditions during Hurricane Harvey were incorporated into the input wind and wave time-series files for 2020 for the duration of the storm. The comparison between the CSAT shoaling rates and model predictions is shown in Figure 4.6 and indicates a reasonable agreement.

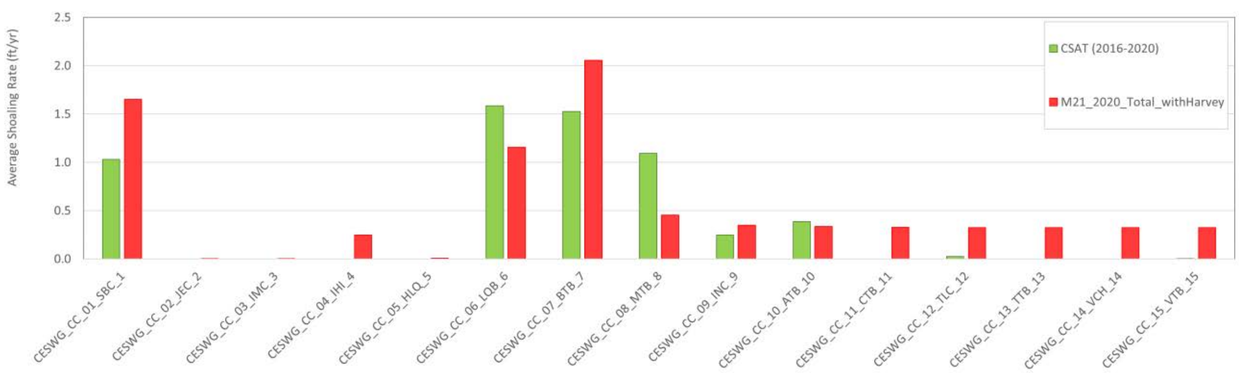


Figure 4.6: Comparison of CSAT shoaling rates (2016-2020) and model predictions (2020)

Figure 4.7 shows the comparison of the average shoaling rate between the two periods above from the CSAT data and model predictions. The model predictions were slightly higher than the CSAT with the exception of reaches 8 and 10, which are both in the inner harbor. It is concluded that the model performance is acceptable for assessment of potential project impacts.

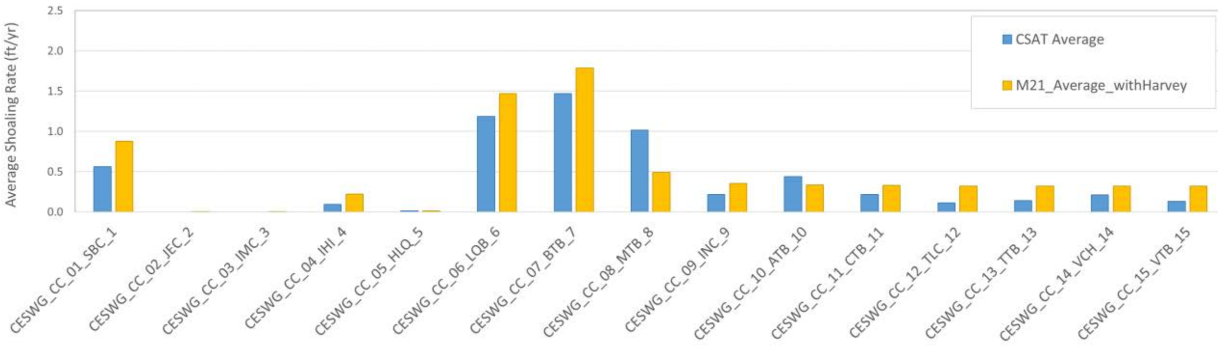


Figure 4.7: Comparison of CSAT shoaling rates (average) and model results (average)

4.4 Comparison of Two-dimensional and Three-dimensional models

Three-dimensional model runs require extensive computer resources and run at relatively slow speeds and thus are not practical for year-round simulations. As noted earlier, model results indicated that most of the sedimentation in the inner channels occur during months of April to July when predominant winds are from the 130 deg direction. Preliminary model runs and analysis of wind data indicated that June 2020, once properly scaled, may be used as a representative month to predict sedimentation in the inland portion of the Corpus Christi channel where mud transport is predominant. The outer channel or Reach 1 is subject to sand transport by waves and currents requiring full year 3D simulations that are not computationally practical. Therefore, only the 2D model was used for Reach 1 simulations. Figure 4.8 shows the comparison between the CSAT shoaling rates and the model results (both 2D and 3D). The 3D run was scaled for the time period (assuming similar sedimentation occurs per month between April and July) and also scaled to be comparable to a typical year (scale factor of 0.55 for 2020) as mentioned in section 4.1. The 3D model results are comparable with the 2D model results.

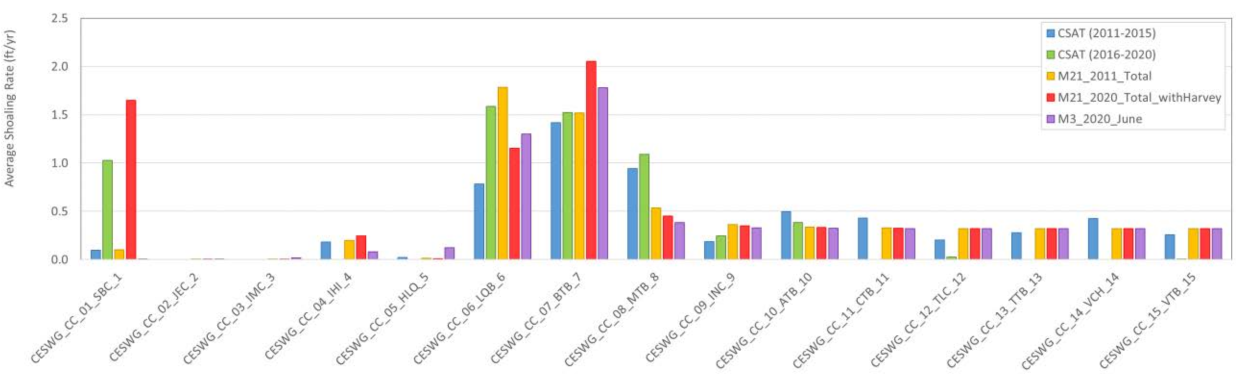


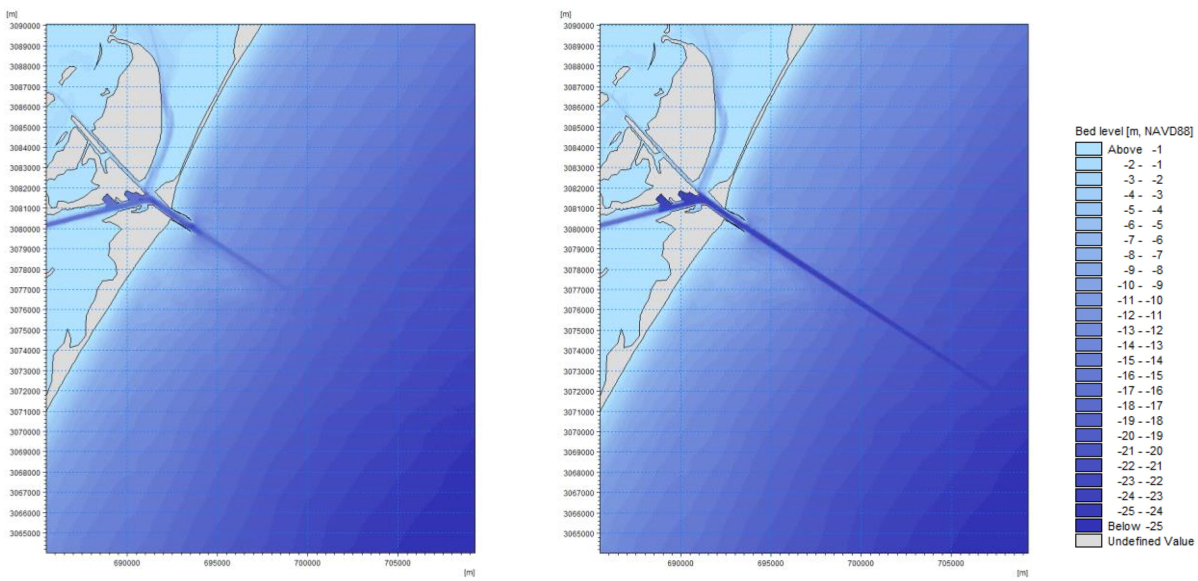
Figure 4.8: Comparison of CSAT shoaling rates and model results (2D and 3D)

5. Modeling Assessment of Potential Project Impacts

5.1 Model Scenarios

To assess the impact of channel deepening on sedimentation in the channel, two scenarios were considered:

1. In the Future Without Project (FWOP) scenario, the shipping channel was dredged to 54 ft MLLW (-16.6 m, NAVD88). The dredging area includes the expansion of Humble Basin and the terminals (Figure 5.2). The model bathymetry of the FWOP scenario is presented in Figure 5.1a.
2. In the Future With Project (FWP) scenario, extent of the shipping channel from the Gulf of Mexico to the end of the terminals was dredged 75 ft MLLW (-23.0 m, NAVD88) and the remaining channel was dredged to 54 ft MLLW (-16.6 m, NAVD88). The model bathymetry of the FWP scenario is presented in Figure 5.1b. The dredging area includes the expansion of Humble Basin and the terminals (Figure 5.2).



(a) (b)

Figure 5.1: Model bathymetry around the jetties for (a) FWOP, and (b) FWP scenarios

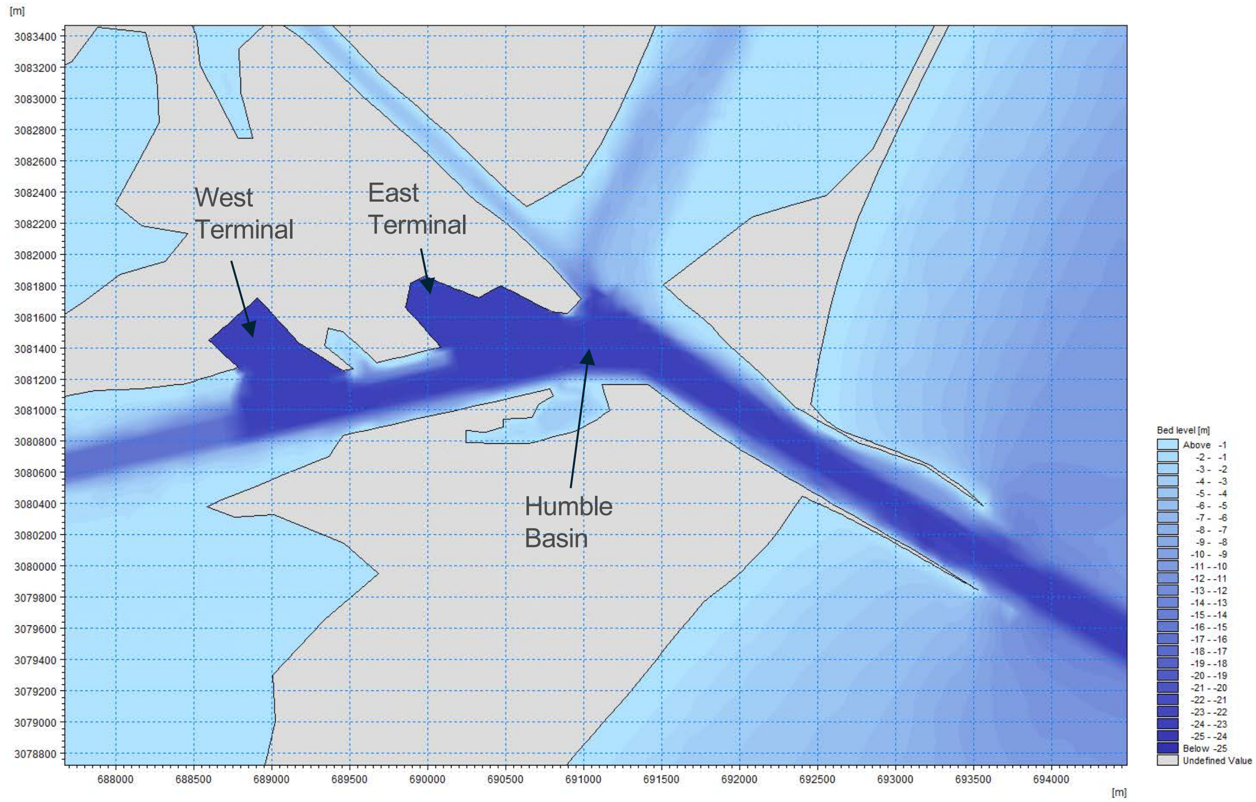


Figure 5.2: Model Bathymetry for FWP scenario showing the terminals

5.2 Impact Assessment

5.2.1 Shoaling Rates in the Inner Channel

Figure 5.3 shows the average annual shoaling rates from CSAT for the period of 2011-2015 and the 2D model predicted results for the existing, FWOP, and FWP conditions. Between the FWOP and FWP scenarios, the model predicted about 5-10% increase in sedimentation in certain reaches. However, both FWOP and FWP shoaling rates were comparable to the existing condition. Figure 5.4 shows the shoaling rates in different reaches as well as the two terminals present in the FWOP and FWP scenario. Predicted sedimentation rates in Reaches 9 to 15 are based on historic bank erosion rates along the inner harbor shoreline. The model predicted a 5-10% increase in sedimentation under the FWP scenario as a result of deeper channel depths.

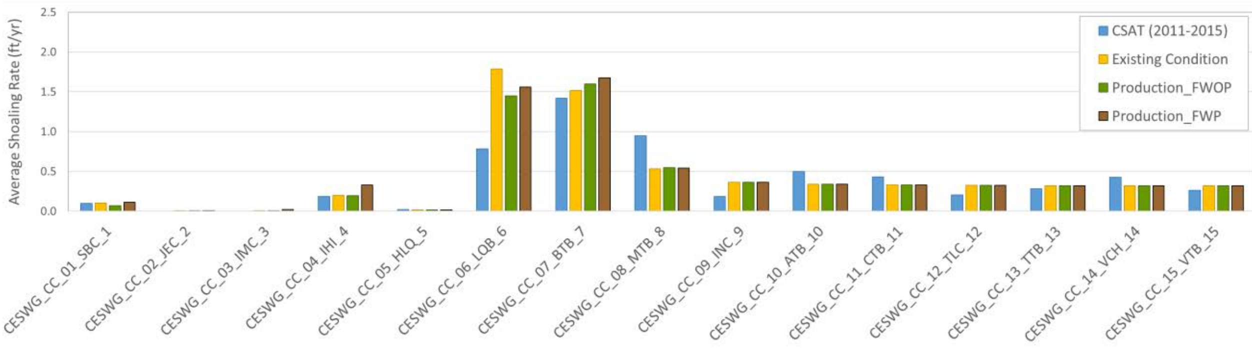


Figure 5.3: Comparison of CSAT shoaling rate (2011-2015) and the 2D model results for existing conditions, FWOP and FWP scenarios

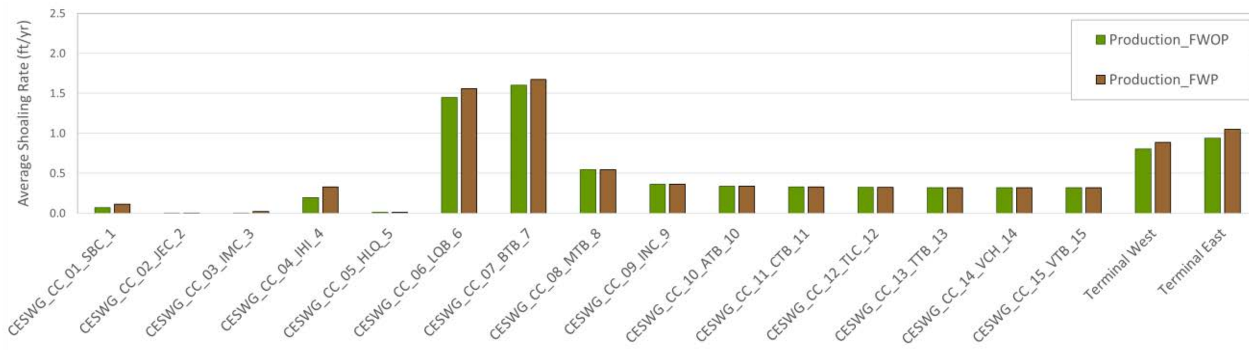


Figure 5.4: Average annual shoaling rates predicted by the 2D model in the channel including the terminals for FWOP and FWP scenarios

Figure 5.5 shows the average annual shoaling rates from CSAT for the period of 2011-2015 and the 3D model results for the existing, FWOP, and FWP conditions. The results are in reasonable agreement with the 2D model results. Between the FWOP and FWP scenarios, there was about 5-10% increase in sedimentation in certain reaches but a slight decrease is observed in reach 7 as opposed to an increase seen in the 2D model results. Predicted FWOP and FWP shoaling rates were comparable to the existing condition. Figure 5.6 shows the shoaling rates in the different reaches and the two terminals present in the FWOP and FWP scenario. Overall, both 2D and 3D model results indicate that the project impact on sedimentation rates is limited to less than 10%.

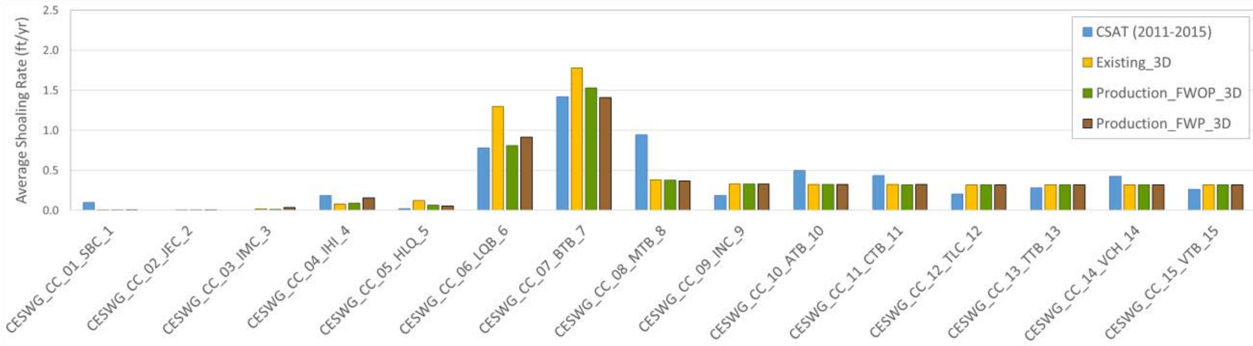


Figure 5.5: Comparison of CSAT shoaling rate (2011-2015) and the 3D model results for existing conditions, FWOP and FWP scenarios

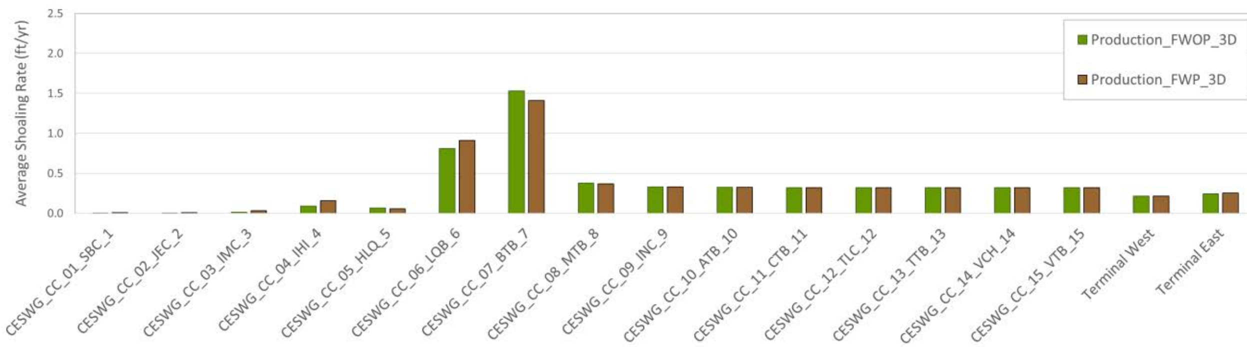


Figure 5.6: Average annual shoaling rates predicted by the 3D model in the channel including the terminals for FWOP and FWP scenarios

5.2.2 Sedimentation Volumes in the Outer Channel

Sedimentation in the outer channel is dominated by sand transport processes. Predicted sedimentation volumes in the outer channel were calculated for segments 1, 2 and 3 as shown in Figure 5.7. Since the model predicts sedimentation on the channel shoulders, the volume calculation polygon includes both the channel bed and shoulders. Segment 1 is the same longitudinal extent as Reach 1 from the National Channel Network but larger in the transverse direction to include the shoulders. Segment 2 extends to up to the end of the channel for the FWOP scenario and Segment 3 extends to that of the FWP scenario. Model simulations were completed for 2011 and the results were compared.

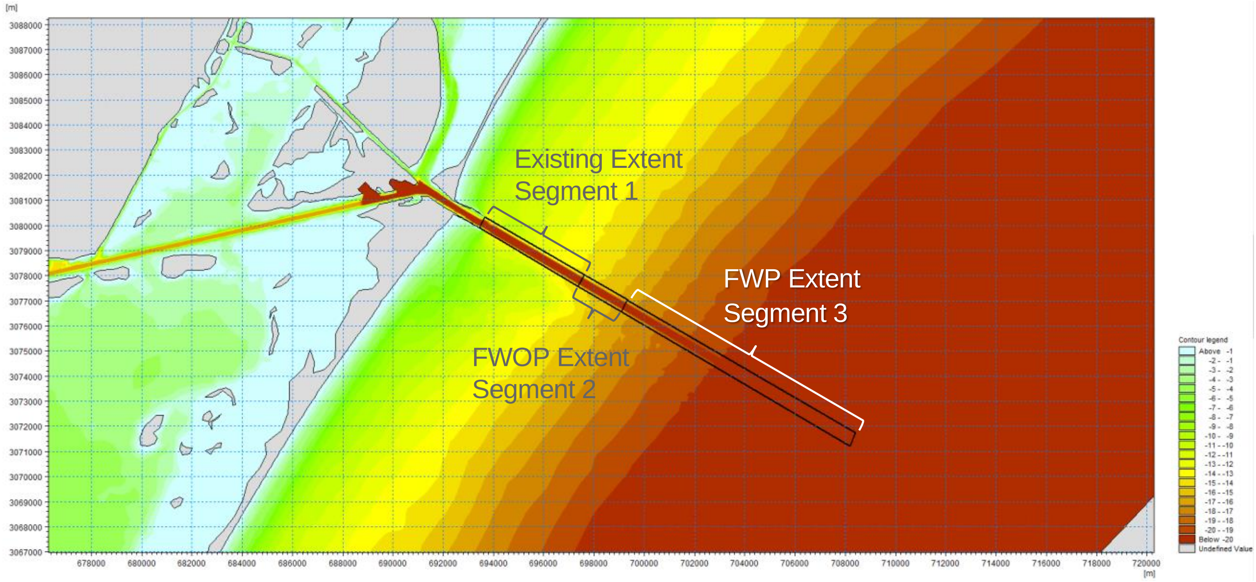


Figure 5.7: Segments for sediment volume calculation

The corresponding sedimentation volumes are shown in Table 5.1. For all scenarios, most sedimentation is predicted to occur in Segment 1. Nevertheless, examination of model results indicated that the deeper channel in the FWP scenario further channelizes the ebb flow resulting in increasing sedimentation farther offshore in the channel. Between the existing scenario and FWOP there was ~3000 yd^3 (2294 m^3) and between the existing scenario and FWP, there was an increase of ~70,000 yd^3 (53,519 m^3) in Segment 1 In Segment 2, the increase between the existing condition and FWOP scenario is ~11,000 yd^3 (8,410 m^3) and that between existing and FWP is ~48,000 yd^3 (36,699 m^3). In Segment 3, the increase between the existing condition and FWOP scenario is ~1,500 yd^3 (1149 m^3) and that between existing and FWP is ~16,000 yd^3 (12,233 m^3). In summary, the model predicted that sedimentation in the outer channel increases from approximately 95,000 yd^3/year (72,633 m^3/year) for the FWOP to approximately 214,000 yd^3/year (163,615 m^3/year) for the FWP scenario, approximately 2.25 times higher. This is primarily due to that fact that the FWP has a deeper and longer channel comparted to FWOP.

Table 5.1: Predicted sedimentation volumes

Scenario	Sedimentation Volume			
	Segment 1 [yd^3 (m^3)]	Segment 2 [yd^3 (m^3)]	Segment 3 [yd^3 (m^3)]	Total [yd^3 (m^3)]
Existing	76,000 (58,000)	3,900 (3,000)	100 (77)	80,000 (61,000)
FWOP	78,900 (60,000)	14,300 (11,000)	1,600 (1,200)	94,800 (72,000)
FWP	145,400 (111,000)	52,300 (40,000)	16,300 (12,000)	214,000 (164,000)

6. Modeling Assessment of Beach Nourishment, Offshore Berms and Offshore Dredged Material Disposal Area (ODMDS)

6.1 Model Scenarios

Three FWP scenarios were evaluated to examine the effect of the beach nourishment, offshore berms and ODMDS on channel sedimentation. (Figure 6.1). The ODMDS geometry was obtained from a Delft3D model by Freese & Nichol's. The model runs were done for 2011. The scenarios are as follows:

1. Beach nourishment and offshore berms (fixed bed)
2. Beach nourishment, offshore berms and ODMDS (fixed bed)
3. Beach nourishment, offshore berms and ODMDS (mobile bed)

For the fixed bed scenario, the only available sediment is from the beach nourishment, offshore berms and ODMDS such that their isolated effect can be examined. For the mobile bed scenario, the bed sediment layer is added in addition to the beach nourishment, offshore berms and ODMDS to examine their combined effect.

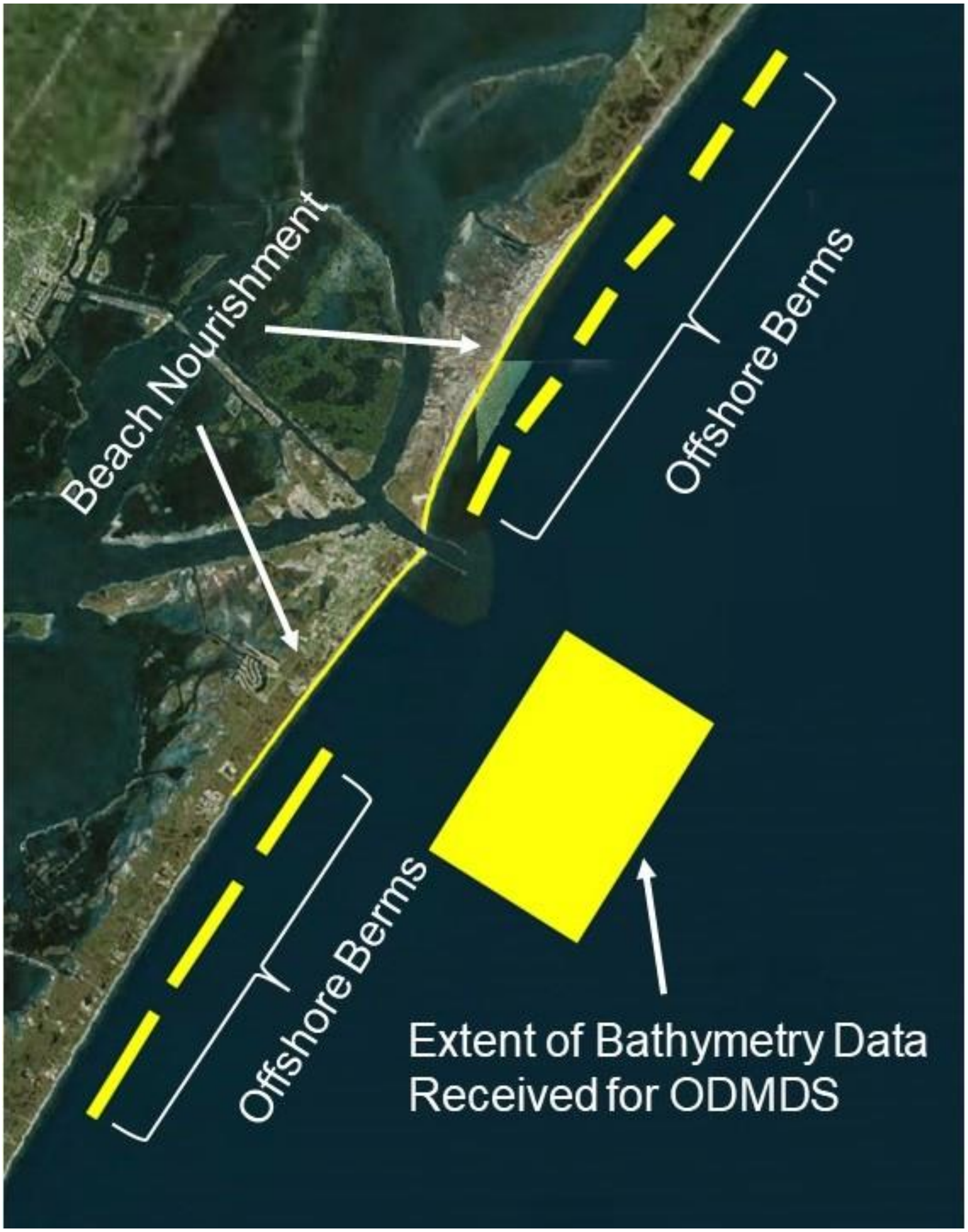


Figure 6.1: Location of the beach nourishment, offshore berms and the extend of data received from Freese and Nichol's for the ODMDS.

6.2 Impact Assessment

6.2.1 Contribution of Beach Nourishment and Offshore berms to Channel Sedimentation

Simulation results from the beach nourishment and offshore berms over fixed bed are shown in Figure 6.3. The model runs show that little to no sediment from the beach nourishment and offshore berms settled in the channel. The volume of sedimentation in segments 1, 2, and 3 (Figure 5.7) from the model scenario with beach nourishment and offshore berms are shown in Table 6.1. Predicted total sedimentation is less than 600 yd^3 (459 m^3) suggesting that the beach nourishment and offshore berms make small contributions to channel sedimentation compared to the overall sedimentation.

Table 6.1: Sedimentation in the channel due to beach nourishment and offshore berms

Scenario	Sedimentation Volume		
	Segment 1 [yd^3 (m^3)]	Segment 2 [yd^3 (m^3)]	Segment 3 [yd^3 (m^3)]
Beach Nourishment + Offshore berms	480 (367)	180 (138)	0

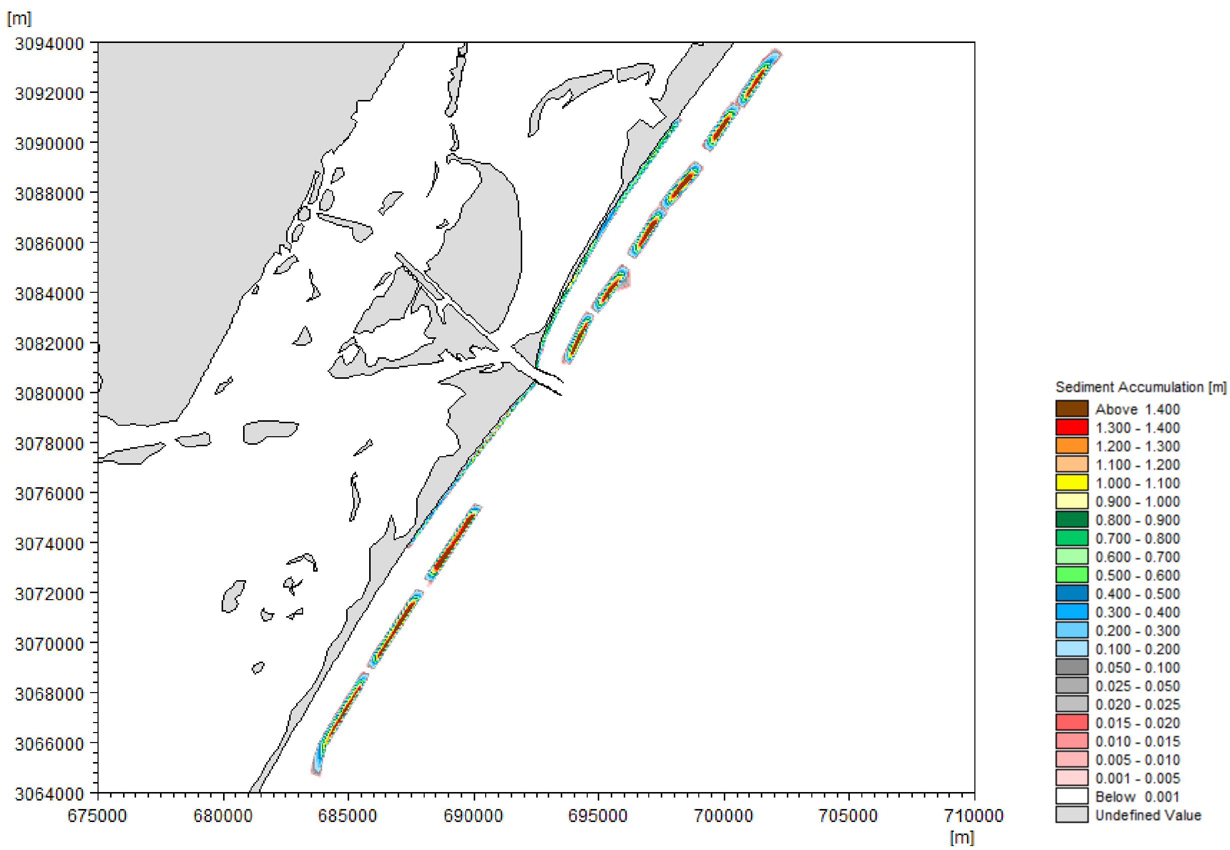


Figure 6.2: Distribution of settled sediment thickness from the beach nourishment and offshore berms over the fixed bed at the beginning of the model run

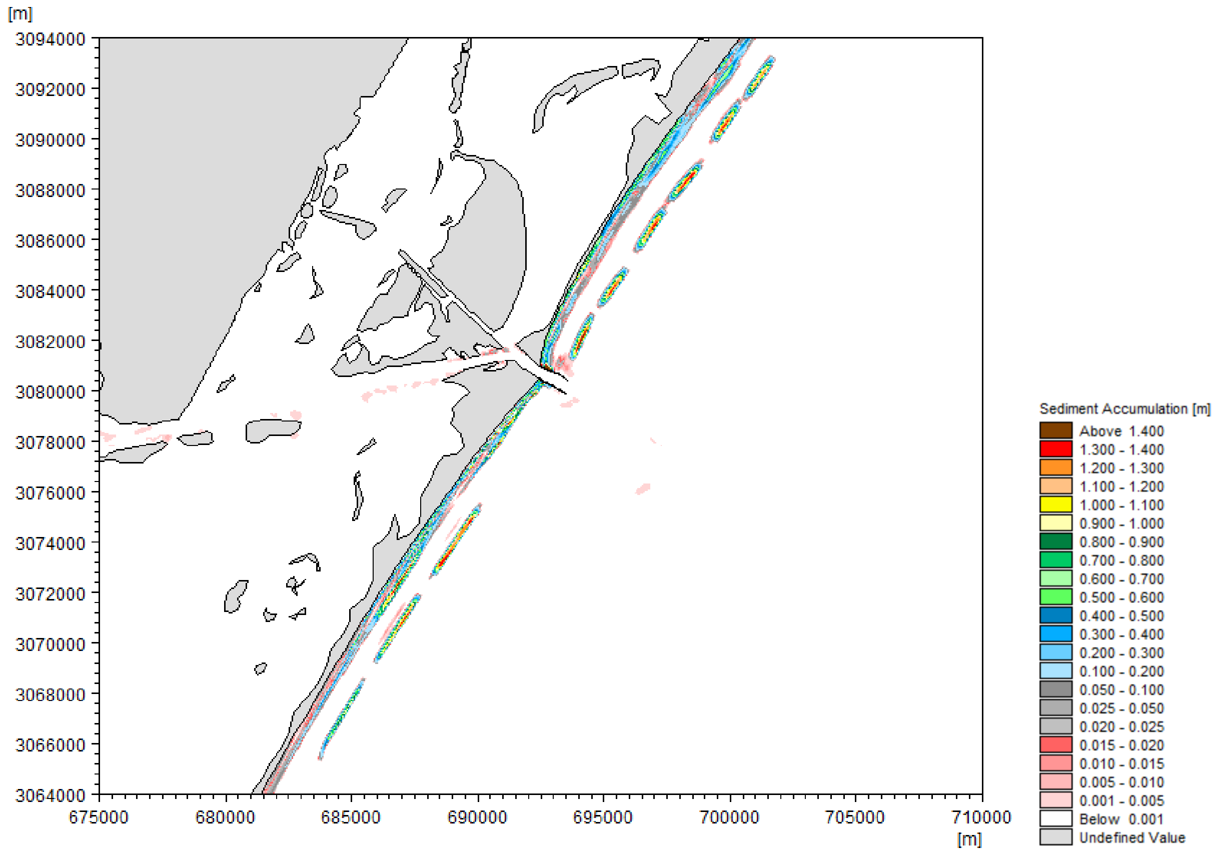


Figure 6.3: Distribution of settled sediment thickness from the beach nourishment and offshore berms over the fixed bed at the end of the model run

6.2.2 Contribution of the ODMDS Sediment to Channel Sedimentation

Scenarios 1 and 2 described in section 6.1 were used to evaluate the potential contribution from the ODMDS sediment to channel sedimentation. Table 6.2 shows the sedimentation calculated in the segments show in Figure 5.7. The predicted maximum increase in sedimentation due to the ODMDS is approximately 1,200 yd^3 (917 m^3). The increase in segments 2 and 3 are less than 500 yd^3 (382 m^3). It is concluded that contribution from the ODMDS sediment to channel sedimentation is small in comparison with the overall sedimentation.

Table 6.2: Sedimentation in the channel with and without ODMDS

Scenarios	Sedimentation Volume		
	Segment 1 [yd^3 (m^3)]	Segment 2 [yd^3 (m^3)]	Segment 3 [yd^3 (m^3)]
with ODMDS	1,840 (1407)	870 (665)	900 (688)
without ODMDS	680 (520)	530 (405)	780 (596)

6.2.3 Impact of the ODMDS Mound on Channel Sedimentation

Table 6.3 provides predicted sedimentation volumes in the outer channel for four different scenarios including with and without the ODMDS over fixed and mobile beds. Beach nourishment and offshore berms were present in all four scenarios. For the scenarios with fixed bed, the maximum increase in sedimentation occurs in Segment 1 and is less than 1,900 yd^3 (1,453 m^3). This confirms that the ODMDS direct impact on channel sedimentation is small compared to the overall sedimentation. On the other hand, in the case of mobile bed the increase happens in Segment 2 and is approximately 72,000 yd^3 (55,048 m^3). Note that Segment 2 is adjacent to the ODMDS mound. The relatively large increase in sedimentation in Segment 2, in the mobile bed run indicates that the ODMDS has an indirect impact on sedimentation through changing the hydrodynamics in the channel as discussed below.

Table 6.3: Sedimentation in the channel due to the presence of the ODMDS

Scenario	Sedimentation Volume			
	Segment 1 [yd^3 (m^3)]	Segment 2 [yd^3 (m^3)]	Segment 3 [yd^3 (m^3)]	Total [yd^3 (m^3)]
w/ ODMDS (Fixed bed)	1,840 (1407)	870 (665)	900 (688)	3,610 (2,760)
w/o ODMDS (Fixed bed)	680 (520)	530 (405)	780 (596)	1,990 (1,522)
w/ ODMDS (Mobile bed)	193,800 (148,000)	124,600 (95,000)	23,900 (18,000)	342,300 (262,000)
w/o ODMDS (Mobile bed)	145,400 (111,000)	52,300 (40,000)	16,300 (12,000)	214,000 (164,000)

To assess the change in hydrodynamics between the scenarios with and without ODMDS, current speeds from 3 points along the channel were extracted (Figure 6.4). Point 1 close to the entrance between the two jetties. Point 2 is further offshore close to the end of the existing channel and Point 3 is in the middle of Segment 2, which is where the highest increase in sedimentation was observed with the ODMDS.

Current roses representing “direction to” for the above 3 points are shown in Figure 6.5, Figure 6.6 and Figure 6.7. At Point1 (Figure 6.5), the flow direction in the run with ODMDS has a higher frequency in the 110 degrees direction and features higher velocities in 110 to 130 degrees directions (i.e., along the channel axis). Although the velocity field at Points 2 and 3 is governed by cross-channel tidal currents, a similar trend as in Point 1 is observed showing stronger along-the-channel velocity component under with-ODMDS conditions.

The presence of the ODMDS adjacent to the channel brings small but important changes to the hydrodynamics of ebb currents creating more channelized flow at a slightly higher velocity that can move more sediment further offshore along the channel. Figure 6.8 shows the comparison of velocity field between with and without the ODMDS mound conditions for an ebb event when the above-mentioned changes in hydrodynamics of the ebb flow is observed. For the scenario without the ODMDS, the velocity plume does not reach as far down the channel. In summary, the model predicted that sedimentation in the outer channel under FWP conditions increases from approximately 214,000 yd^3/year (164,000 m^3) in the absence of the ODMDS mound to approximately 342,000 yd^3/year (262,000 m^3) (approximately 1.6 times greater) when the ODMDS mound is present.

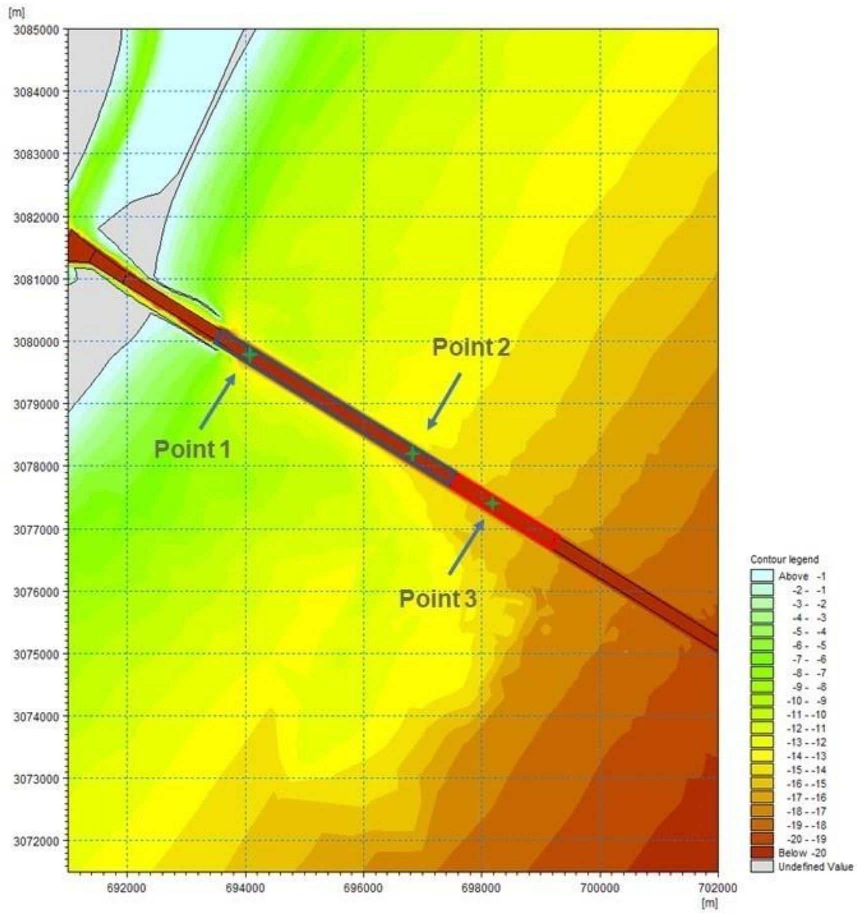


Figure 6.4: Locations used to investigate the change in hydrodynamics due to the ODMDS

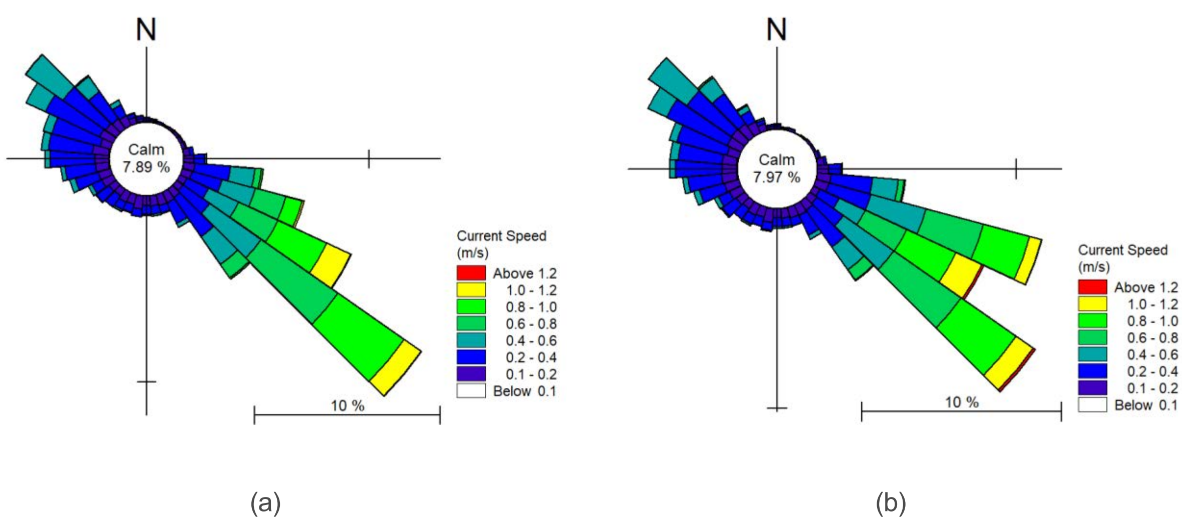
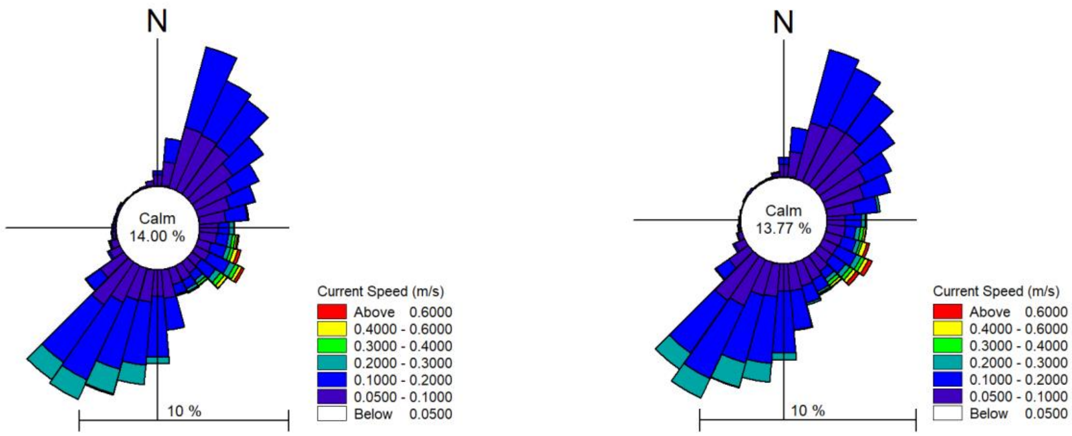
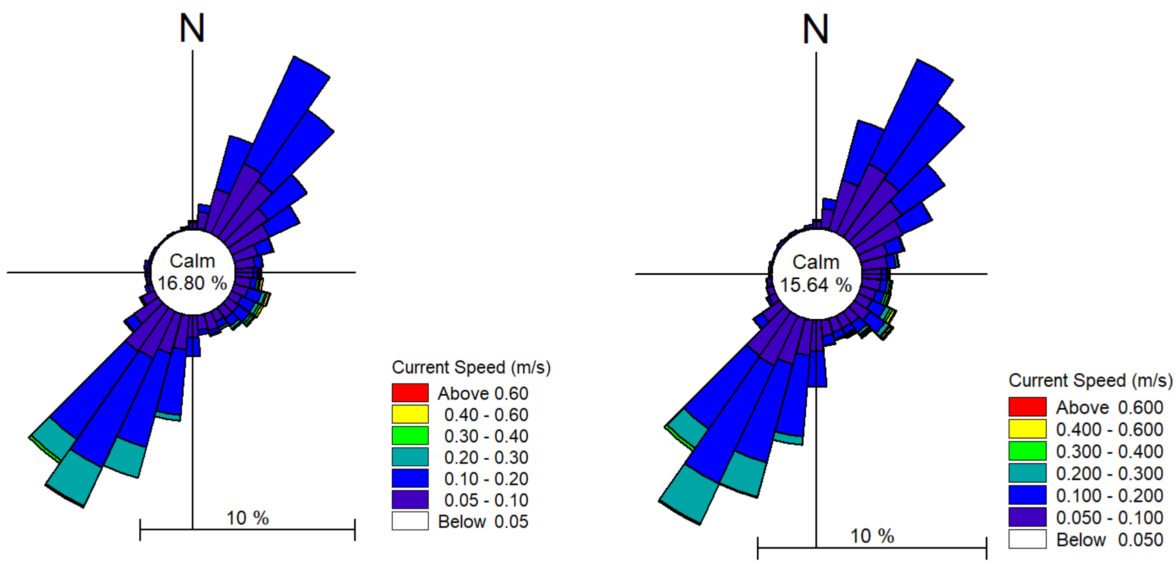


Figure 6.5: Current rose plots at point 1 for scenario (a) without ODMDS and (b) with ODMDS



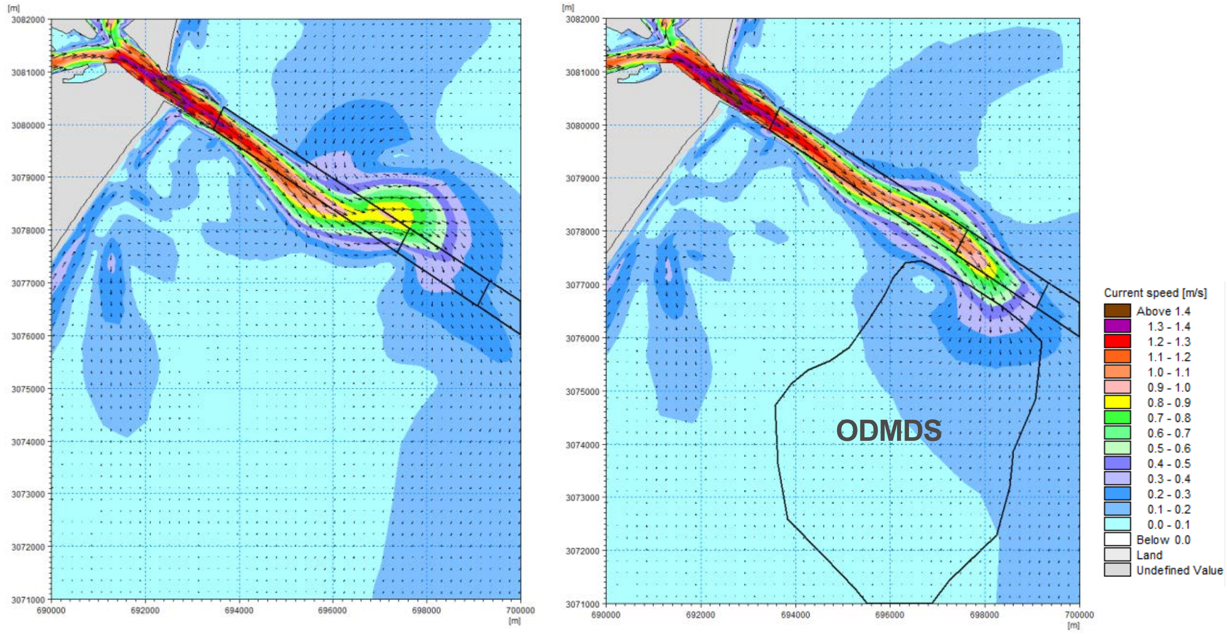
(a) (b)

Figure 6.6: Current rose plots at point 2 for scenario (a) without ODMDS and (b) with ODMDS



(a) (b)

Figure 6.7: Current rose plots at point 3 for scenario (a) without ODMDS and (b) with ODMDS



(a) (b)

Figure 6.8: Velocity field during typical ebb tide for scenario (a) without the ODMDS and (b) with the ODMDS mound

6.2.4 Impact of Hurricanes on Sedimentation in the Outer Channel

The impact of hurricane on channel sedimentation was assessed by conducting one-month model runs using hurricane Harvey. Due to data availability, 2020 HYCOM data was used for the tidal boundaries while the wind and wave conditions were replaced with conditions during Hurricane Harvey (thus providing indicative results). FWP scenarios including beach nourishment, offshore berms and the ODMDS over both fixed and mobile beds were simulated and compared with the existing conditions.

Predicted sedimentation volumes in Segments 1, 2 and 3 are presented in Table 6.4. The fixed bed scenario reflects the sedimentation coming only from the offshore berms, beach nourishment and the ODMDS. Comparing the existing to the FWP mobile bed scenarios, the predicted total sedimentation increased significantly from approximately 675,000 yd^3 (516,000 m^3) for existing conditions to 1,574,000 yd^3 (1,203,000 m^3) for FWP conditions, which is about 2.3 times higher similar to the increase under annual wave conditions (Table 5.1). Volumes calculated from the USACE surveys before and after hurricane Harvey indicated that the sedimentation in Segment 1 was approximately 1,000,000 yd^3 (765,000 m^3). The difference in the model predicted sedimentation (i.e., 675,000 yd^3) and that from the surveys can be mainly attributed to the fact that the model used 2020 HYCOM currents instead of the 2017 currents due lack of HYCOM data for 2017.

Table 6.4: Sedimentation in the outer channel due to hurricane

Scenario	Sedimentation Volume			
	Segment 1 [yd^3 (m^3)]	Segment 2 [yd^3 (m^3)]	Segment 3 [yd^3 (m^3)]	Total [yd^3 (m^3)]
Existing	610,300 (467,000)	49,000 (37,000)	16,100 (12,000)	610,300 (467,000)
FWP – fixed bed	169,200 (129,000)	52,200 (40,000)	16,100 (12,000)	169,200 (129,000)
FWP – mobile bed	992,800 (759,000)	379,100 (290,000)	201,900 (154,000)	992,800 (759,000)

The above results indicate that individual hurricane events could result in sedimentation volumes in the outer channel that are several times higher than the average annual sedimentation. However, it is noted that Hurricane Harvey was a rare powerful storm that impacted the Texas coastline. The impact of other hurricanes on sedimentation could be significantly different depending on individual hurricane's track and intensity.

Sedimentation in the inner channel was evaluated similarly and the predicted volumes are shown in **Error! Reference source not found.**. The location of segments 4, 5 and 6 are shown in Figure 6.9. The extents of these segments are analogous to the reach extents of the National Channel Framework, but the transverse extent is modified to include the shoulders. The predicted sedimentation volumes indicate that the total volume increase between existing conditions and FWP due to Hurricane Harvey is about ~3%. The most increase in sedimentation happens in Segment 4 at ~11%, which is consistent with the results of section 5.2, which predicted an increase of ~10% in shoaling rate. The volume in segment 6 is lower for the FWP condition by ~15%. The eastern portion of segment 6 which is adjacent to the terminals is part of the deeper outer channel which allows higher volume of water coming in from GOM likely resulting in removal of the local sediment.

Table 6.5: Sedimentation in the inner channel due to hurricane

Scenarios	Sedimentation Volume			
	Segment 4 [yd^3 (m^3)]	Segment 5 [yd^3 (m^3)]	Segment 6 [yd^3 (m^3)]	Total [yd^3 (m^3)]
Existing	66,100 (51,000)	470,200 (359,000)	46,400 (35,000)	66,100 (51,000)
FWP – mobile bed	73,400 (56,000)	486,000 (372,000)	39,400 (30,000)	73,400 (56,000)

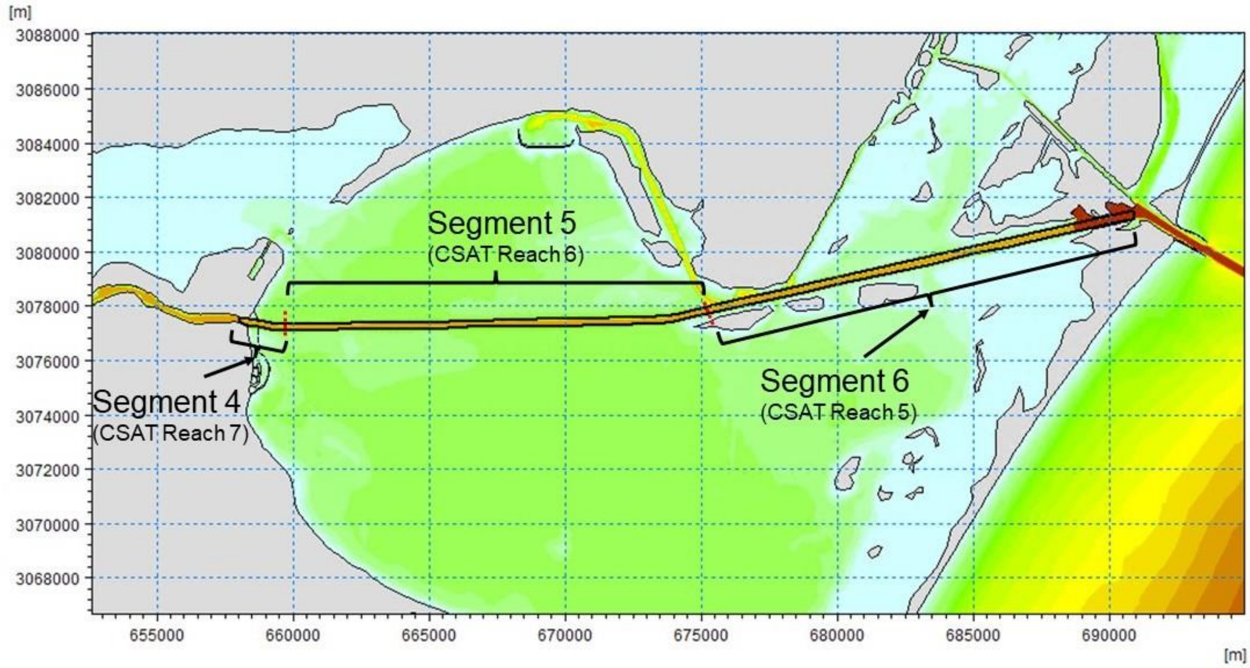


Figure 6.9: Segments for sediment volume calculation in the Corpus Christi Bay

7. Stability of Offshore Berms and Beach Nourishment

This section assesses the stability of the designed offshore berm and beach nourishment using 1D cross-shore transport numerical models. Waves from the Gulf of Mexico were used as the driving force to determine if the placed sediment will stay in place, move onshore to build the beach (offshore berms), overwash inland (beach nourishment), and/or be lost offshore to deeper waters. Long-term (annual) and short term (storm) wave conditions are applied in the analysis. The potential benefits of the offshore berm to reduced beach erosion was also assessed.

7.1 Numerical Models

Two numerical models were used to assess the stability of the offshore berms and beach nourishment: XBeach (https://oss.deltares.nl/web/xbeach/) developed by Deltares and CSHORE (https://usace.contentdm.oclc.org/digital/collection/p266001coll1/id/4558/) developed by USACE.

XBeach is a numerical model for wave propagation, long waves and mean flow, sediment transport and morphological changes of the nearshore area, beaches, dunes and back barrier during storms. It is a public-domain model that has been developed with major funding from the USACE, Rijkswaterstaat and the EU, supported by a consortium of UNESCO-IHE, Deltares, Delft University of Technology and the University of Miami. It is currently the leading-edge model for simulation of beach and dune erosion under severe storm events.

In this study we have employed the CSHORE model along with XBeach to bring added confidence in the model results as topographic and bathymetric data for calibration is limited. CSHORE is a simple and phase-averaged 1-D nearshore model for predicting hydrodynamics and profile change from depth of closure into the swash zone developed by the USACE.

7.2 Beach Profile

The unnourished beach profile was extracted from the Continuously Updated Digital Elevation Model (CUDEM) from San Jose Island as shown in Figure 7.1. The profile extends seaward to an offshore elevation of -65 ft NAVD88. The beach nourishment and offshore berm was added to the profile using placement information sent via CAD files (“BU_MOD1_s-ft.dwg” and “Beach_Dune Fill Features_s-ft_.dwg”) by Freese and Nichols on October 28, 2021.

Figure 7.2 shows the design profile used for the modeling assessment. In the design profile, the offshore berm is placed between the -28 and -31 ft NAVD88 (-8.5 and -9.5 m NAVD88) contours with a berm crest elevation of -25 ft NAV88 (-7.6 m NAVD88). The berm crest width is 900 ft (274 m) on San Jose Island. Side slopes of 1V:24H are used. On Mustang Island, the characteristics of the offshore berm are similar, but the berm crest width is slightly narrower at 800 ft (244 m). On the beach, the nourishment is placed as a dune with crest elevation of 10 ft NAVD88 (3.1 m NAVD88) and width of 75 ft (23 m). Side slopes of 1V:3H are used on the dune. Fronting the dune, an approximately 200 ft (61 m) beach is placed with at an elevation of 6 ft NAVD88 (1.8 m NAVD88). The beach slopes down to the existing profile at a slope of 1V:50H.

Two versions of the design profile were used in the modeling assessment, one that includes the offshore berm and one without the offshore berm in order the determine the potential impact of the offshore berm on the stability of the beach nourishment.

A median (D_{50}) sediment size of 0.14 mm was used in both models.

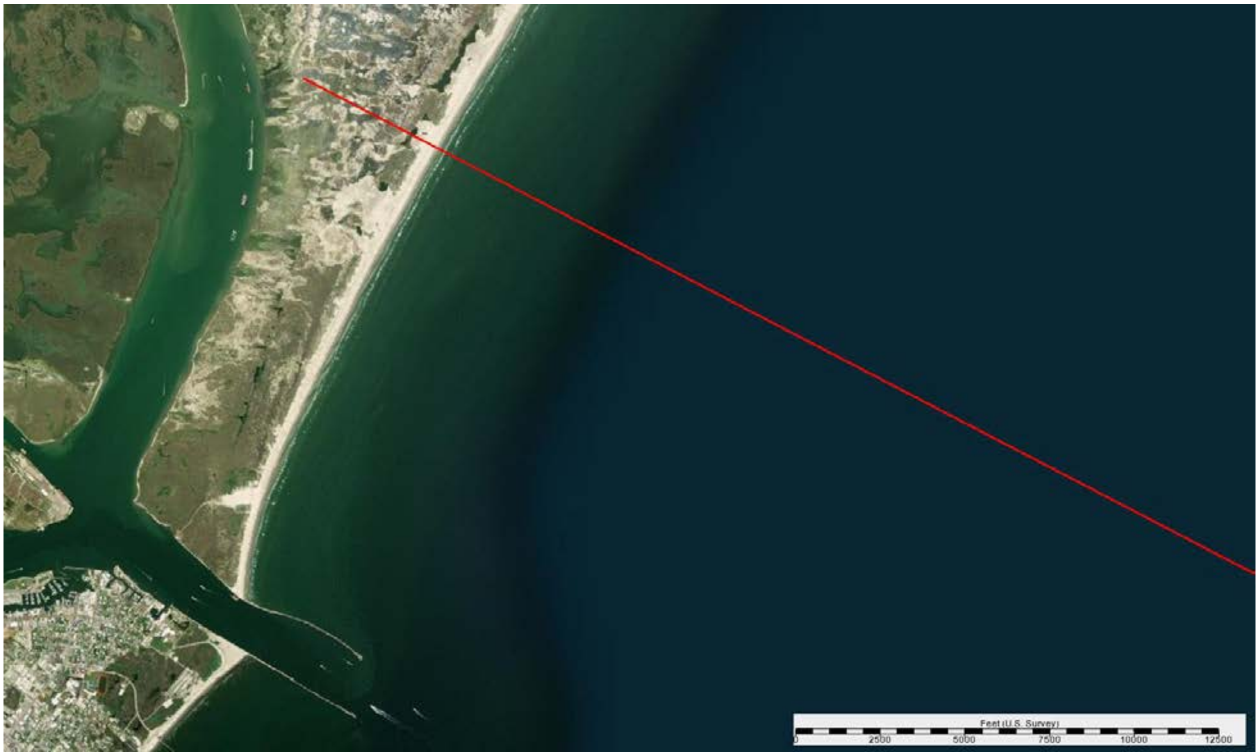


Figure 7.1: Location of design profile

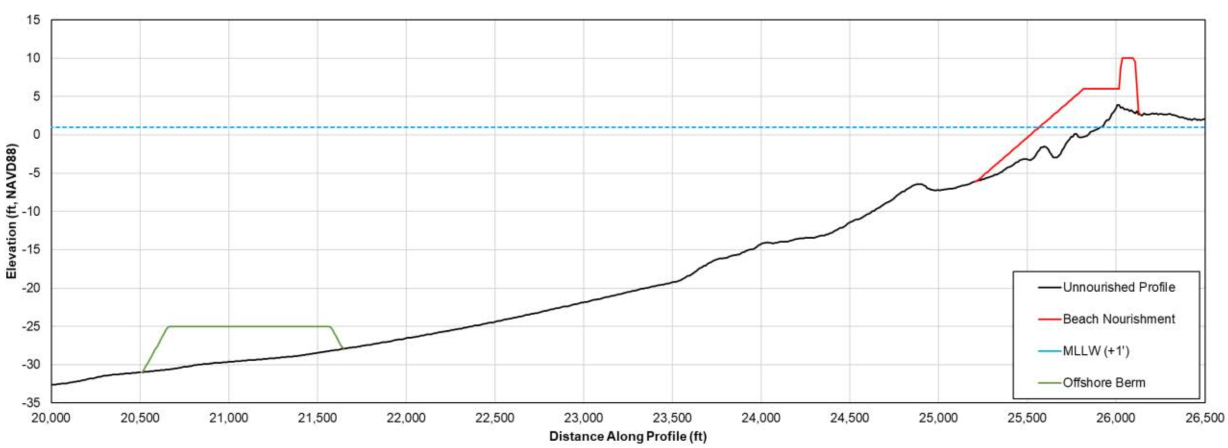


Figure 7.2: Design profile used for the modeling assessment typical on San Jose Island and Mustang Island

7.3 Modeling Assessment

7.3.1 Profile Response to Long Term Wave Conditions

Figure 7.3 shows the average annual wave energy density from WIS Station 73040 from 1980 to 2019. The year 2016 was chosen to represent an average wave energy year (approximately 7 million kJ/m^2) and 2017 was chosen to represent an exceptionally high wave energy year (approximately 11 million kJ/m^2, partly due to occurrence of Hurricane Harvey in August 2017). Waves from WIS 73032 and water levels from Bob Hall Pier were used as hydrodynamic forcing.

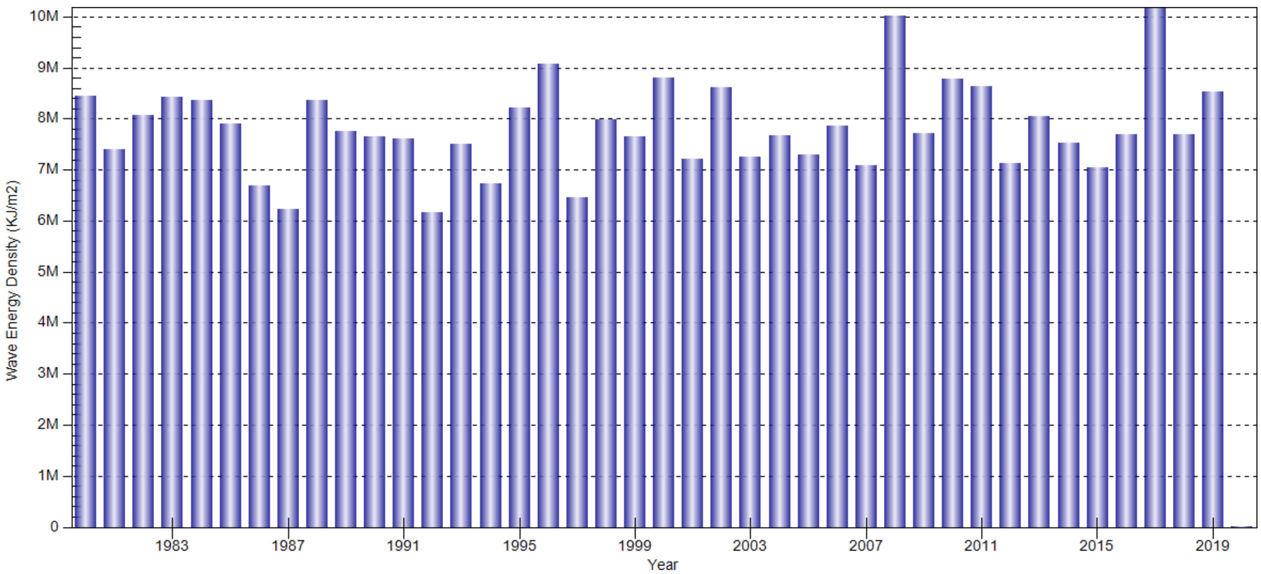


Figure 7.3: Annual wave energy density from WIS Station 73040 from 1980-2019

Figure 7.4 and Figure 7.5 show the evolution of the design profile under annual wave conditions in 2016 and 2017, respectively, as predicted by the XBeach and CSHORE models. Results shown in with a solid line include the offshore berm while the dashed-line results do not include the berm. The unnourished profile is shown for reference.

In the 2016 simulation, both XBeach and CSHORE predict erosion and steepening of the nourished beach slope. The eroded material is transported offshore to a depth of -6.5 to -19.5 ft NAVD88 (-2 to -5.9 m NAVD88). The XBeach model predicted more erosion and transported the eroded material farther offshore. In both models, the dune is stable and predicted profile changes with and without the offshore berm are identical, indicating that the offshore berm has little influence on beach stability. Slight erosion on the landward side and accretion on the seaward side of the offshore berm is predicted by XBeach, however the change in berm volume is negligible. CSHORE does not predict any movement of the berm.

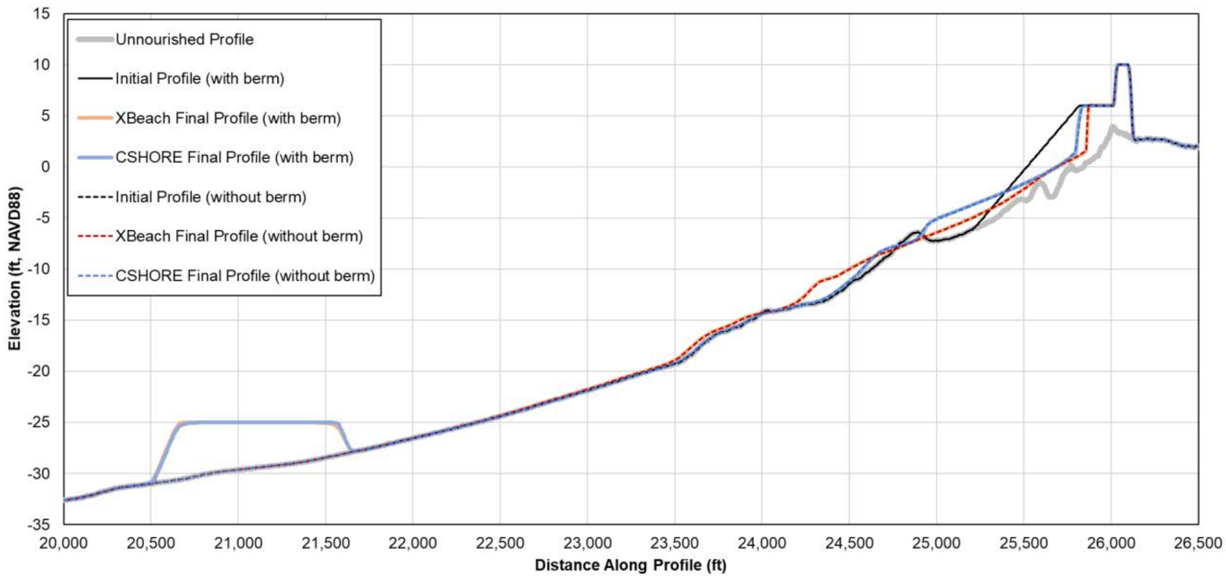


Figure 7.4: Modeled profile response to 2016 wave conditions from WIS Station 73040

In 2017, overtopping is predicted by XBeach as a result of Hurricane Harvey (August 2017) and the dune crest elevation is reduced approximately 1.5 ft (0.5 m). The corresponding over-washing deposits the sediment inshore behind the dune. CSHORE does not predict dune crest erosion and the results are similar to the 2016 predictions with a small increase in beach erosion. As in the 2016 simulation, the offshore berm is stable, and the presence of berm does not seem to improve the stability of the nourishment.

Using the USACE Sediment Mobility Tool (https://navigation.usace.army.mil/SEM/SedimentMobility), the mean depth of closure in the area was estimated to be 28 ft (8.5 m) with range of 19 to 48 ft (5.8 to 15 m), depending on the method of calculation. As the offshore berm is placed near the limit of the depth of closure or deeper, and as confirmed from the annual runs, it is unlikely that the offshore berm will move substantially at it's designed placement depth. Both models predict little to no change in the profile beyond the -19.5 ft NAVD88 (-5.9 m NAVD88) contour.

As most of the beach nourishment is eroded and placed offshore between -6.5 to -19.5 m NAVD88 (-2 to -5.9 m NAVD88), it is expected that the material will move back onshore over time during favorable/accretional wave conditions (see next section). However, beach recovery processes are not well simulated by the XBeach and CSHORE models. To date, simulation of beach recovery has remained a challenge for all profile change models.

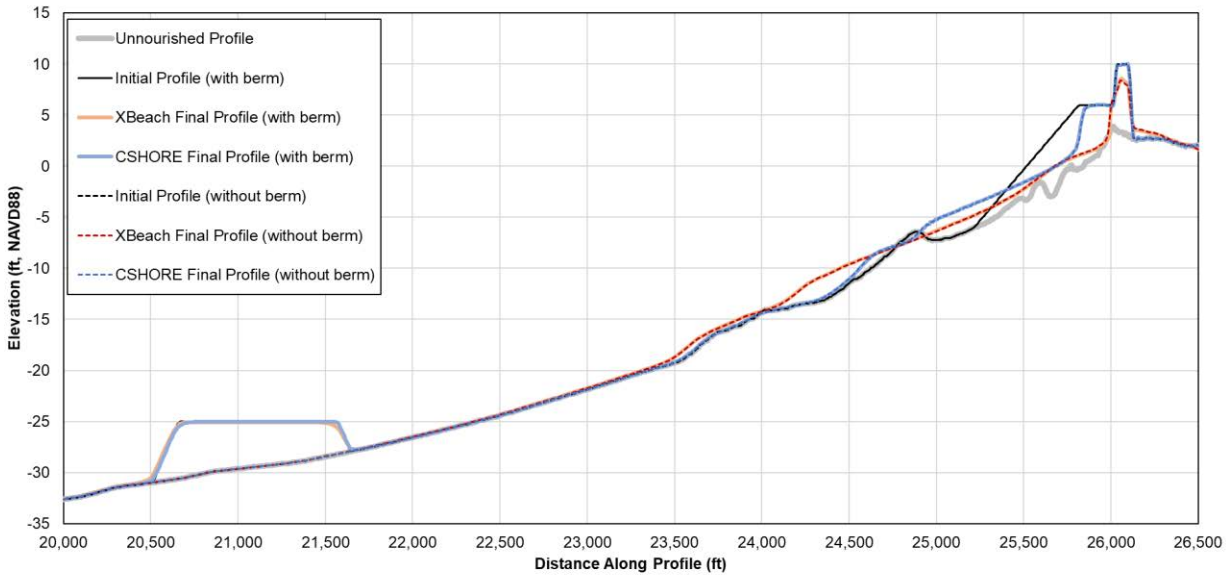


Figure 7.5: Modeled profile response to 2017 wave conditions from WIS Station 73040

7.3.2 Short-term Profile Response to Individual Storm Conditions

Table 7.1 summarizes the storms selected to assess the stability of the offshore berms and beach nourishment in response to hurricane events. Hurricane Allen and Hurricane Harvey were chosen as two historically significant storms. Hurricane Hanna and Delta were selected as two storms in recent history that are less extreme but feature characteristics such as higher water level (Hurricane Hanna) and long wave period (Hurricane Delta). Measured waves from the National Data Buoy Center (NDBC) Buoy 42020 were used that provides hourly data at depth of 276 ft (84 m). Compared to the hindcast waves, the buoy waves capture the peaks of the storms more accurately, therefore the buoy waves were used for the storm simulations. Water levels from Bob Hall Pier were used as hydrodynamic forcing for all storms except for Hurricane Allen as the Bob Hall Pier data starts in 1983. Water levels for Hurricane Allen were obtained from an ADCIRC model of Hurricane Allen (Legacy USACE Texas Study, Save Point 28) obtained from the Coastal Hazard System (https://chs.erdc.dren.mil/Study).

Table 7.1: Storm conditions for offshore berm and beach nourishment stability assessment

Storm	Simulation Period	Maximum Values during Storm		
		Peak Significant Wave Height (H_{m0}, ft)	Peak Wave Period (T_p, s)	Peak Water Level at Bob Hall Pier (ft, NAVD88)
Hurricane Allen	1980/8/8 0:00 to 1980/8/12 0:00	22.7	14.7	5.6**
Hurricane Harvey	2017/8/24 0:00 to 2017/8/26 12:00	24.1	13.8	3.9
Hurricane Hanna	2020/7/25 0:00 to 2020/7/27 0:00	22.8	10.8	6.4

Storm	Simulation Period	Maximum Values during Storm		
		Peak Significant Wave Height (H_{m0}, ft)	Peak Wave Period (T_p, s)	Peak Water Level at Bob Hall Pier (ft, NAVD88)
Hurricane Delta	2020/10/8 12:00 to 2020/10/10 12:00	15.1	14.8	3.8

** Water levels for Hurricane Allen were obtained from an ADCIRC model of Hurricane Allen (Legacy USACE Texas Study, Save Point 28) obtained from the Coastal Hazard System

Figure 7.6 and Figure 7.7 show the evolution of the design profile during Hurricane Allen and Hurricane Harvey, respectively. These storms were particularly strong with large wave heights, periods, and long storm durations. In both storms, XBeach predicts overtopping and erosion of the entire dune, from 10 ft NAVD88 (3.1 m NAVD88) to an elevation of 1.5 ft NAVD88 (0.5 m NAVD88) after Hurricane Allen and 3 ft NAVD88 (0.9 m NAVD88) after Hurricane Harvey. In both simulations, the offshore berm was not impacted and is stable. In both cases, CSHORE does not predict significant dune erosion.

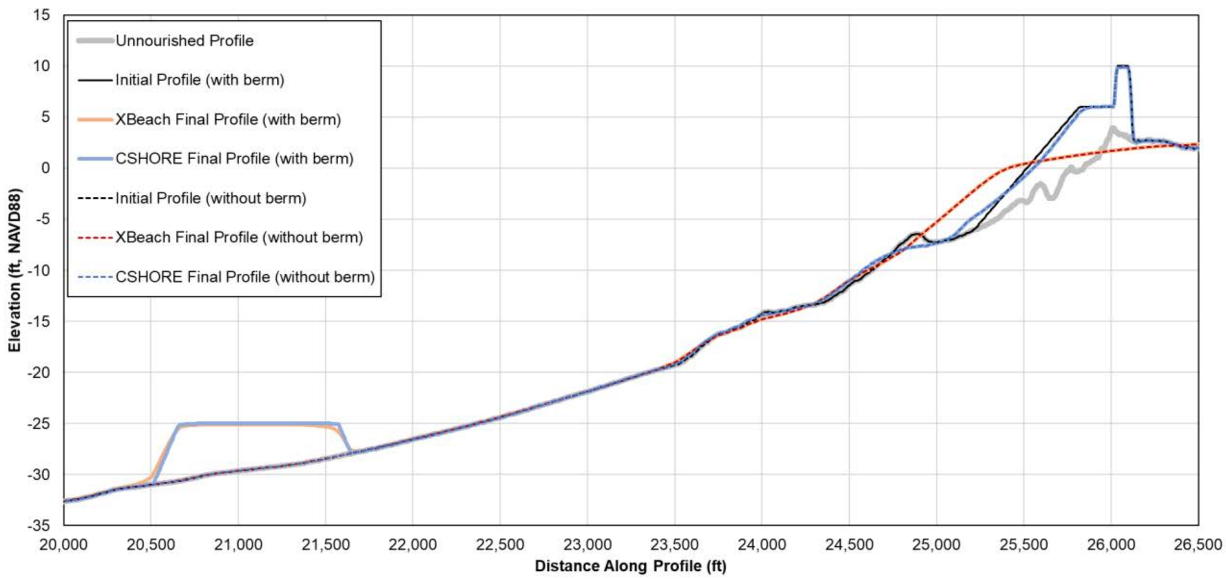


Figure 7.6: Modeled profile response to Hurricane Allen

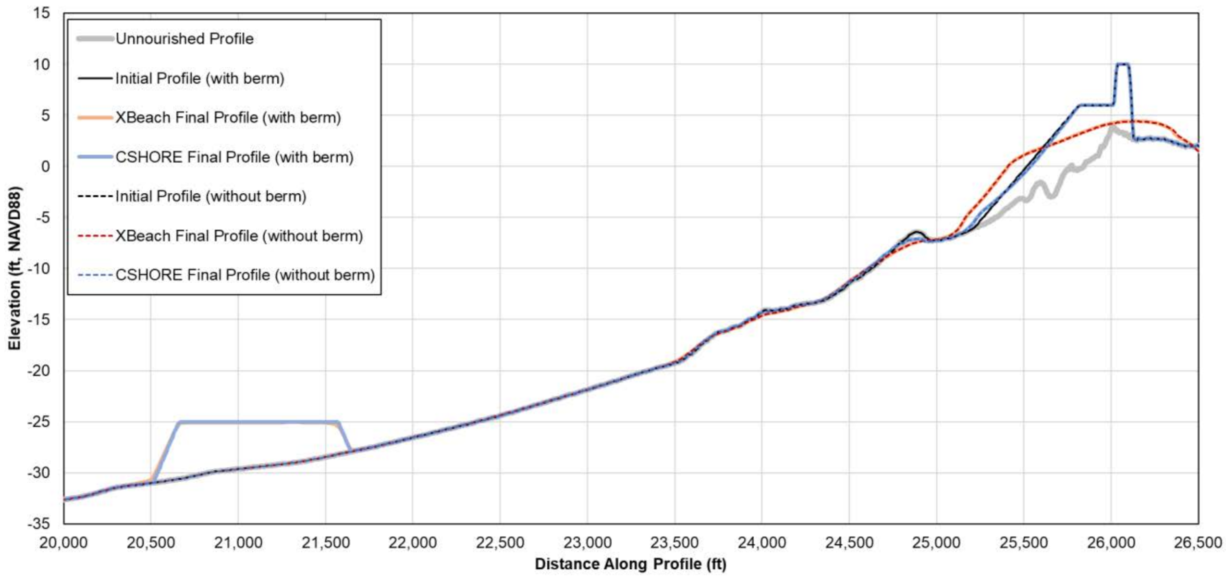


Figure 7.7: Modeled profile response to Hurricane Harvey

To support the beach erosion predicted by XBeach during Hurricane Harvey, dune crest elevation was obtained across the transect shown in Figure 7.8 from a 2016 LiDAR survey (pre-Hurricane Harvey) and 2018 USACE LiDAR survey (post-Hurricane Harvey). The satellite image in Figure 7.8 (from July 6, 2020) and Figure 7.9 (from August 28, 2017) show post-Hurricane Harvey overwash fans behind the beach approximately 3 miles (5 km) northeast from Aransas Pass.

Figure 7.10 shows that pre-Hurricane Harvey, the dune crest was generally above 9 ft NAVD88 (2.7 m NAVD88), up to approximately14 ft NAVD88 (4.3 m NAVD88). After Hurricane Harvey, breached areas have elevations as low as -3 ft NAVD88 (-0.9 m NAVD88). These surveyed elevations support predictions from XBeach during Hurricane Harvey where the dune crest elevation is lowered from 10 to 3 ft NAVD88 (3.1 to 0.9 m NAVD88). Both Figure 7.9 and Figure 7.10 indicate that the amount of erosion varied along the shoreline which can be influenced by the local profile morphology and particularly by the pre-hurricane dune crest elevation, presence of vegetation, and variations in beach sediment composition that were not included in the simulations.

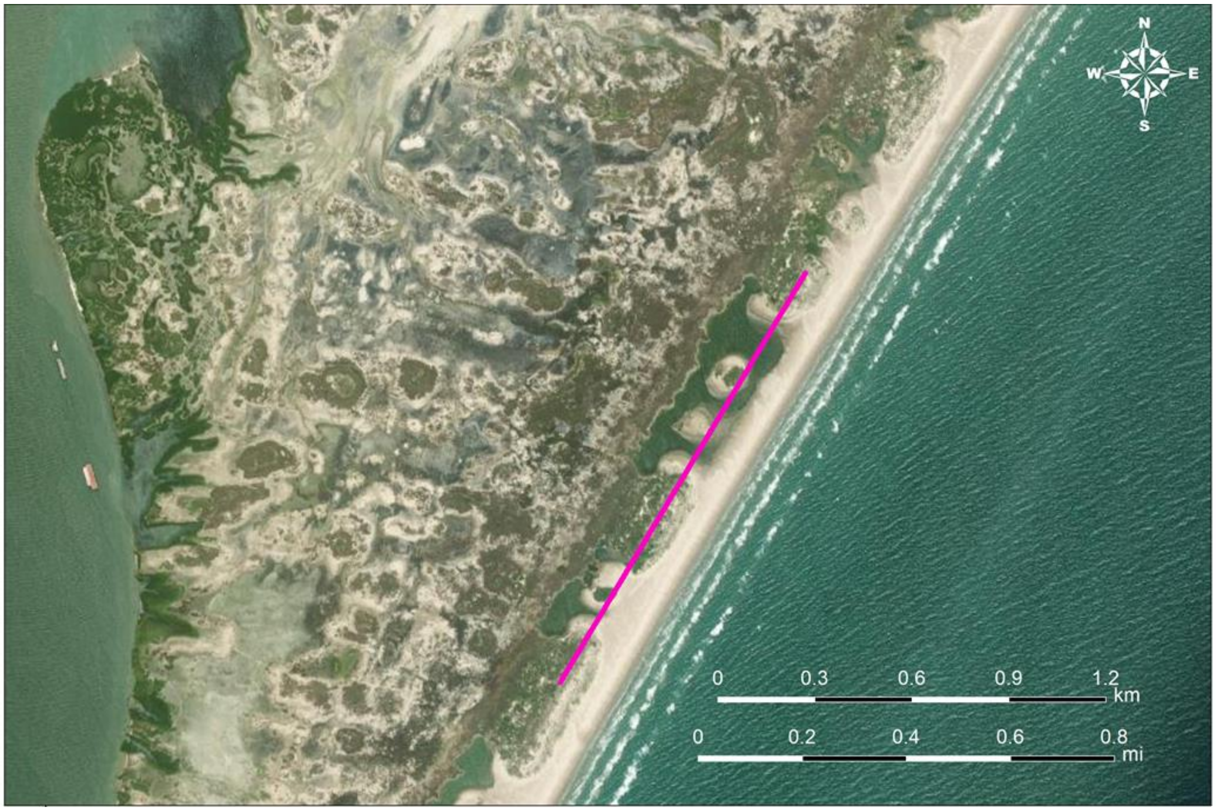


Figure 7.8: Transect location (pink) across the dune crest (satellite image dated July 6, 2020)

Figure 7.9: Satellite image from August 28, 2017 (post-Hurricane Harvey) from Google Earth

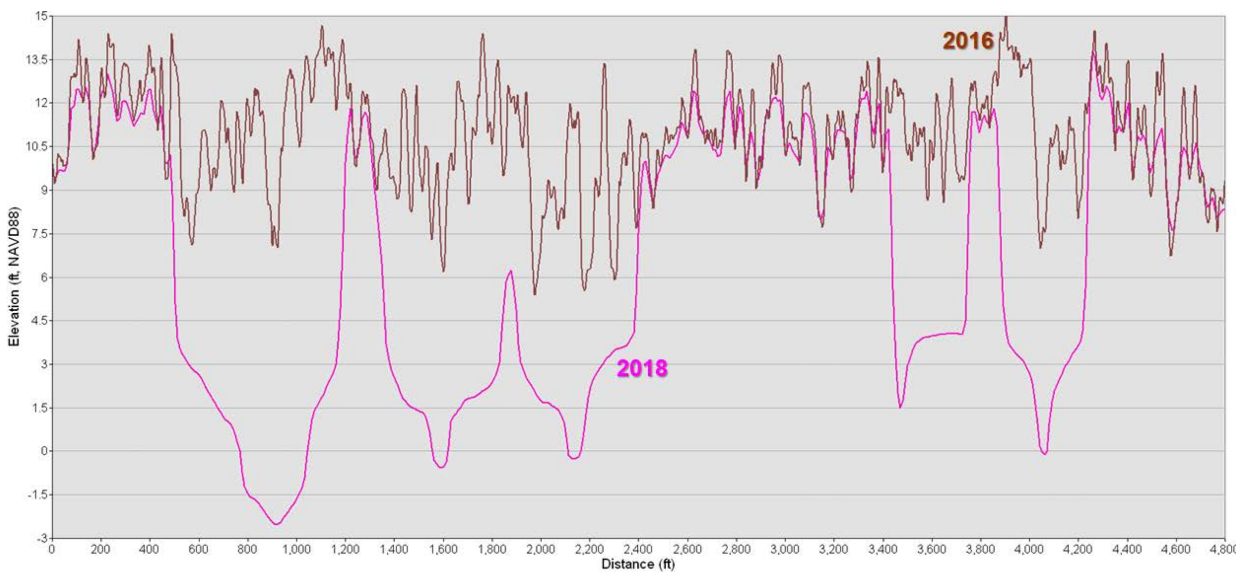


Figure 7.10: Pre- (2016) and post-Hurricane Harvey (2018) dune crest elevations

Figure 7.11 and Figure 7.12 show the evolution of the design profile during Hurricane Hanna and Hurricane Delta. These storms were not as strong as Hurricane Allen and Hurricane Harvey and had lower wave heights and/or periods. During Hurricane Hanna, XBeach predicts beach erosion with sediment moving to the lower part of the beach between 0 to -6.5 ft NAVD88 (0 to -2 m NAVD88). CSHORE does not predict significant erosion during Hurricane Hanna. Both models predict that the offshore berm is stable and unimpacted during the storm and that the berm does not improve beach stability.

During Hurricane Delta, a difference is observed in the XBeach predicted profiles with and without the offshore berm. The berm provides protection to the beach under the waves with long periods and relatively low surge. Waves with longer wave periods have a deeper wave base (maximum depth at which a wave causes significant water motion) and can be impacted by morphological features in deeper water, like the offshore berm. In larger storm events with long wave periods like Hurricane Allen, the waves and surge are large enough that the presence of the berm is not significant. Neither CSHORE nor XBeach predict any significant change in the offshore berm morphology.

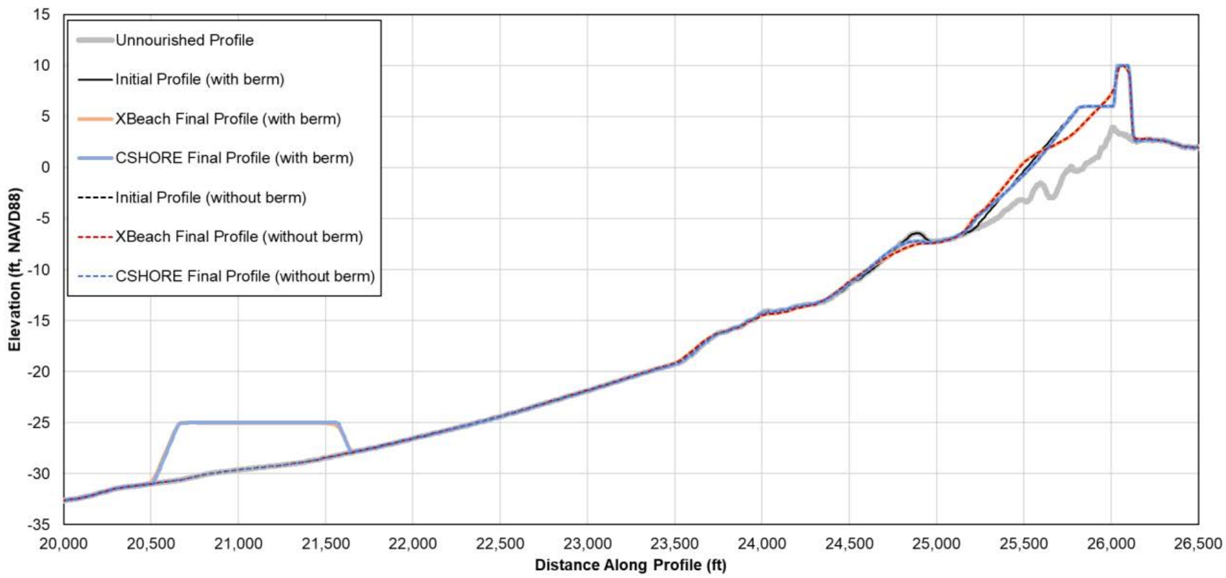


Figure 7.11: Modeled profile response to Hurricane Hanna

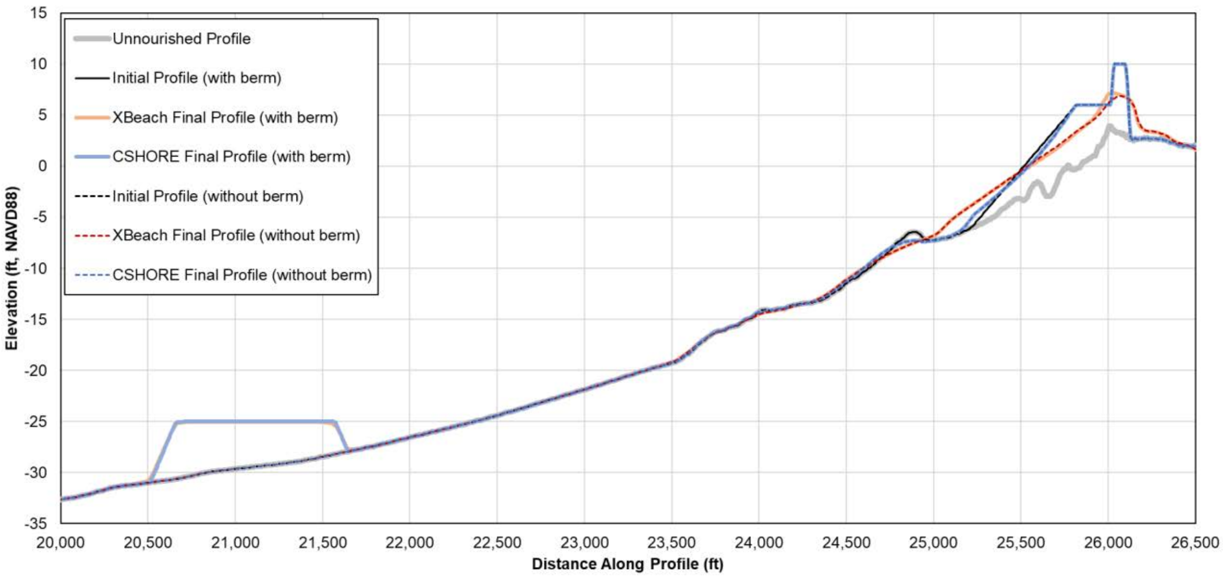


Figure 7.12: Modeled profile response to Hurricane Delta

8. Fate of Beach Nourishment

The fate of the placed beach nourishment was assessed using a sediment budget model developed by Baird. Cross-shore and longshore transport processes were incorporated in the model using XBeach (cross-shore) and Baird's COSMOS model (longshore) (Southgate and Nairn, 1993; Nairn and Southgate, 1993). The potential channel infilling volumes and the stability of the offshore berms were also assessed. The development of the model, calibration, and results are discussed in the follow section.

8.1 Development and Setup of the Sediment Budget Model

8.1.1 Representative Profiles and Model Domain

Four representative profiles are used to represent the model domain:

- Nourished profile with offshore berm
- Unnourished profile with offshore berm
- Nourished profile without offshore berm
- Unnourished profile without offshore berm (existing profile)

While the actual profiles along the domain can vary (i.e., between areas with and without offshore berms), these four profiles are used in combinations to approximate defining features of each area of the model domain. These approximations allow the sediment budget model to execute quickly as cross-shore and longshore transport rates are pre-computed for four profiles only. Figure 8.1 shows the cross-shore calculation grid for the sediment budget model. The cross-shore cells are numbered from 1 to 6 starting from the offshore moving onshore:

1. Offshore portion of the profile extending from the -65 ft NAVD88 (-20 m NAVD88) contour to approximately -35 ft NAVD88 (-11 m NAVD88); this area is assumed to be beyond the depth of closure and has minimal changes in elevation over time
2. Offshore area between -35 and -25 ft NAVD88 (-11 and -7.6 m NAVD88) where the offshore berm may be placed in profiles where the offshore berm exists
3. Nearshore area between -25 and -15 ft NAVD88 (-7.6 and -4.6 m NAVD88)
4. Nearshore area between -15 and -7 ft NAVD88 (-4.6 and -2.1 m NAVD88), toe of beach nourishment in profiles where beach nourishment exists
5. Beach area from -7 ft NAVD88 (-2.1 m NAVD88), toe of beach nourishment in profiles where beach nourishment exists to the backside of the dune
6. Backdune area where overwashed sediment may be deposited

A median (D_{50}) sediment size of 0.14 mm was used in the model for both existing and placed sediment.

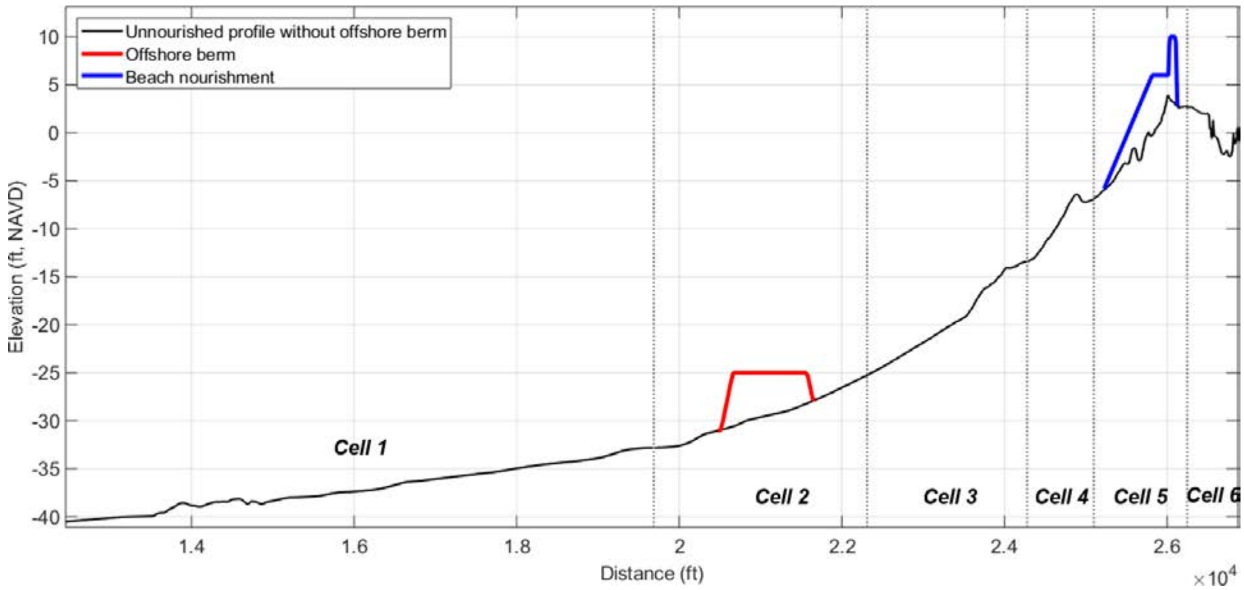


Figure 8.1: Cross-shore sections of the representative beach profile; profile with beach nourishment and offshore berm shown

In the alongshore direction, the sediment budget model is comprised of two separate domains: the Mustang Island domain extending 11 miles (18 km) southwest from the Aransas Pass south jetty and the San Jose Island domain which extends nine miles (15 km) northeast of the north jetty, as shown in Figure 8.2. The Mustang Island domain is comprised of 29 cells in the alongshore and six (as described above) cells in the cross-shore direction. The San Jose Island domain is comprised of 26 cells in the alongshore direction and 6 cells in the cross-shore direction.

For this modeling assessment, it is assumed that there is no exchange of sediment between the two model domains. In other words, the sediment budget model does not allow sediment to pass through the north boundary on the Mustang Island domain to the south boundary on the San Jose Island domain (i.e., boundaries adjacent to the navigation channel). Because of this assumption, the sediment volume accumulating in the first cells (offshore cell) along the north and south boundary of the Mustang Island and San Jose Island domain, respectively, are assumed to be trapped by the navigation channel. This assumption is consistent with a deep navigation channel and the corresponding predicted volume roughly represents the potential channel infilling volume under FWP conditions. However, this process was more accurately modeled by the assessment of channel sedimentation which was discussed in Section 6.2.

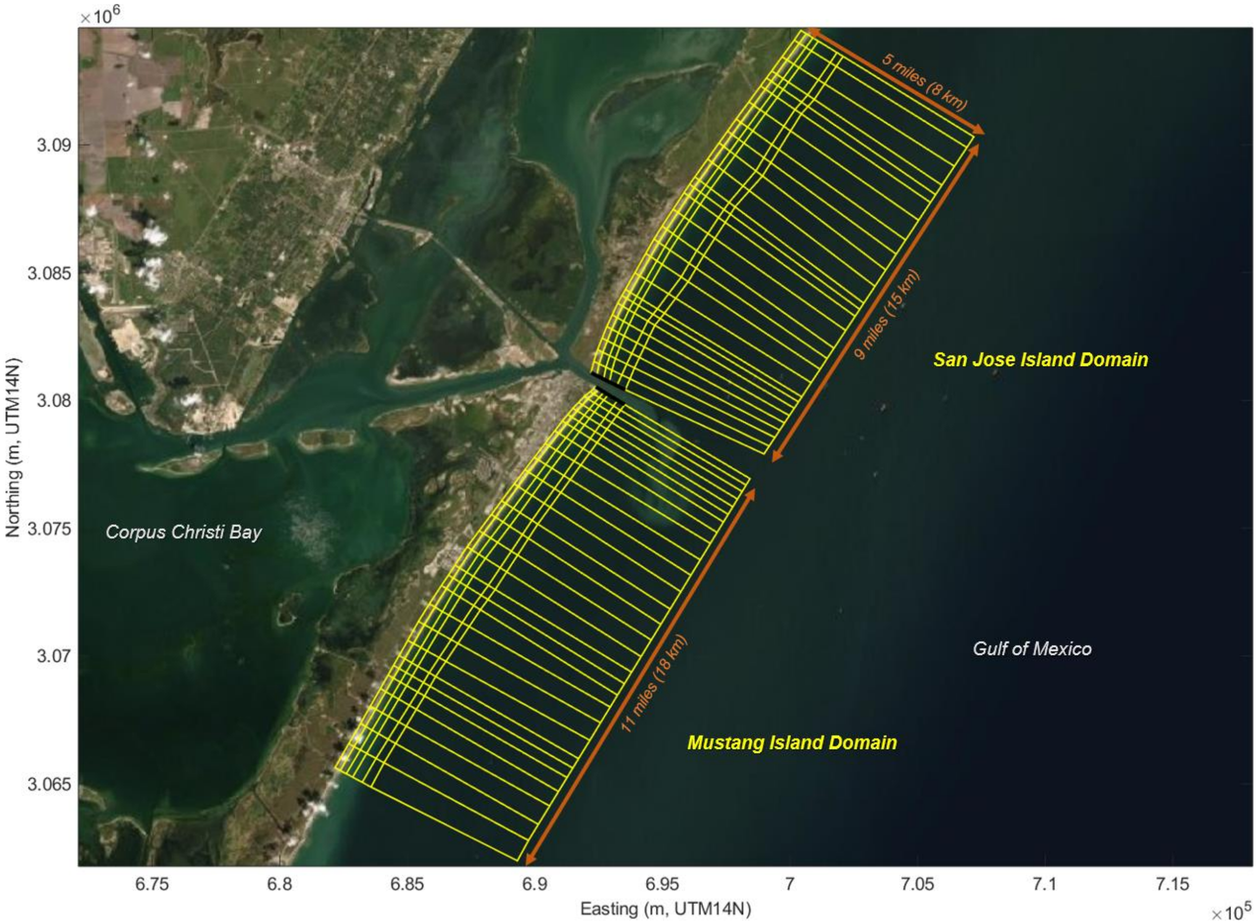


Figure 8.2: Sediment budget model domains

8.1.2 Model Equations

The sediment budget model sign convention for sediment transport is positive for northeastward transport and negative for southwestward transport. The variables *i* and *j* specify the cell numbering in the alongshore direction (from west to east) and cross-shore direction (offshore to onshore), respectively. The timestep, t, is measured in hours. The cell volumes, in cubic yards, are in reference to the unnourished profile (i.e., existing conditions). For example, beach nourishment is specified by a positive cell volume and may decrease over time, indicating gradual erosion (loss of the nourishment volume). The cell volume can become negative, indicating that the cell has lost all the initial nourishment volume and is now eroding sediment on the existing beach. The sediment budget model runs in MATLAB.

The sediment model calculations follow the sequence of time steps in the input wave time series from WIS Station 73040. At each timestep, the cell volume, $V(t)_{ij}$, is calculated based on changes due to cross-shore transport, $C(t)_{ij}$, and longshore sediment transport gradient, $\Delta L(t)_{ij}$:

$$V(t)_{ij} = V(t-1)_{ij} + C(t)_{ij} - \Delta L(t)_{ij}$$

Note that $V(0)_{ij}$ is equal to the initial beach volume.

The volume change due to cross-shore transport, $C(t)_{ij}$, is obtained for the wave condition at each timestep using the matrix of XBeach profile model results through an interpolation function or through the onshore transport algorithm, as described in Section 8.1.3, for each of the four representative profiles. This rate is then weighted based on the portion of sediment available in Cell 5 (on the beach) in the previous timestep, $P(t)_i$:

$$P(t)_i = V(t-1)_{i5}/V_{i5}^{max} \text{ when } V(t-1)_{i5} \geq 0$$

$$P(t)_i = V(t-1)_{i5}/V_{i5}^{min} \text{ when } V(t-1)_{i5} < 0$$

When $V(t-1)_{i5}$ is positive, $P(t)_i$ represents volume in the cell divided by the fully nourished cell volume, V_{i5}^{max}, and the $C(t)_{ij}$ is calculated by:

$$C(t)_{ij} = w_{ij} \times CSF \times [(1 - P(t)_i) \times C(t)_{ij}^u + P(t)_i \times C(t)_{ij}^n]$$

Where *CSF* is the cross-shore scaling factor, $C(t)_{ij}^u$ is the volume change for the unnourished profile (yd^3/ft), $C(t)_{ij}^n$ is the volume change for the nourished profile (yd^3/ft), w_{ij} is the cell width (ft, alongshore). Depending on the features of the profile, the values of $C(t)_{ij}^u$ and $C(t)_{ij}^n$ may be for the profile with or without an offshore berm.

When $V(t-1)_{i5}$ is negative, $P(t)_i$ represents volume in the cell divided by the minimum cell volume (negative), V_{i5}^{min}, and $C(t)_{ij}$ is calculated by:

$$C(t)_{ij} = w_{ij} \times CSF \times [(1 - P(t)_i) \times C(t)_{ij}^u]$$

In this situation, it is assumed that a cell without any volume to erode has a volume change of 0.

The longshore sand transport gradient, $\Delta L(t)_{ij}$, at each timestep is calculated in a similar way to the cross-shore transport. The longshore transport rate, $L(t)_{ij}$, is obtained for the wave condition at each timestep using the matrix of COSMOS longshore transport model results through an interpolation function, as described in Section 8.1.4, for each of the four representative profiles:

$$L(t)_{ij} = LSF(t)_{ij} \times [(1 - P(t)_i) \times L(t)_{ij}^u + P(t)_i \times L(t)_{ij}^n]$$

Where $LSF(t)_{ij}$ is the longshore scaling factor, $L(t)_{ij}^u$ is the longshore transport rate for the unnourished profile (m^3), and $L(t)_{ij}^n$ is the volume change for the nourished profile (m^3). Depending on the features of the profile, the values of $L(t)_{ij}^u$ and $L(t)_{ij}^n$ may be for the profile with or without an offshore berm.

The average longshore transport of adjacent cells is calculated to estimate the transport at each cell boundary. The gradient in longshore transport is calculated by subtracting the east boundary from the west boundary, therefore a positive gradient indicates that the cell is losing volume (eroding) and negative number means the cell is gaining volume (accreting):

$$\Delta L(t)_{ij} = \left[\left(\frac{L(t)_{i+1j} + L(t)_{ij}}{2}\right) - \left(\frac{L(t)_{ij} + L(t)_{i-1j}}{2}\right)\right]$$

At the jetty boundary, the longshore transport rate is set to 0 to not allow sediment to pass through and for a fillet beach to develop. For a jetty on the east side of a cell (Mustang Island):

$$\Delta L(t)_{ij} = \left[0 - \left(\frac{L(t)_{ij} + L(t)_{i-1j}}{2}\right)\right]$$

For a jetty on the west side of a cell (San Jose Island):

$$\Delta L(t)_{ij} = \left[\left(\frac{L(t)_{i+1j} + L(t)_{ij}}{2}\right) - 0\right]$$

At the west boundary in the Mustang Island domain, the longshore transport west of the first cell, $L(t)_{i-1j}$, is equal to the first cell, $L(t)_{ij}$:

$$\Delta L(t)_{ij} = \left[\left(\frac{L(t)_{i+1j} + L(t)_{ij}}{2}\right) - L(t)_{ij}\right]$$

Similarly, in the San Jose Island domain at the east boundary, $L(t)_{i+1j} = L(t)_{ij}$:

$$\Delta L(t)_{ij} = \left[L(t)_{ij} - \left(\frac{L(t)_{ij} + L(t)_{i-1j}}{2}\right)\right]$$

Maximum and minimum cell volumes are also specified in the sediment budget model. Minimum volumes prevent erosion of the profile beyond the historic low elevation (approximately 3 ft NAVD88 or 0.9 m NAVD88 based on dune crest surveys post Hurricane Harvey) while maximum volumes are set to prevent excessive accretion in cells. For example, in the cells adjacent to the jetties, when the maximum volume is reached, the excess material will move offshore until the maximums are no longer exceeded. This process simulates the process in which the sediment will move offshore along the jetty by rip currents.

8.1.3 Cross Shore Transport

8.1.3.1 Beach Erosion (Offshore Transport)

The XBeach model, introduced in Section 0, was used to determine the cross-shore volume change for each representative profile due to erosion. The 1D cross-shore model returns the profile change corresponding to a wave (wave height, period, and direction) and water level condition.

In total, 269 wave conditions (nine wave heights, seven wave periods, and seven wave directions) with three water levels were simulated for the four representative profiles resulting in a total of 269×3×4 = 3,228 individual XBeach model runs. Figure 8.3 shows the 269 wave conditions each represented by the red points. The blue points represent all wave conditions measured at WIS Station 73040 from 1980 to 2019. The red points form a matrix of conditions from which any wave condition can be interpolated. The XBeach model results were post-processed to determine an erosion/accretion rate (yd^3/ft/hr) for each of the 6 profile cells and saved to a MATLAB MAT-file. The resulting matrix of XBeach results is interpolated to find the corresponding erosion/accretion volume for each time step in the simulation period wave and water level timeseries.

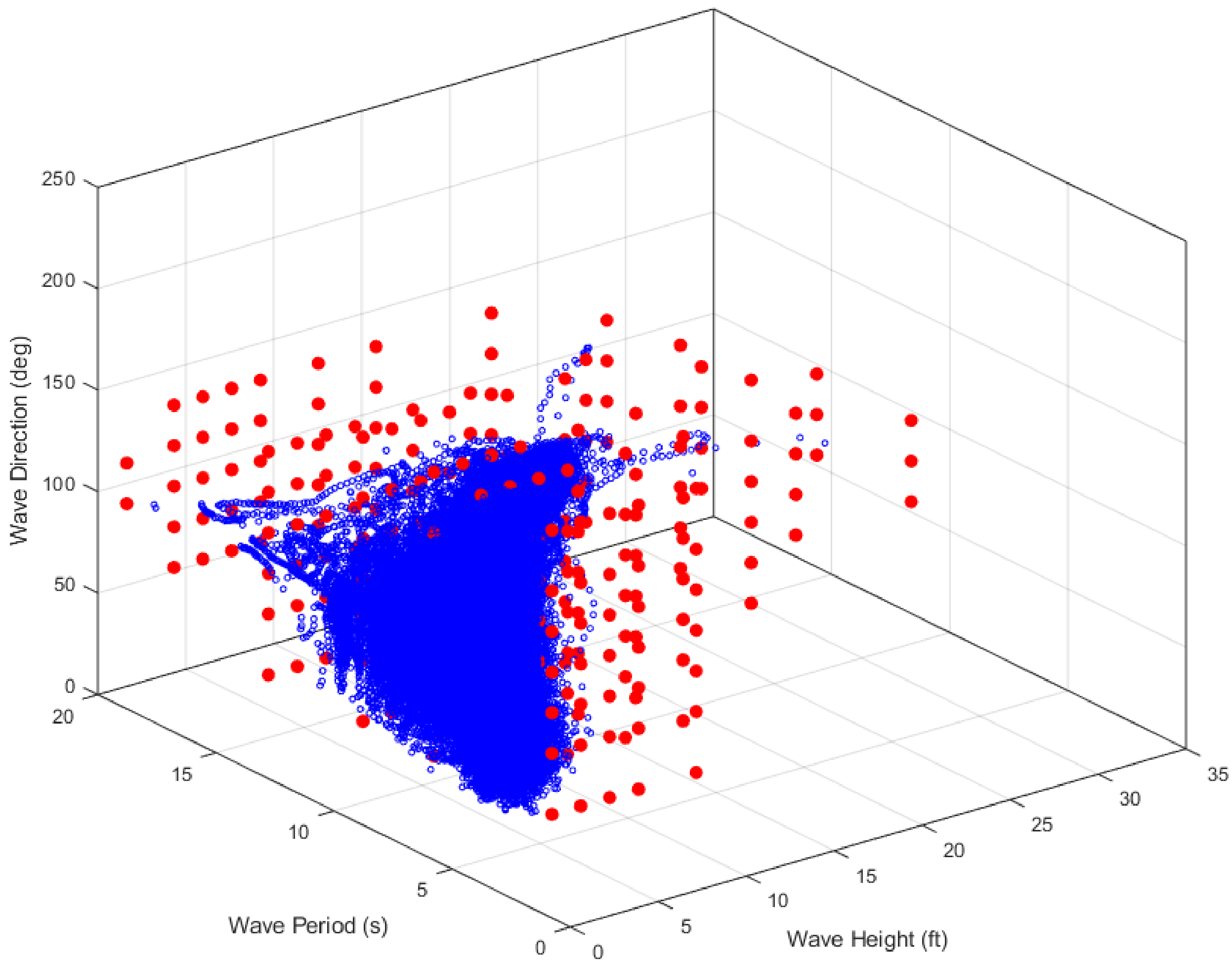


Figure 8.3: Matrix of XBeach wave conditions (red points) and all wave conditions measured at WIS Station 73040 from 1980 to 2019 (blue points)

Figure 8.4 shows an example of the summarized data from a single XBeach run {3.2 ft NAVD88 (1 m NAVD88) water level, 26.2 ft (8 m) wave height, 10 s wave period, 90-degree wave direction}. The results show a loss of 1.9 yd^3/ft/hr (4.7 m^3/m/hr) over the beach nourishment cell (Cell 5) after one hour of the above wave attack. The sediment lost from the nourishment area is deposited in the backdune (Cell 6; 1.4 yd^3/ft/hr or 3.4 m^3/m/hr) and moved offshore to Cell 4 (0.7 yd^3/ft/hr or 1.7 m^3/m/hr). Minor erosion is predicted for Cell 2 and 3. No changes are predicted for the offshore cell (Cell 1).

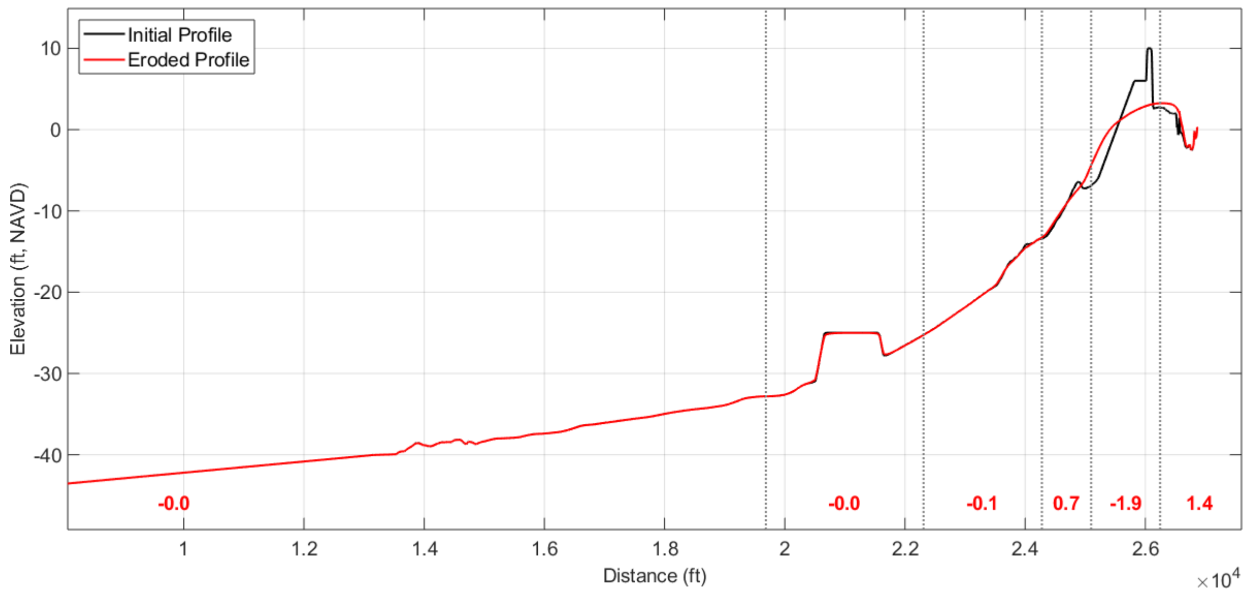


Figure 8.4: Example of XBeach results for one wave condition {3.2 ft NAVD88 (1 m NAVD88) water level, 26.2 ft (8 m) wave height, 10 s wave period, 90-degree wave direction} and summarized cross-shore volume change rates (in yd^3/ft/hr)

Figure 8.5 summarizes the cross-shore volume change rates for all wave conditions at Cell 5 (nourished beach) with a water level of 3.2 ft NAVD88 (1 m NAVD88). The figure shows that little to no cross-shore change is predicted over the beach when wave direction is less than 40 degrees or larger than 180 degrees. When waves approach the shore more directly in the 110 and 130-degree wave conditions, greater wave heights and longer periods result in more erosion, up to approximately 4 yd^3/ft/hr (9 m^3/m/hr).

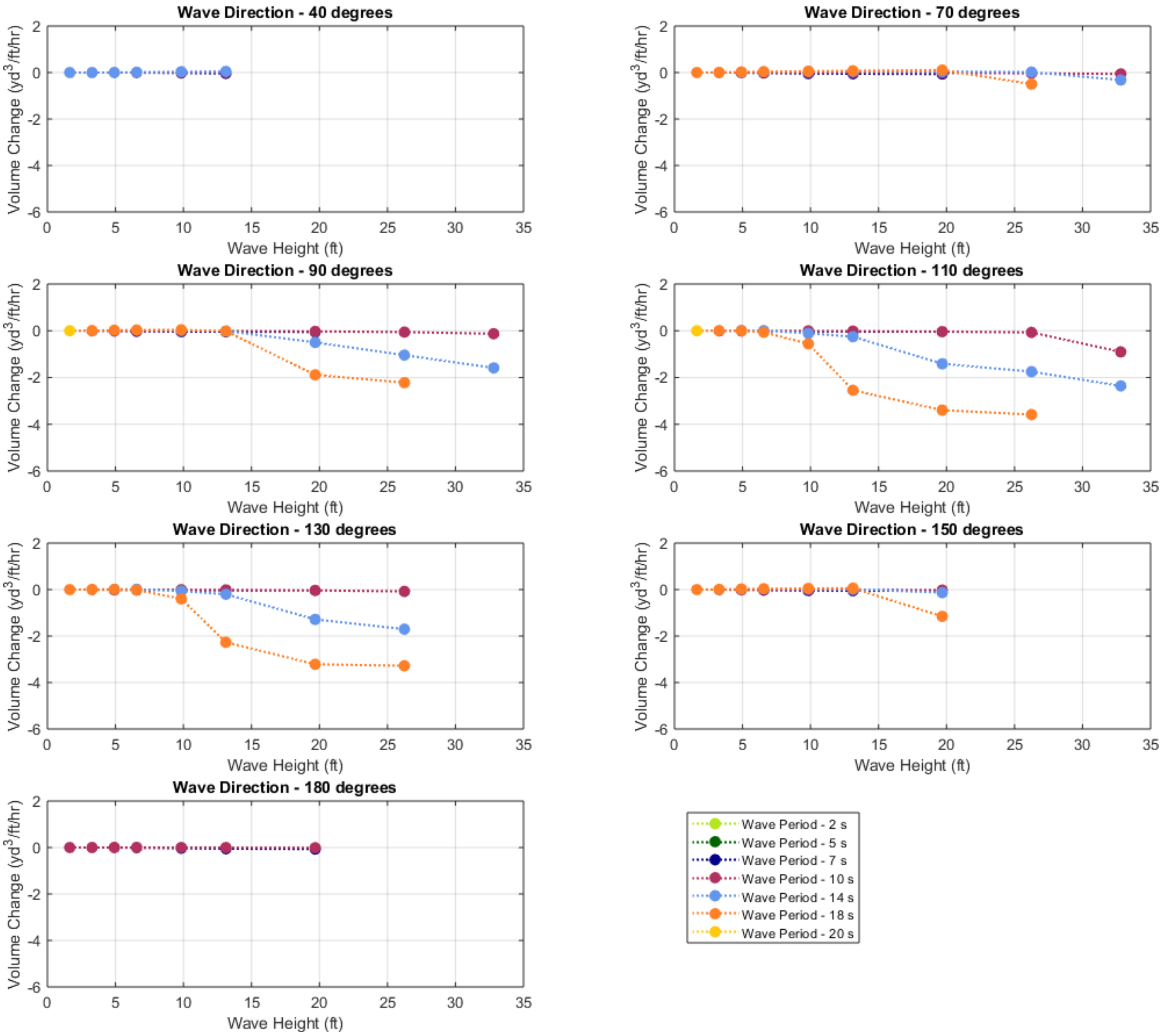


Figure 8.5: Summary of cross-shore volume change over Cell 5 (nourished beach with offshore berm) under all wave conditions with a water level of 3.2 ft NAVD88 (1 m NAVD88)

8.1.3.2 Beach Recovery (Onshore Transport)

As mentioned in Section 7.3.1, the XBeach model does not simulate onshore sediment movement and the corresponding beach recovery. Onshore sediment movement typically occurs when waves have relatively smaller heights and longer wave periods (or wave lengths). These waves are gently sloped and tend to deposit sediment on the beach. Sunamura and Horikawa (1974) developed the criterion, C_s, as a function of wave steepness, beach slope, and sediment size to determine if the beach will erode or accrete under a particular wave condition:

$$C_s = (H_0/L_0)(\tan\beta)^{0.27}(L_0/d)^{0.67}$$

where H_0 is the deepwater wave height, L_0 is the deepwater wavelength, $\tan\beta$ is the bottom slope, and d is the sediment grain size.

When C_s is less than the critical C_s value (C_{scrit}), the beach is likely to accrete (onshore movement). The value of C_{scrit} is approximately 18 for natural beaches but can vary for different beach environments. In the present sediment budget model, the value of C_{scrit} is used as a calibration factor.

The model calculates the C_s value for each timestep. If the C_s value is greater than the critical value, the cross-shore volume changes predicted by XBeach (previous section) is used. If the C_s value is less than the critical value and the wave height is greater than a certain threshold (to limit movement during very calm periods), onshore movement is allowed. Onshore movement is applied by removing a portion of the accumulated sediment in Cell 2 and 3 (V_o) and distributing the sediment back to Cells 4 and 5. The portion that is removed and the subsequent redistribution is tuned during calibration. A schematic of the application of onshore movement process is shown in Figure 8.6.

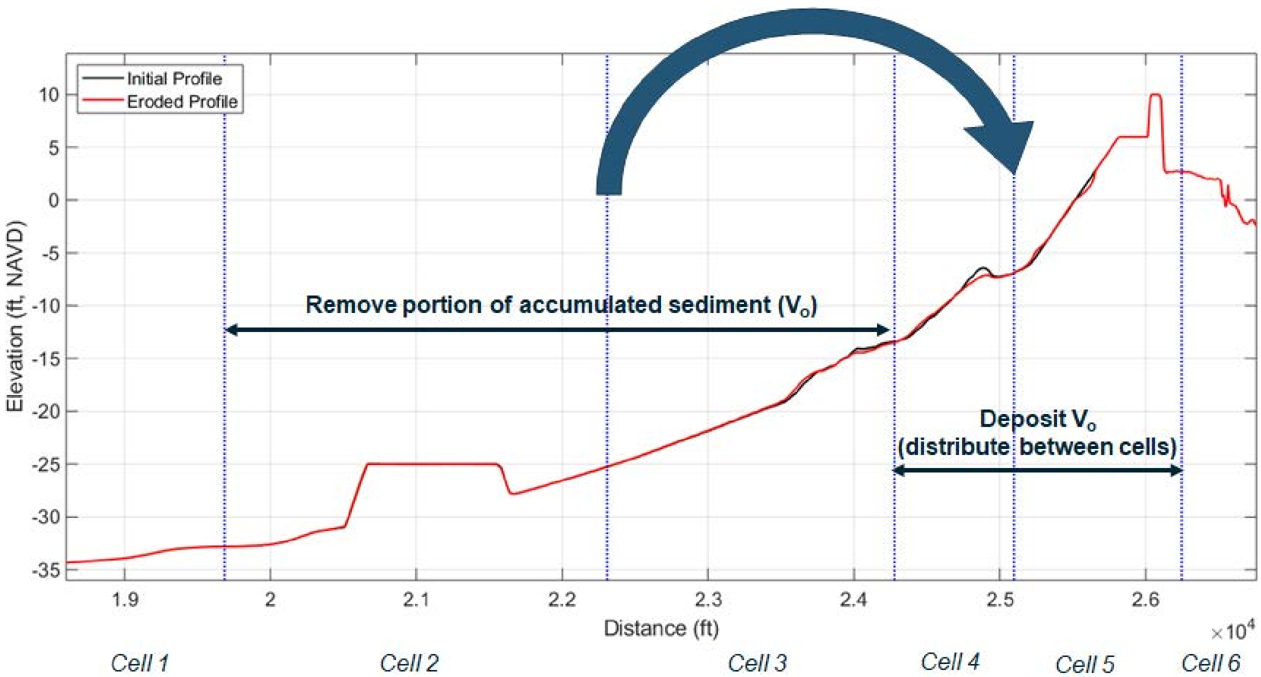


Figure 8.6: Schematic of onshore sediment movement process applied in the sediment budget model

8.1.4 Longshore Transport

Longshore transport gradient is defined as variation in longshore transport rate in the alongshore direction that can create a positive or negative imbalance in the sediment budget resulting in accretion or erosion, respectively. Longshore transport rates are determined using the COSMOS model. COSMOS is a processes-based numerical model that estimates wave transformation, wave-induced currents, and sediment transport across a user-specified nearshore profile. The model can be run for a single wave and water level condition or for a long sequence of wave and water level conditions at specified time increments. COSMOS has been extensively used and verified by Baird in numerous projects around the world.

Figure 8.7 shows the potential longshore transport rates for a nourished profile with offshore berm from 1980 to 2019 using waves from WIS Station 73040. Positive numbers indicate transport towards the northeast. Over the 40-year period, the net transport is towards the northeast on average. Years where the transport is towards the southwest coincide with significant hurricanes where the counterclockwise winds generate easterly waves that move nearshore sediment towards the west. Significant hurricanes included in this 40-year period are Hurricane Allen (1980), Hurricane Gilbert (1988), Hurricane Katrina (2005), Hurricane Ike (2008), and Hurricane Harvey (2017).

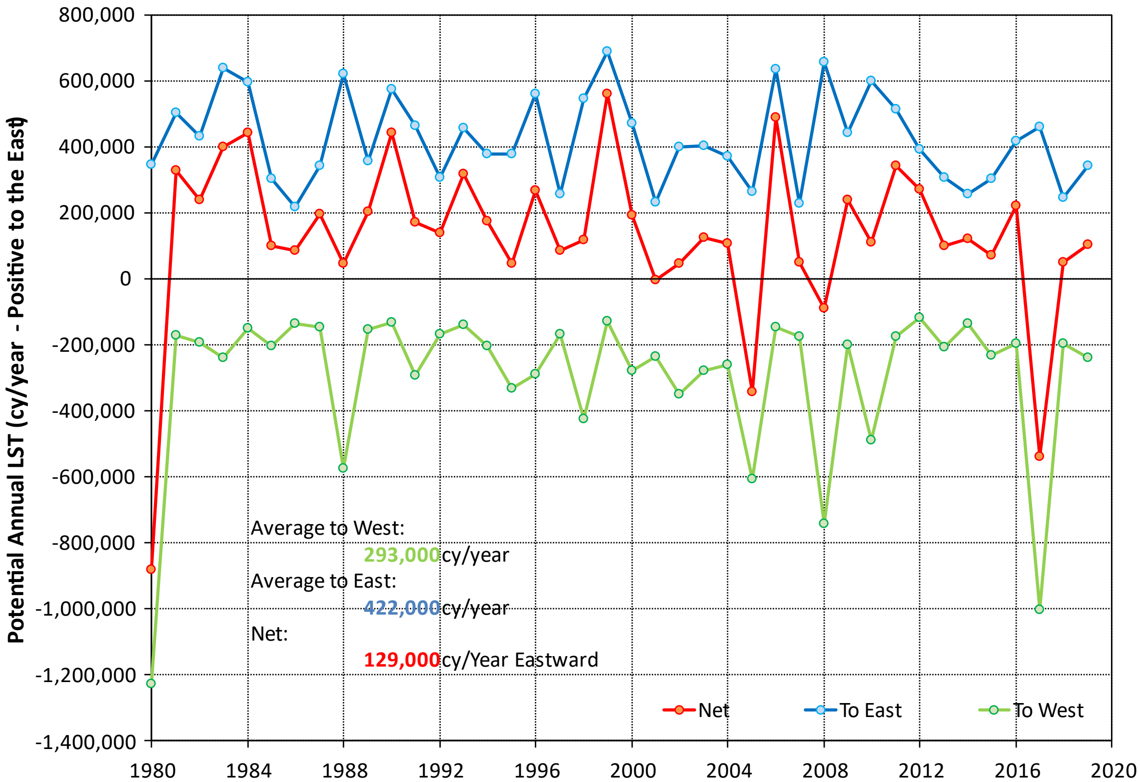


Figure 8.7: Potential annual longshore transport rates from 1980 to 2019 for a nourished profile with offshore berm

Similar to the cross-shore volume change modeling completed with the XBeach model, a total of 269 wave conditions (nine wave heights, seven wave periods, and seven wave directions) with three water levels were run for the four representative profiles in COSMOS (3,228 individual model runs). The COSMOS model results were post-processed to determine a longshore transport rate (yd^3/hr) for each of the 6 profile cells. The matrix of COSMOS results is interpolated to find the corresponding longshore transport rate at each time step in the input wave and water level timeseries. Alongshore transport rates are highest in the nearshore area between the -20 and -5 ft NAVD88 (-6 and -2 m NAVD88) contours (Cells 3 and 4) and decrease towards the onshore and offshore directions.

Figure 8.8 summarizes the longshore transport rates for all wave conditions at Cell 5 (nourished beach) with a water level of 3.2 ft NAVD88 (1 m NAVD88). The figure shows that longshore transport is towards the west (negative) when wave directions are less than 110 degrees. Longshore transport rates are higher when wave heights are greater and wave periods are longer.

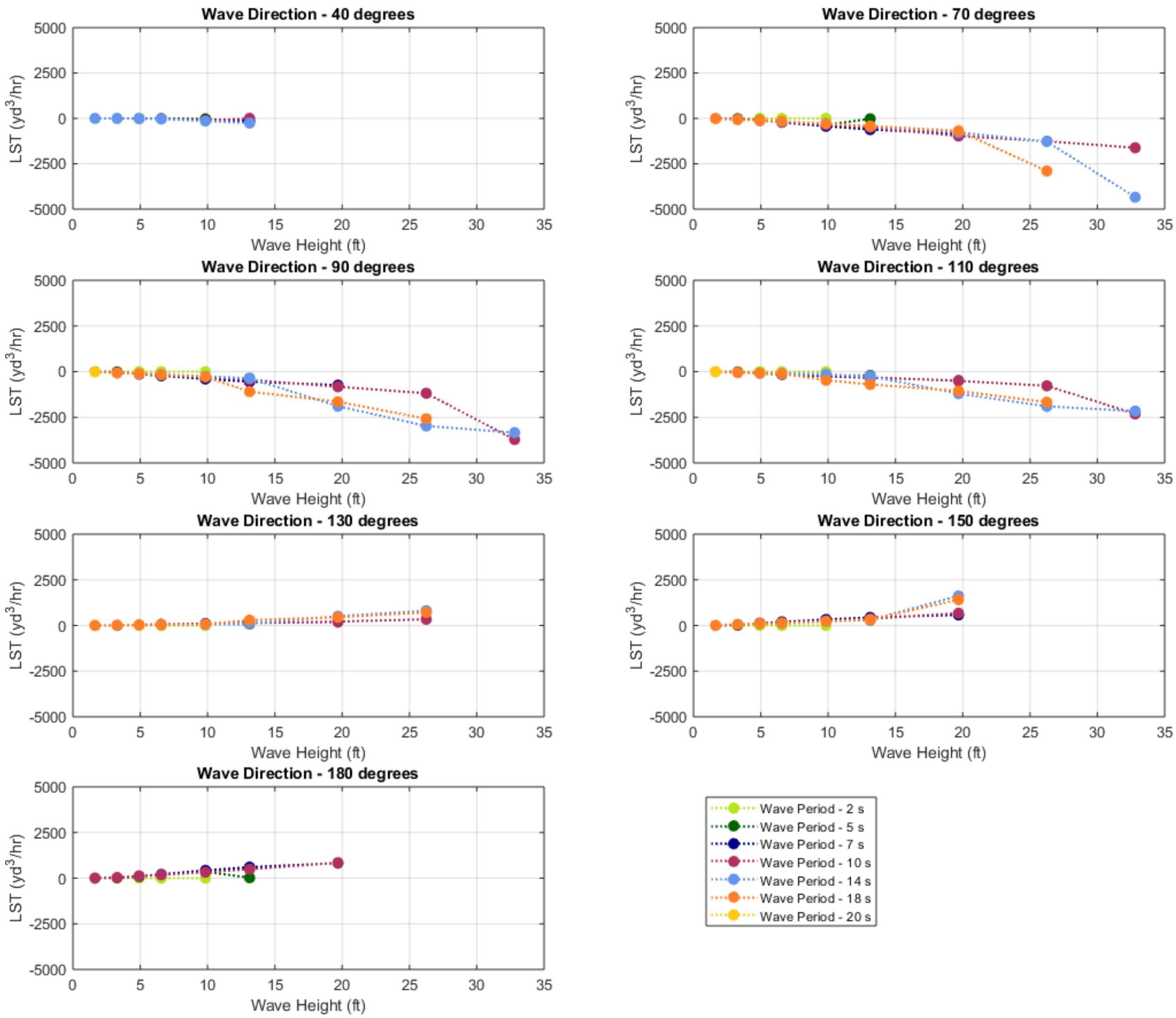


Figure 8.8: Summary of potential longshore transport rates at Cell 5 (nourished beach with offshore berm) under all wave conditions with a water level of 3.2 ft NAVD88 (1 m NAVD88)

8.1.5 Scaling Factors

A cross shore scaling factor (CSF) can be specified in the sediment budget model as a calibration parameter. The cross-shore factor is constant throughout the domain and does not change over time.

The long shore scaling factor (abbreviated as LSF; $LSF(t)_{ij}$ in model equations) varies with time and space, depending on the wave condition. Figure 8.9 shows the distribution of LSF for an eastward wave. As the wave approaches the north jetty, the wave diffracts around the tip, creating a counterclockwise circulation that moves sediment towards the west. This is reflected in the LSF distribution where the LSF is negative and small (approximately -0.05) in the shadow zone of the north jetty. The negative LSF, multiplied by the positive longshore transport rate (as overall transport is towards the east), changes the transport direction to negative/westward to capture littoral processes behind the north jetty. The more oblique the wave, the larger the shadow zone.

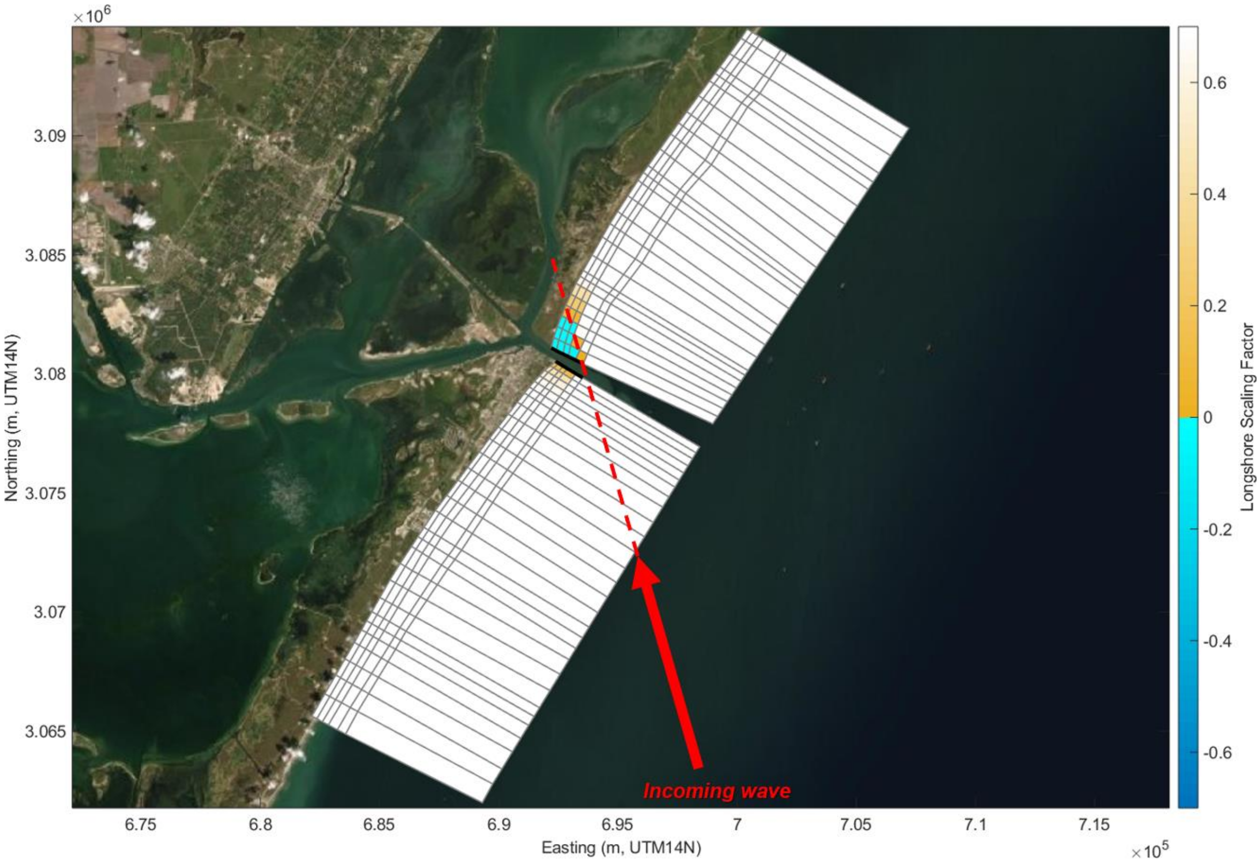


Figure 8.9: Longshore scaling factors for incoming wave from the south (164 degrees from north)

8.2 Model Calibration

The shoreline along the Mustang Island and San Jose Island domains are relatively stable. The shoreline change analysis from the University of Texas at Austin Bureau of Economic Geology estimated ±2 ft/yr (±0.6 m/yr) of shoreline change from 1950-2019 (Paine et al., 2021).

Because of the lack of definitive accretion/erosion trends to calibrate the model against, the objective of the sediment budget model calibration was to simulate a long-term FWOP (unnourished, no offshore berms) scenario that would produce relatively small changes along the shoreline cells. Calibration of the model primarily focused on the San Jose Island domain and the calibrated parameters were extended to the Mustang Island domain for validation. The 1992-2002 period was chosen for calibration as it is a calmer period with no major hurricanes with an overall net easterly alongshore transport.

Figure 8.10 shows the sediment budget model results for the calibration period. The colored cells in the figure show the change in sediment thickness relative to the initial FWOP seabed elevation at the end of the modeling period. To create the plot, the cell volume is divided by the cell area to represent average thickness. Cells with warm colors (positive thickness) represent volume gain above the FWOP elevation. Cool colors (negative thickness) indicates that volume has been lost/eroded below the FWOP seabed elevation. The figure is intended to visualize the trends in the domain only and the value of the thickness should not be taken literally.

Figure 8.10 shows that erosion generally occurs on the beach and in the nearshore area while sediment is overwashed to the back dune area. Cells along the shoreline (Cell 5) generally lose 1 yd^3/ft/yr (3 m^3/m/yr). This loss rate corresponds to a lateral shift of approximately 1 ft/year of the FWOP profile, measured between the depth of closure and the top of the dune, which is within the range reported by Paine et al., 2021. Most of the lost sediment is redistributed across the domain through overwashing to the back dune area and also moved offshore. Sediment that is moved offshore may be transported to the channel area, where it is assumed to be trapped by the deep navigation channel.

In the Mustang Island domain, 267k yd^3/yr (204 m^3/yr) enters (i.e., moves eastward to) the domain from the west boundary and 155k yd^3/yr (119 m^3/yr) exits (i.e., moves westward out of the domain) for a net exchange of 112k yd^3/yr (86 m^3/yr) to the east (into the domain). The volume exiting the domain on the east boundary (potential channel infilling) is 165k yd^3/yr (126 m^3/yr). The total volume change in the domain is 53k yd^3/yr (41 m^3/yr) representing net erosion. Similarly, on San Jose Island, the sediment budget is balanced: 52k yd^3/yr (40 m^3/yr) leaves the domain from the east boundary while 25k yd^3/yr (19 m^3/yr) leaves the domain from the west boundary and is balanced by 77k yd^3/yr (59 m^3/yr) of net erosion within the domain. As the net longshore transport is towards the east during the calibration period, potential channel infilling volumes are greater from the Mustang Island domain. The predicted total potential channel infilling volume from both domains is 190k yd^3/yr (146 m^3/yr).

Table 8.1 summarizes final parameters and values used for the calibrated sediment budget model.

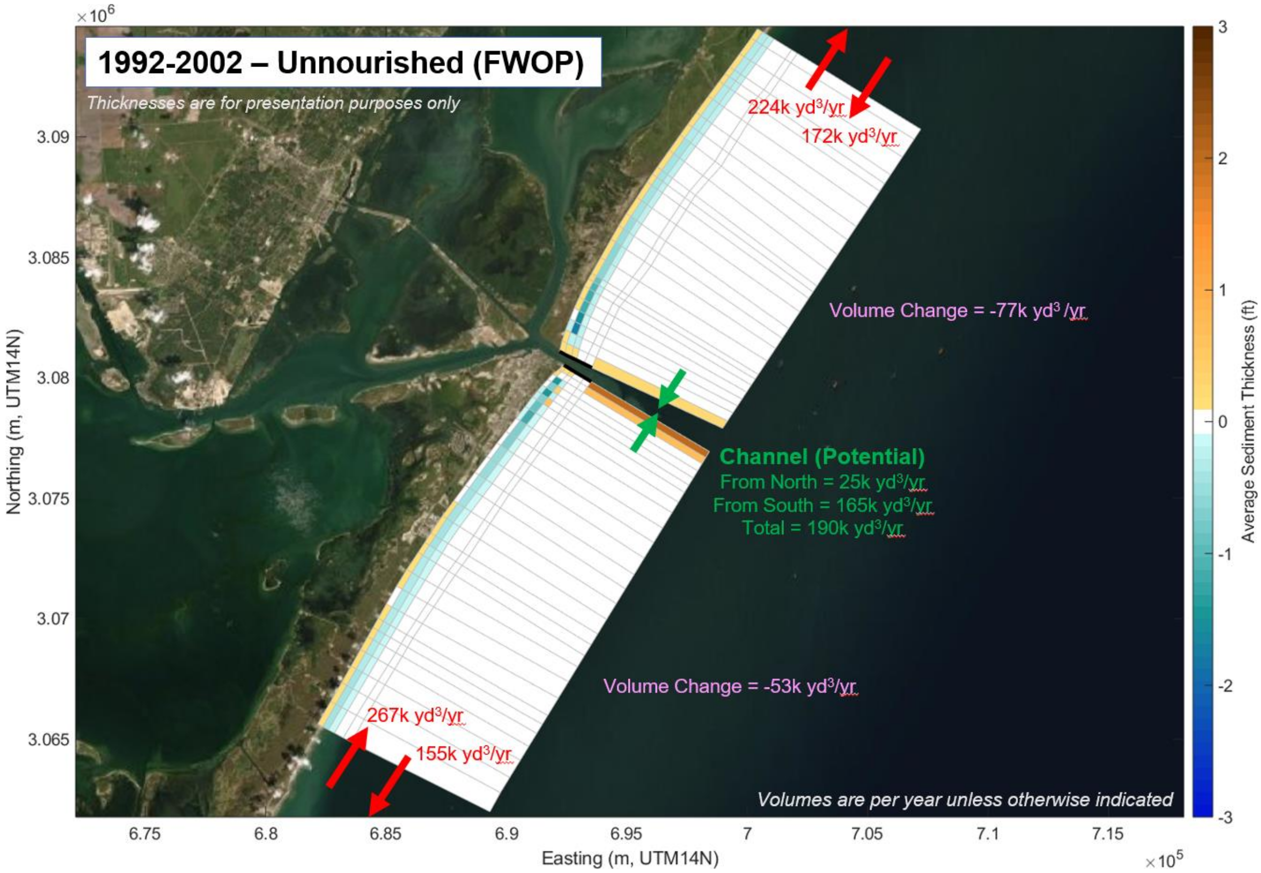


Figure 8.10: Sediment budget model results for the 1992-2002 calibration period (FWOP, average thicknesses shown are for presentation purposes only and should not be taken literally)

Table 8.1: Sediment budget model parameters

Parameter	Value
CSF	0.5
LSF (max)	0.7
C_{scrit}	40
Minimum wave height threshold for onshore movement	0.8 ft (0.25 m)
Accumulated sediment relocated during onshore transport	2.5%
Distribution of placed sediment during onshore transport	25% in Cell 4 and 75% in Cell 5

8.3 Beach Nourishment Assessment Runs

Three modeling periods were used for the beach nourishment assessment runs:

- 2011 – one year run with net eastward longshore transport (same period as the 2D model runs)

- 1992 to 2002 – eleven-year run with no major hurricane events (net eastward longshore transport)
- 2000 to 2019 – 20-year run that includes several significant hurricanes (Hurricane Katrina, Hurricane Ike, and Hurricane Harvey) that can move sediment back towards the west

Figure 8.11 shows the cells where the beach nourishment and offshore berms were placed (i.e., volume added) to represent the FWP scenario. The orange cells indicate beach nourishment while the green cells indicate the offshore berms. According to the CAD file "Beach_Dune Fill Features_s-ft_.dwg" by Freese and Nichols sent via email on October 28, 2021, approximately 2.0 million yd^3 (1.5 million m^3) and 4.0 million yd^3 (3.1 million m^3) of beach nourishment is to be placed on Mustang Island and San Jose Island, respectively, in the FWP scenario. Three offshore berms are placed on Mustang Island with a total volume of 4.3 million yd^3 (3.3 million m^3) and six berms are placed on San Jose Island totaling 5.1 million yd^3 (3.9 million m^3).

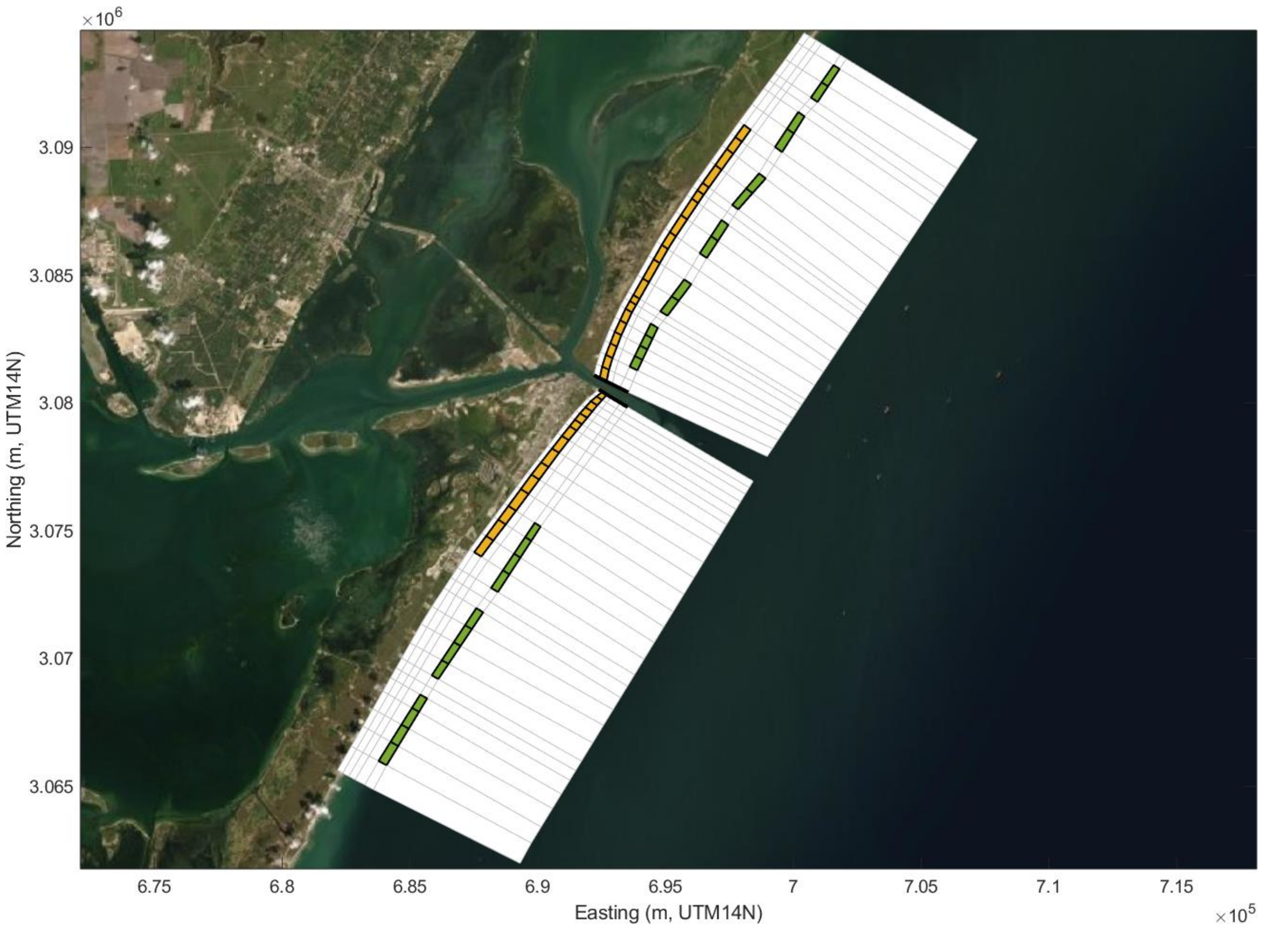


Figure 8.11: Beach nourishment (orange) and offshore berm (green) placement cells within the Mustang Island and San Jose Island domains

Figure 8.12 summarizes the sediment budget model run results for the FWP conditions for the 2011 model period. During 2011, the Mustang Island domain gains sediment in the nourishment footprint area due to the filling of the fillet beach on the west side of the jetty as the sediment is transported east. In the San Jose Island domain, 65k yd^3 (50k m^3; 3% of the total placed volume) of beach nourishment is lost from the nourishment footprint. The total potential channel infilling volume from both domains is 179k yd^3/yr (138 m^3/yr) which is in reasonable agreement with MIKE21 prediction (Table 5.1) for the FWP (i.e., deepened channel) conditions in 2011.

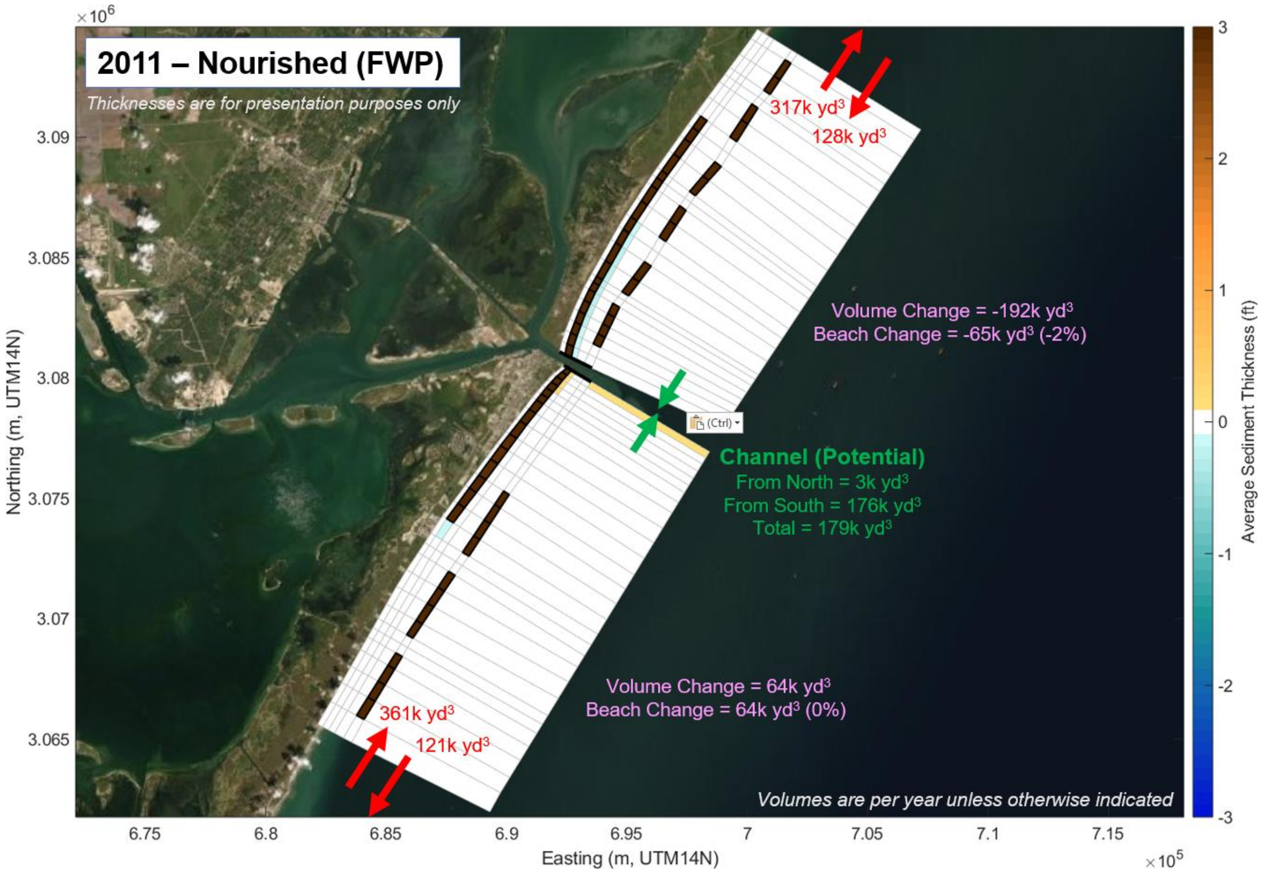


Figure 8.12: Sediment budget model results for 2011 (FWP, thicknesses shown are for presentation purposes only and should not be taken literally)

Figure 8.13 and Figure 8.15 summarize the sediment budget model run results for the FWP conditions for the 1992-2002 simulation period. In the 1992-2002 period, 321k yd^3 (245k m^3) of sediment is lost from the Mustang Island domain nourishment footprint (16% of the total placed volume) while 34k yd^3 (26k m^3) is gained in the San Jose Island domain nourishment footprint. During this period, the sediment has filled out the Mustang Island fillet beach and sediment is being transported along the jetty offshore towards the channel, similar to the FWOP conditions. The larger footprint of the beach nourishment on San Jose Island allows the sediment to move back and forth (i.e., northeastward or southwestward) along the nourishment footprint while staying within (and moving back into) the nourishment footprint over time. While the beach nourishment volume of the Mustang Island domain generally goes down over time, the San Jose Island domain volume cycles positive and negative as the sediment has a larger footprint to stay within. The nourishment along San Jose Island is also fronted by offshore berms to a greater extent than the Mustang Island nourishment, adding additional stability to the beach.

The predicted total potential channel infilling volume from both domains is 180k yd^3/yr (138 m^3/yr). This is similar to the predicted volume under the FWOP conditions (190k yd^3/yr, Figure 8.10) and indicates that the impact of beach nourishment and offshore berms on channel sedimentation is small.

While the beach nourishment volume in the San Jose Island domain stays relatively constant over the modeling period, the distribution of sediment changes over time. At the end of the 1992-2002 period, an area of localized erosion approximately 1000 ft (300 m) in length located approximately 1000 ft (300 m) northeast of the north jetty in the San Jose Island domain. This area is where the diffracted waves change directions (e.g., the northeastward waves reverse direction and advance towards the southwest) and localized erosion occurs. A similar area is seen on the Mustang Island domain. These areas lose sediment faster than others within the nourishment footprint.

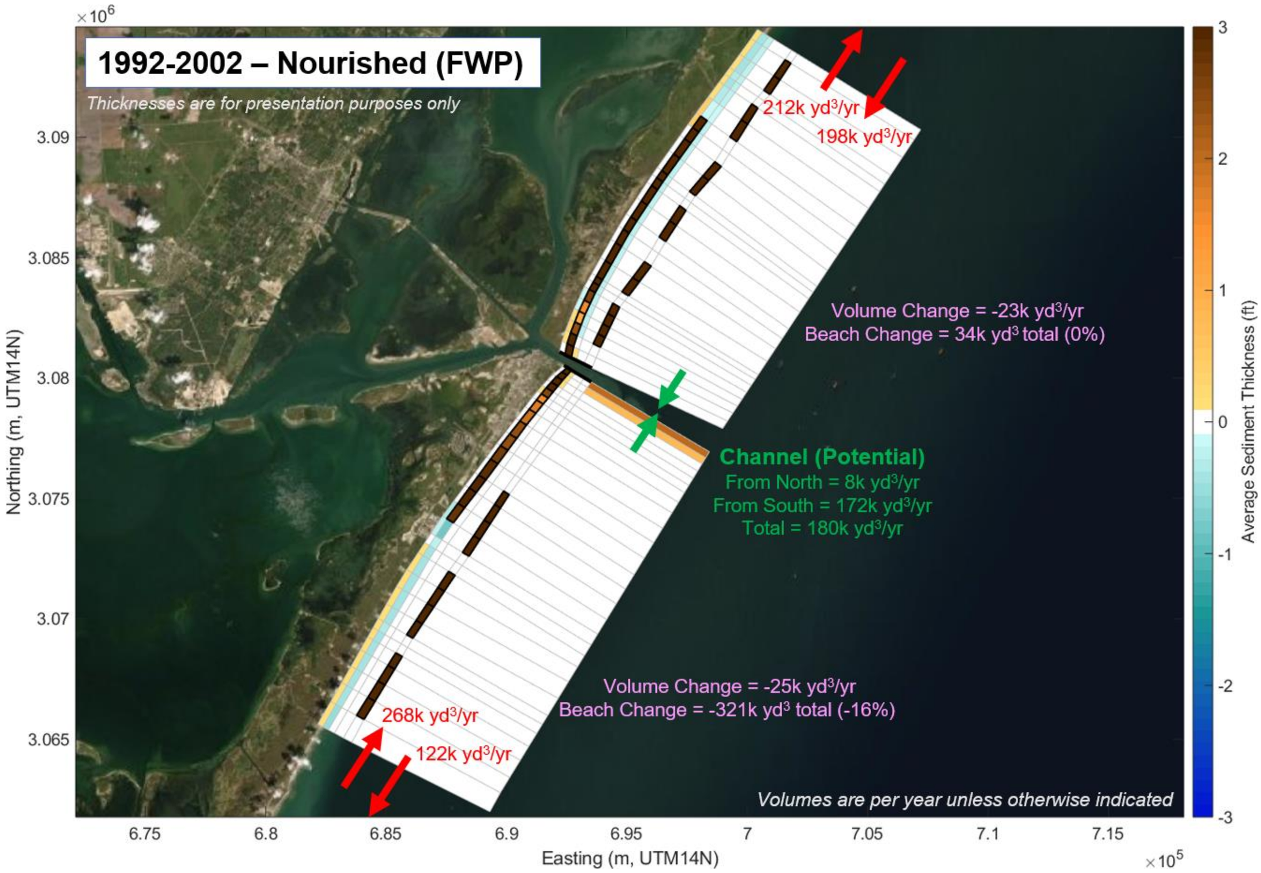


Figure 8.13: Sediment budget model results for the 1992-2002model period (FWP, thicknesses shown are for presentation purposes only and should not be taken literally)

The 2000-2019 simulation period results are shown in Figure 8.14 and Figure 8.16. The northeastward and southwestward volumes at the northeast and southwest boundaries of the San Jose Island and Mustang Island domain boundaries are more balanced in the 2000-2019 run as the hurricanes transport more sediment to the southwest, offsetting the typical northeastward transport. By the end of the 2019-2019 modeling period, all the nourishment volume placed at Mustang Island has been eroded while 40% (1,613k yd^3 or 1,233k m^3) is eroded from San Jose Island. The larger volume of beach nourishment, longer nourishment length, and presence of offshore berms help to extend the longevity of nourishment at San Jose Island. The volume of sediment entering the channel from the San Jose Island domain is increased during this period as the hurricanes push sediment to the southwest. As with the 1992-2002 period, there are also areas of localized erosion north and south of the San Jose Island and Mustang Island fillet beaches.

In all modeling periods, the offshore berms are predicted to be stable. The impact of placement of beach nourishment and offshore berms on channel sedimentation was predicted to be small.

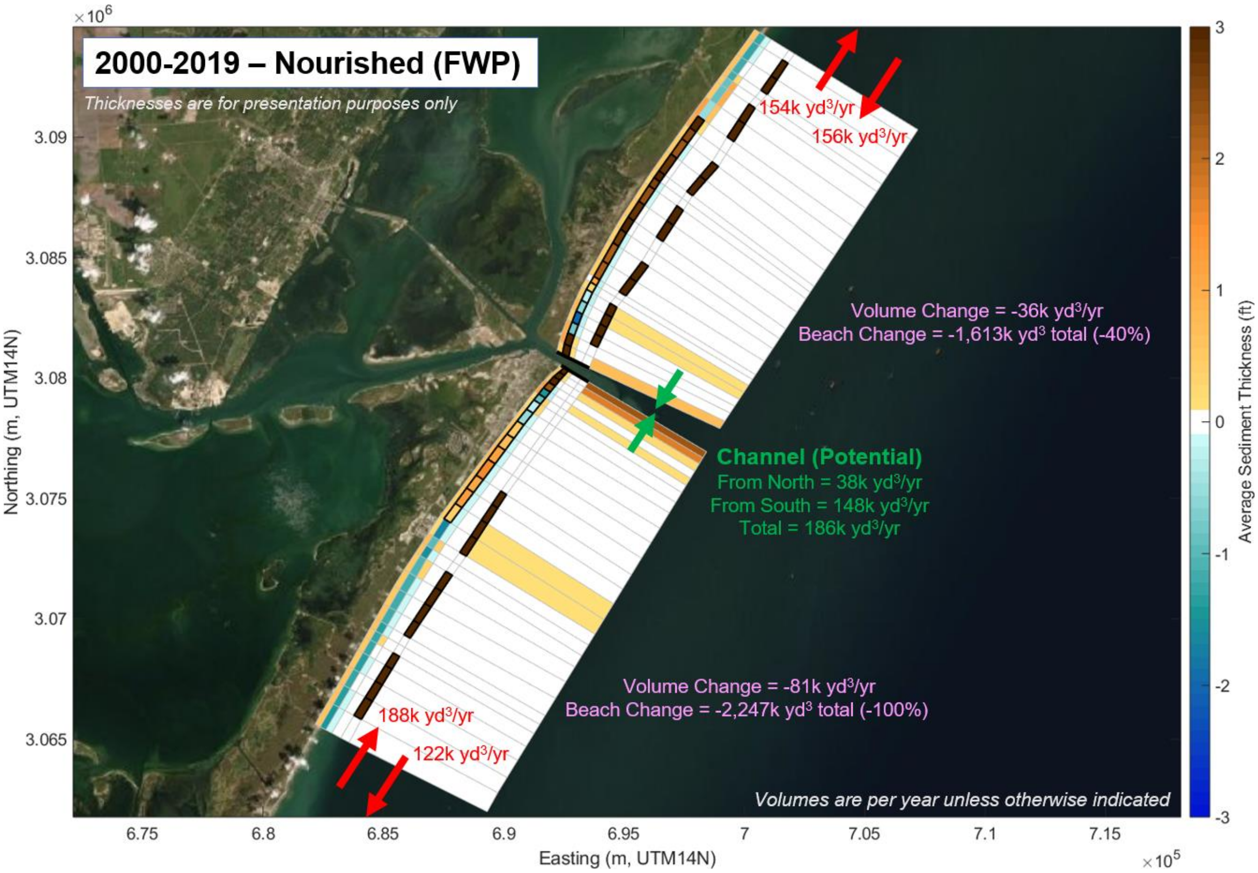


Figure 8.14: Sediment budget model results for the 2000-2019 model period (FWP, thicknesses shown are for presentation purposes only and should not be taken literally)

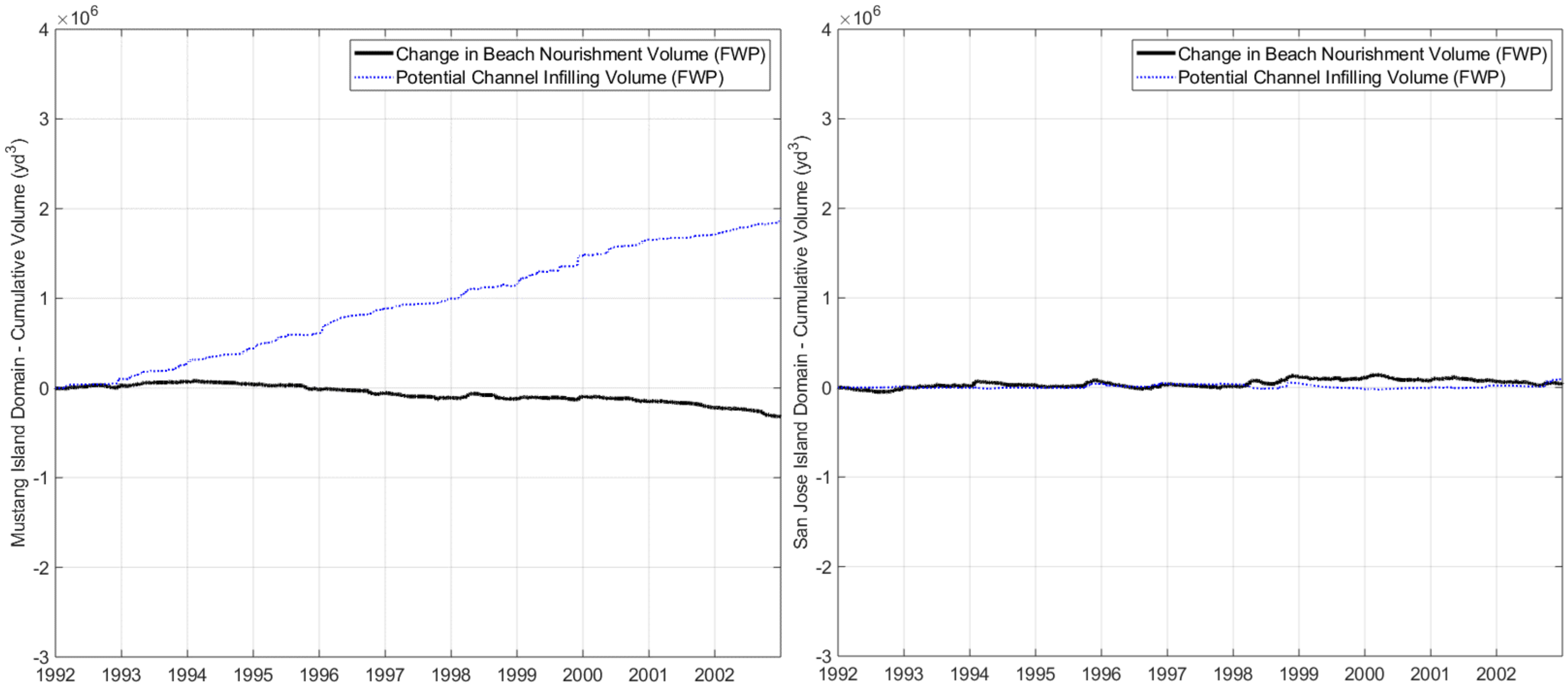


Figure 8.15: Change in beach nourishment volume and potential channel infilling volumes for the Mustang Island (left) and San Jose Island (right) domains for the period from 1992-2002

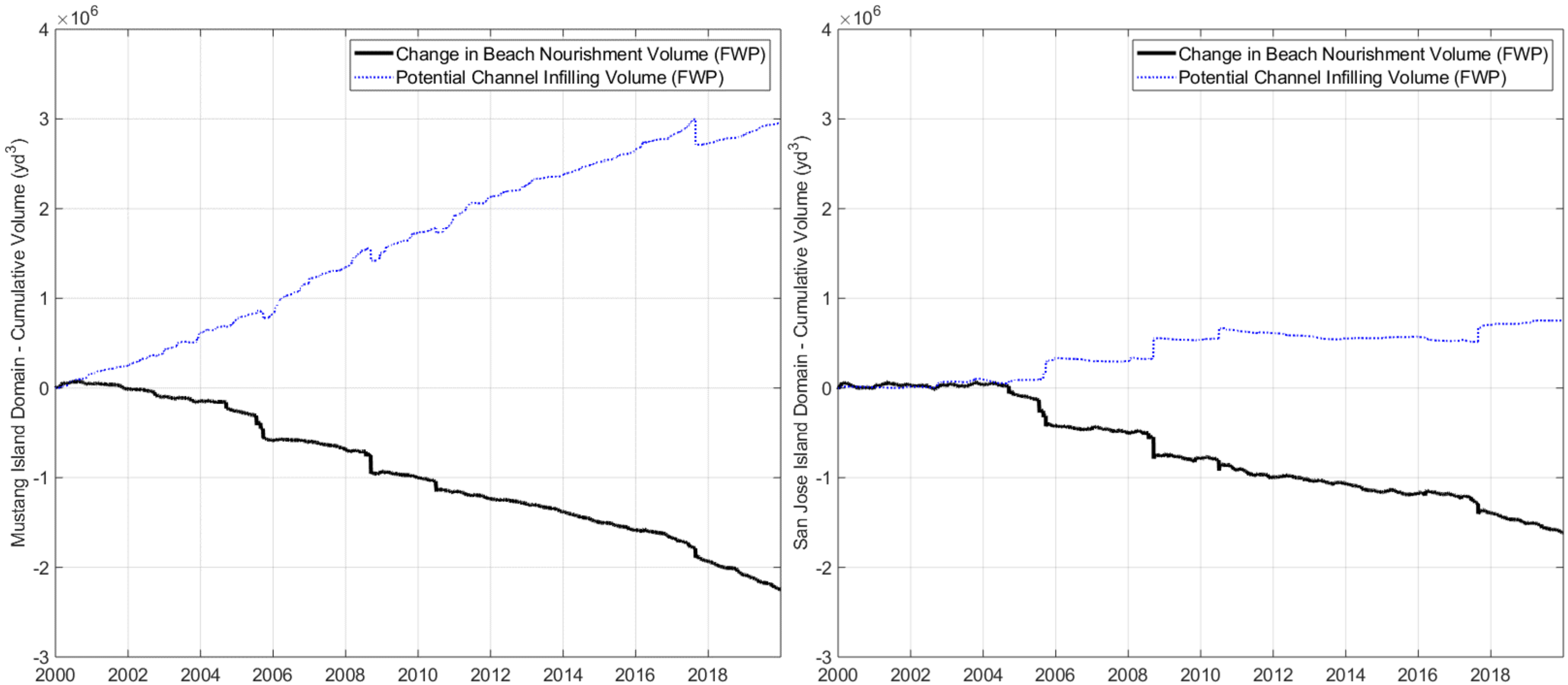


Figure 8.16: Change in beach nourishment volume and potential channel infilling volumes for the Mustang Island (left) and San Jose Island (right) domains for the period from 2000-2019

9. Conclusions

The impacts of the Future With Project (FWP) scenario on channel sedimentation are summarized below:

- Predicted FWOP and FWP shoaling rates for the inner channel were comparable to the existing condition. Overall, both 2D and 3D model results indicate that the project impact on sedimentation rates is limited to less than 10%.
- The model predicted that sedimentation in the outer channel increases from approximately 95,000 yd^3/year (73,000 m^3/year) for the FWOP to approximately 214,000 yd^3/year (164,000 m^3/year) for the FWP scenario, approximately 2.25 times higher. This is primarily due to that fact that the FWP has a deeper and longer channel comparted to FWOP.
- The beach nourishment and offshore berms make small contributions to channel sedimentation with less than 600 yd^3 (459 m^3) of total sedimentation per year as predicted by the 2D model.
- The model predicted that sedimentation in the outer channel under FWP conditions increases from approximately 214,000 yd^3/year (164,000 m^3/year) in the absence of the ODMDS mound to approximately 342,000 yd^3/year (262,000 m^3) (approximately 1.6 times greater) when the ODMDS mound is present.
- Individual hurricane events could result in sedimentation volumes in the outer channel that are several times higher than the average annual sedimentation. In contrast, the impact of hurricane on the inner channel is small.

The modeling assessment of the cross-shore profile response to long term wave conditions and short-term storm conditions found that:

- No significant movement of the offshore berm is expected
- The offshore berm is placed beyond the mean depth of closure, and it is unlikely that significant sediment movement will occur at the designed placement depth
- XBeach predicts overtopping of the dune during severe storms (e.g., Hurricane Allen and Hurricane Harvey)
- XBeach storm response predictions were validated using pre- and post-Hurricane Harvey imagery and surveys
- The offshore berm is not expected to provide significant shore protection, except in smaller storms with longer wave periods
- The true extent of beach erosion varies along the shoreline and is influenced by local profile morphology including the dune crest height among other factors which are not reflected in a one-dimensional model

The modeling assessment of the fate of beach nourishment found that:

- In the Mustang Island domain, the average nourishment loss rate is approximately 29k to 112k yd^3 (22k to 86k m^3) per year (1 to 5% of the total volume per year); the lost sediment is generally transported to the northeast where it moves along the jetty and offshore towards the channel
- In the San Jose Island domain, the average nourishment erosion rate is approximately 0 to 80k yd^3 (0 to 62k m^3) per year (0 to 2% of the total volume per year); the lost sediment is generally redistributed over the model
- The larger footprint of the beach nourishment on San Jose Island allows the sediment to move back and forth along the nourishment footprint while staying within (and moving back into) the nourishment footprint over time

- The nourishment along San Jose Island is also fronted by offshore berms to a greater extent than the Mustang Island nourishment, adding additional stability to the beach
- Areas between 1,000 to 2,000 ft (300 to 600 m) north and south from the jetty in both the Mustang Island and San Jose Island domain are expected to lose sediment earlier
- The impact of beach nourishment on channel sedimentation is expected to be small
- The offshore berms are expected to remain stable over time

10. References

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Appendix H

Vessel Wake Analysis

Note: The Section 508 amendment of the Rehabilitation Act of 1973 requires that the information in Federal documents be accessible to individuals with disabilities. The USACE has made every effort to ensure that the information in this appendix is accessible. However, this appendix is not fully compliant with Section 508, and readers with disabilities are encouraged to contact Mr. Jayson Hudson at the USACE at (409) 766-3108 or at SWG201900067@usace.army.mil if they would like access to the information.

Port of Corpus Christi Authority Channel Deepening Project

Vessel Wake Analysis

January 25 2022 | 13242.102.R4.RevA

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Port of Corpus Christi Authority Channel Deepening Project

Vessel Wake Analysis

Prepared for:	Prepared by:
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Revision	Date	Status	Comments	Prepared	Reviewed	Approved
A	01/25/2022	Draft	For Client Review	SG	LW	LW

Executive Summary

Freese & Nichols, Inc. (FNI) has engaged W.F. Baird & Associates Ltd. to provide coastal engineering and modeling services for the proposed Corpus Christi Channel Deepening project. The project will comprise deepening of the Outer and Approach Channels to 77 ft, and the Jetty Channel and seaward-most portion of the Corpus Christi Ship Channel to 75 ft. The channel will be used by vessels including laden VLCC's at a maximum draft of 68 ft departing from the planned Axis and Harbor Island terminals. A vessel wake analysis as described in this report was part of these studies developed for the purposes of assessing project adequacy for the Environmental Impact Statement. The study included an analysis of vessel transits and modeling of vessel transits and the resulting bed and shoreline change under channel scenarios with and without the channel deepening project.

Vessel induced wakes consist of both a primary and secondary wave and the magnitude of each (both absolute and relative) are a function of the vessel characteristics, speed through water and channel geometry. Being a constrained deep dredged channel with vessels traveling at relatively low speeds, the primary wave is dominant along the Corpus Christi channel for large tanker vessels. The constrained channel increases the primary drawdown wave, while typical vessel speeds result in relatively small secondary waves that reduce in magnitude as they propagate away from the vessel. As a result, the primary wave is the predominant driver for bed and shoreline change.

An estimate of annualized bed and shoreline change as a result of vessel wakes was made with a comparison of the following:

- Suezmax results compare the Future Without Project (FWOP) channel scenario against the FWP channel scenario with no change in traffic numbers.
- VLCC results compare the Future With Project (FWP) channel scenario with 2022 traffic projections against the FWP channel scenario with 2023 traffic projections (5% increase in VLCCs)

A comparison of the FWOP and FWP channel scenarios for both the Suezmax and VLCC indicate that there would be very limited change in bed morphology as a result of the channel deepening project. In general, the bed morphology results suggest a scouring pattern on the channel shoulders with sedimentation along top of channel bank and no sedimentation within the channel bed width for all scenarios. Some localized changes are observed for the FWP channel scenario; however, these are not considered significant.

Consistent with the bed change results, shoreline change modeling indicates that changes in vessel wakes as a result of the channel deepening project will have minimal impact on the future evolution of natural shorelines along the length of the Corpus Christi Shipping channel. A general recession trend is observed in the analysis of historical shoreline positions and the annual shoreline change modeling, however no discernable increase in the recessional trend as a result of the project could be identified.

In addition, both the vessel wake bed change and shoreline change modeling indicate that any change in vessel hydrodynamics due to the future project condition will not contribute to an increase in sedimentation within federal navigation channels.

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Tables

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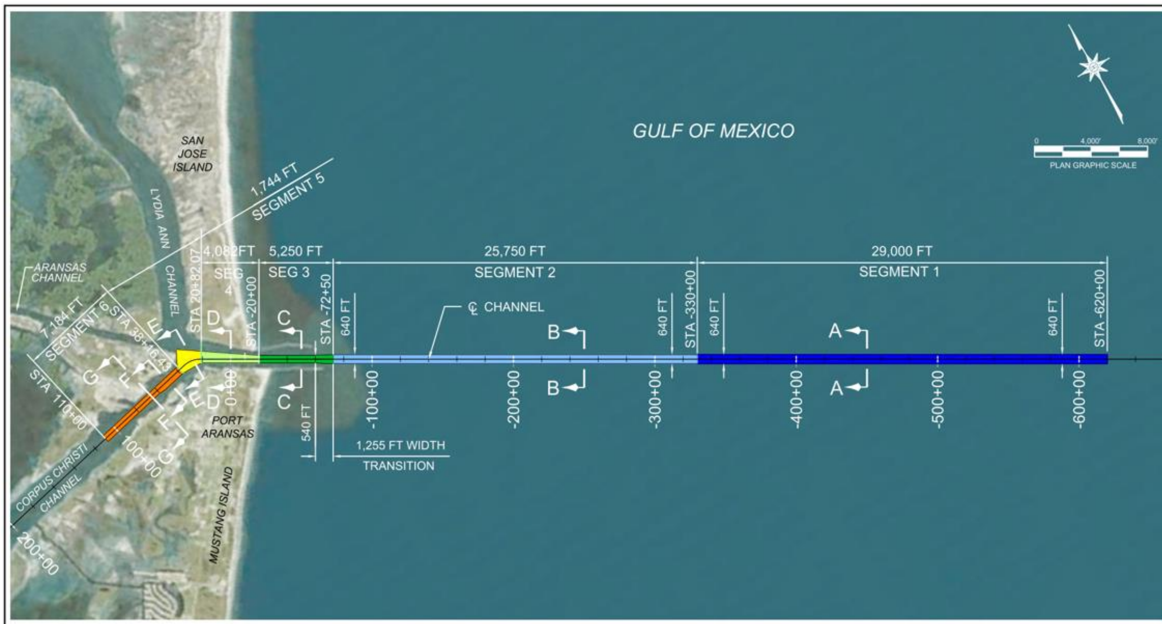
1. Introduction

1.1 Project Background

W.F. Baird & Associates Ltd. (Baird) was engaged by Freese & Nichols, Inc. (FNI) to provide coastal engineering and modeling services for the Corpus Christi Ship Channel Deepening Project (CDP). The project is the proposed deepening of the Offshore Channel to a nominal depth of 77 ft (Segments 1 and 2 in Figure 1.1), and the Entrance Channel and seaward-most portion of the Corpus Christi Ship Channel to 75 ft (Segments 3 to 6 in Figure 1.1). The channel will service the planned Harbor Island and Axis terminals with laden vessels, including very large crude carriers (VLCC's), departing from these terminals.



DREDGING PLAN

SCALE: 1" = 8000'

SEGMENT	STATIONING (@ CHANNEL CL)		*DEPTH (FT BELOW MLLW)	DESCRIPTION	PLAN VIEW LEGEND
	FROM	TO			
1	STA -620+00	STA -330+00	-77.0	*Outer Channel*	
2	STA -330+00	STA -72+50	-77.0	*Approach Channel*	
3	STA -72+50	STA -20+00	-75.0	*Jetties to Harbor Island Transition Flare*	
4	STA -20+00	STA 20+82.07	-75.0	*Harbor Island Transition Flare*	
5	STA 20+82.07	STA 38+16.43	-75.0	*Harbor Island Junction*	
6	STA 38+16.43	STA 110+00	-75.0	*Corpus Christi Channel*	

* DESIGN DEPTH SHOWN. DOES NOT INCLUDE 2.0 FT ADVANCED MAINTENANCE DREDGING OR 2.0 FT ALLOWABLE OVER DREDGE.

Corpus Christi Ship Channel Deepening Project
Individual Permit Application SWG-2019-00067

Preferred Channel Alternative

County: Aransas and Nueces State: Texas
Application By: Port of Corpus Christi Authority Date: April 2020

Figure 1.1: Dredging plan for the Corpus Christi Ship Channel Deepening Project

Baird's services include the following tasks:

- Vessel wake analysis
- Dynamic Underkeel Clearance (UKC) study
- Propeller scour study
- Tidal and hydrodynamic modeling

- Storm surge analysis
- Sediment transport modeling

The vessel wake analyses are addressed in this Report.

1.2 Study Objectives

The objectives of the vessel wake analyses are to assess model vessel generated hydrodynamics, including primary drawdown/surge wave and secondary bow and stern waves, for proposed project vessel traffic following the channel deepening. Further, the potential impacts from the vessel generated hydrodynamics on adjacent shorelines and any contribution to sedimentation within federal navigation channels are to be considered.

1.3 Vessel Wake Definitions

Two main types of waves are generated by moving vessels:

- Primary (or drawdown) wave; and,
- Secondary waves caused by discontinuities in the hull profile (bow and stern waves).

These two main types of waves are schematically presented in Figure 1.2.

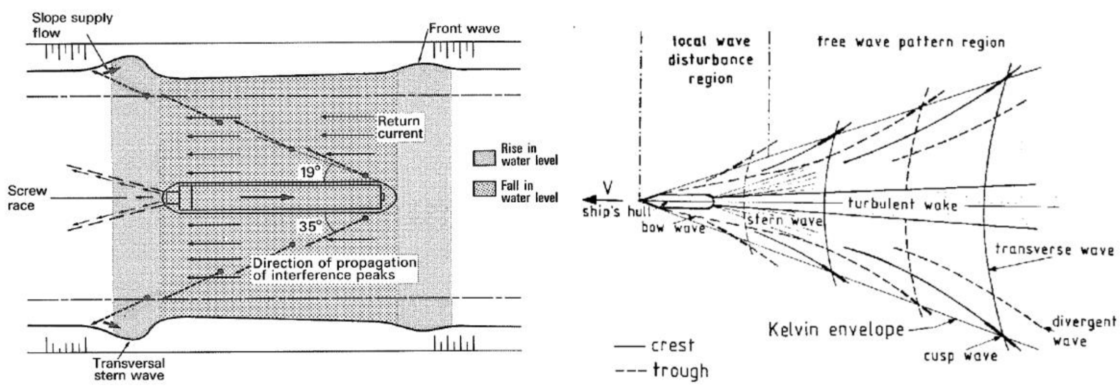


Figure 1.2: Schematics of the Primary (left, from PIANC, 1987) and Secondary (right, from CRISP, 2001) Waves Induced by Ship Motion

As the ship travels through the water, water flows past the vessel hull in the opposite direction of travel, known as the return current. This return flow causes the water level along the vessel's length to fall in order to maintain the total head (energy) constant and as a result the water level around the vessel is lowered. This water level depression is referred to as the primary or drawdown wave. In front of the vessel the water surface is elevated by the approaching vessel, known as the front waves, while in the transition between the water level depression and normal water level at the stern of the vessel is known as the transversal stern wave. When a vessel is in deep, open water the primary waves is of relatively small magnitude, however a vessel traveling at speed within a confined channel can generate a large drawdown wave. Further, this primary wave can interact with the channel slopes to shoal and propagate away from the vessel, as is observed at the Port of Corpus Christi.

Secondary waves are generated by surface oscillations at the bow and stern of the moving vessel that propagate away from the vessel as free surface waves. The free wave pattern spreads out from the vessel with decreasing wave amplitudes due to dispersion and diffraction and consists of symmetrical sets of diverging waves that move obliquely out from the sailing line and a single set of transverse waves that move in the direction of the sailing line. Two sets of diverging waves are generated (bow and stern).

The dominance of either the primary or secondary waves (in terms of magnitude) is highly dependent on the vessel (including draft), speed through water and waterway characteristics, however through the Corpus Christ channel primary waves are understood to be the dominant of the two and as a result produce the largest waves at the shoreline. This is due to the confined nature of the channel and large displacement of the tankers that amplify the primary wave, while typical vessel speeds for Suezmax and VLCCs are such that the secondary waves are lower magnitude and dissipate quickly as they propagate away from the vessel. Figure 1.3 presents examples along the Corpus Christi channel of tanker generated primary waves breaking at the shoreline. Figure 1.4 presents secondary wave patterns from a tanker in the Corpus Christi channel, indicating how the shorter period wakes dissipate relatively quickly away from the vessel.

Figure 1.3: Examples of Tanker Generated Primary Waves Breaking along the Shoreline of Corpus Christi Channel

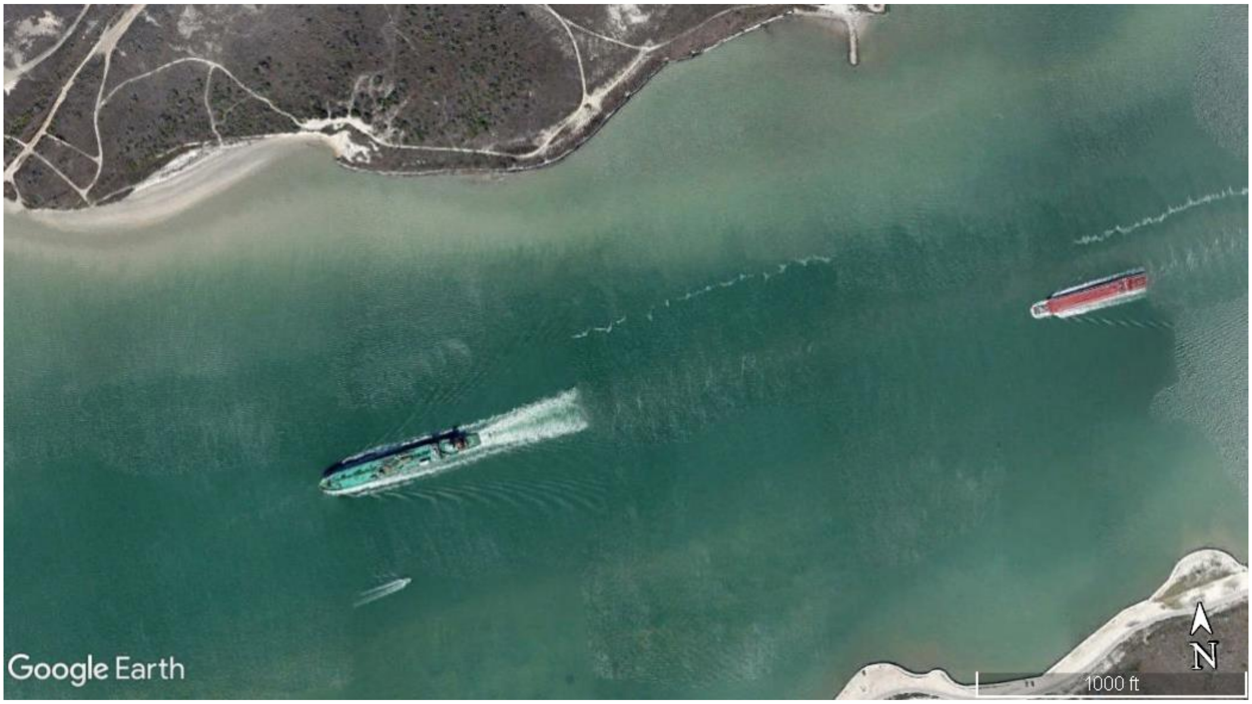


Figure 1.4: Example of Tanker Generated Secondary Waves in the Corpus Christi Channel

1.4 Report Outline

This report provides a brief description of the overall study methodology, model results and outcomes. The numerical models that are used to quantify the vessel generated hydrodynamics and shoreline response are summarized in Section 2. Input data to the vessel wake analyses are considered in Sections 3, including channel dimensions, vessel dimensions and vessel speeds. The vessel wake results are provided in Section 4 focusing on the vessel induced hydrodynamics. Sections 5 and 6 consider the associated bed change and shoreline responses by comparing the pre and post project scenarios. Conclusions are provided in Section 7.

2. Numerical Model Descriptions

Two numerical models were applied in these analyses. Vessel hydrodynamics, including the primary and secondary waves around the moving vessels, have been simulated in FUNWAVE with the results applied as boundary conditions to a series of XBEACH profile models to quantify the shoreline impacts to the change in vessel traffic.

2.1 FUNWAVE

FUNWAVE–TVD is the Total Variation Diminishing (TVD) version of the fully nonlinear Boussinesq wave model (FUNWAVE) developed by Shi et al. (2012). The central module of FUNWAVE solves the Boussinesq equations and also takes care basic functions such as wavemaker, wave breaking, sponge layers, boundary conditions and model input and output. More recently a ship-wake generation model has been implemented (Shi et al., 2018), that applies a moving vessel as either a pressure or slender source term in the model. While the FUNWAVE model allows various options to describe the shape of the vessel, Baird implemented an additional pressure source term that reads in a detailed vessel hull shape, such that the shape of the bow and stern for specific vessels are more accurately described in the simulation. Figure 2.1 presents an example of a VLCC hull shape as described in the model by Baird's updated source term.

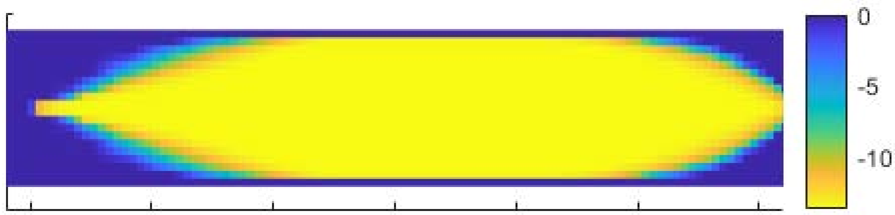


Figure 2.1: Example of a pressure field describing a VLCC hull shape in the FUNWAVE model

One notable limitation in the Boussinesq equations is the propagation of short period waves in deep water. For the specific case of large tankers at Port of Corpus Christ, modeling the channel and vessel at actual depth (i.e., >50ft) means that the short period secondary waves generated by the moving vessel cannot propagate away from the vessel due to the depth limitation of the Boussinesq equations.

To this end, a decoupled modeling approach has been adopted for this study, whereby the primary and secondary waves are modeled in separate simulations and the results combined into a post-processed result. The primary wave simulations are modeled at full depth, which is critical in quantifying the primary drawdown magnitude that is dependent on the relative depth of the vessel in the water column and the geometry of the channel. To ensure model stability for deep draft vessels with low underkeel clearance the 'Deep Draft Module' in FUNWAVE was activated for the primary wave simulations. The secondary wave simulations are modeled with a maximum depth of 15ft, and vessel draft that is proportional to the actual draft to water depth. This capping of the water depth to 15ft allows the short period secondary waves generated by the vessel (with periods less than 4s) to propagate in the model and produce the wake field.

FUNWAVE has a sediment transport module, that includes a suspended sediment advection/diffusion and bedload model, which was used to model sediment transport and bed morphology changes that occur during ship movements. The sediment transport model was applied in the primary wave simulations only.

The FUNWAVE model extent is presented in Figure 2.2. The model extent covers the full length of channel from the MODA terminal at Ingleside to past the Harbor Island terminals at 5m resolution for the primary wave simulations and 1m resolution for the secondary wave simulations. This extent covers the channel margin and unarmored shorelines that may be affected by a change in vessel traffic as a result of channel deepening project.

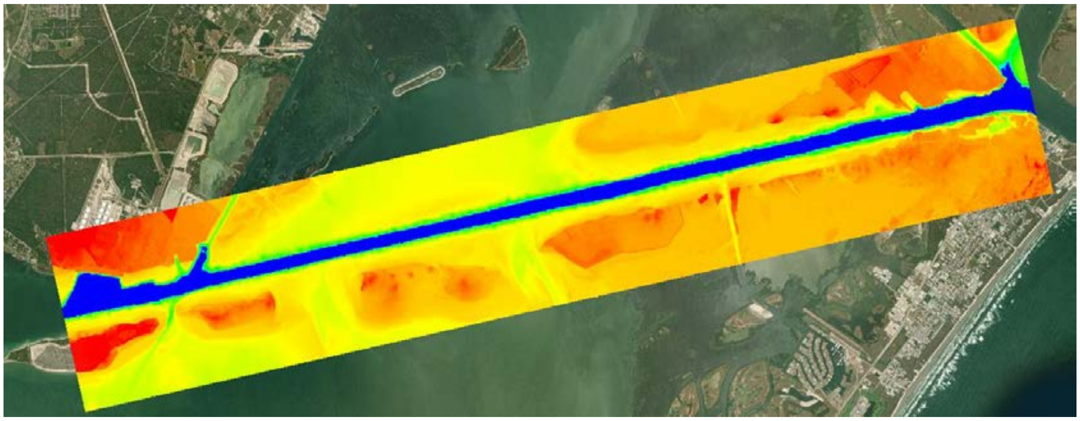


Figure 2.2: Extent of the FUNWAVE domain with color scale based on model depths for the existing channel condition

2.2 XBEACH Model

Shoreline changes as a result of ship generated hydrodynamics has been assessed using the XBEACH model (Roelvink et. al., 2009). The XBEACH model has been run in profile mode (2DV) and can accommodate the non-linear wave profile time series from the FUNWAVE simulations as boundary conditions and is well suited to describe the shoreline evolution as a result of run-up and drawdown at the shoreline from vessel wake.

XBEACH profiles were setup for 9 shoreline profiles along the channel length where ship hydrodynamic effects are observed as being most significant, informed by the vessel wake modeling and located at natural shoreline areas deemed most at risk due to the proximity to the channel deepening. Figure 2.3 presents the locations of the profile models.

Figure 2.3: Location of the XBEACH profile models (red) along the Port of Corpus Christi Channel

3. Physical Data Overview

The following section summarizes the relevant data and assumptions adopted in the vessel wake analyses. To confirm and validate the data and assumptions, Baird facilitated a workshop in May 2021 with pilots from the Port of Corpus Christi to discuss the vessel transits and maneuvers that are undertaken for both inbound and outbound vessel movements within the port. This ensured that the adopted data for vessel transits and tug operations for these studies were consistent with actual operations at the port.

3.1 Channel Dimensions

The length of channel assessed for the vessel wake analysis covers channel areas that are to be modified by the channel deepening project. It is noted that the USACE is currently embarking on a channel maintenance project along the full length of the Corpus Christi channel that will deepen the navigable depth to 54 feet. The channel deepening project will further deepen the channel to at least 75 feet from the Harbor Island Terminals, through the Jetty Channel to offshore (see Figure 1.1). Figure 3.1 provides a typical section of the channel deepening project at the eastern end of the Corpus Christi channel. The stated bed level that is assumed in the modeling and analysis is the authorized bed level. The channel will be dredged deeper to accommodate sedimentation that is expected to occur up to the guaranteed bed level before subsequent maintenance dredging occurs (i.e., advanced maintenance dredging).

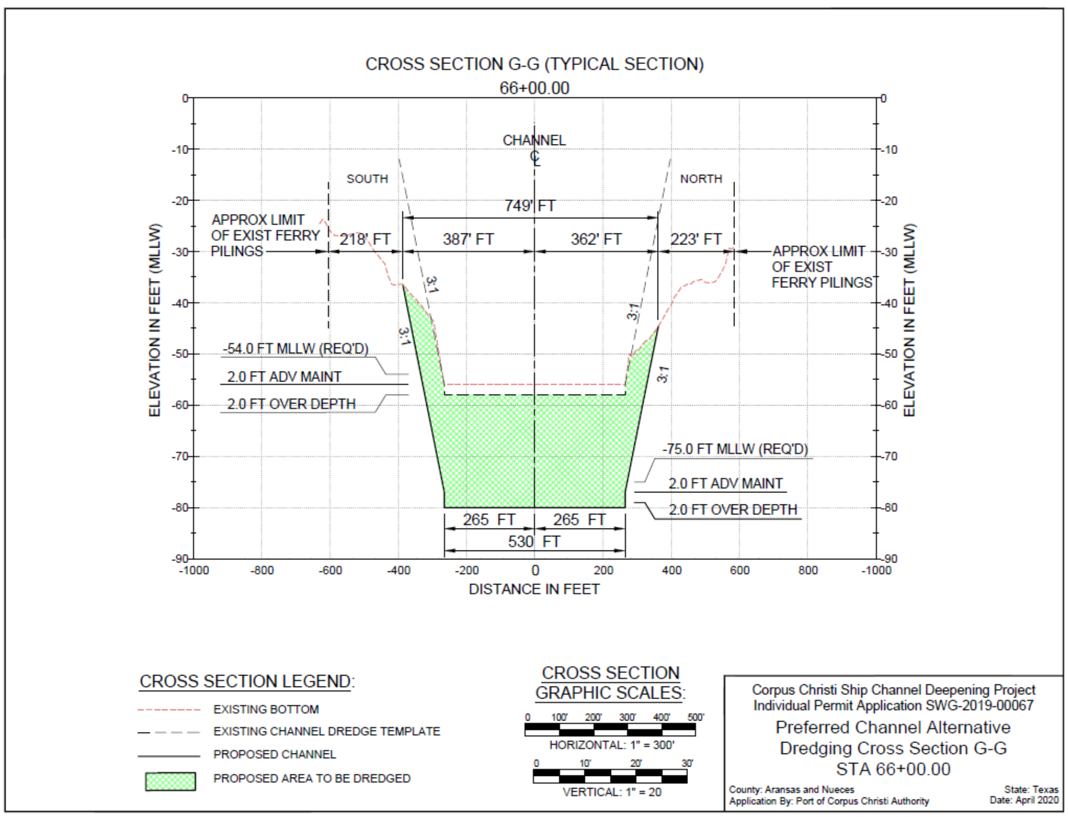


Figure 3.1: Design Section for the Corpus Christi Channel Deepening Project in the Corps Christi Channel (see Figure 1.1 for section location)

The vessel wake analysis has therefore been completed on two channel scenarios, as follows:

- Future Without Project (FWOP): An existing channel configuration following the maintenance dredging campaign with a navigable depth of 54 feet along the full length of the channel.
- Future With Project (FWP): A future channel configuration that includes the channel deepening project.

Figure 3.2 compares the plan bathymetry of the two channel scenarios.

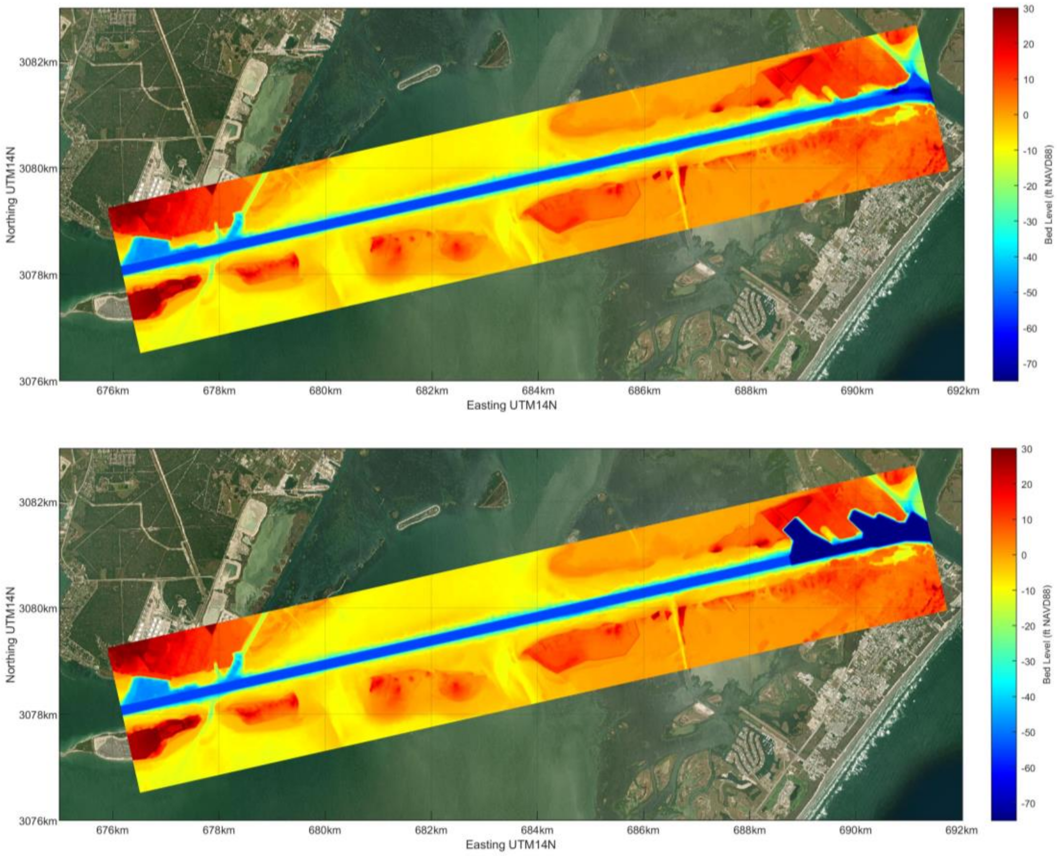


Figure 3.2: Channel Bathymetry from the FUNWAVE model for the Future Without Project (top) and Future With Project (bottom) Scenarios.

Bathymetric data for the vessel wake models was derived from the Cooperative Institute for Research in Environmental Sciences (CIRES), Continuously Updated Digital Elevation Model (CUDEM) - 1/9 Arc-Second Resolution Bathymetric-Topographic Tiles (v2020). Elevations were converted to the North American Vertical Datum of 1988 (NAVD 88) at Port Aransas. The horizontal coordinate system of Universal Transverse Mercator 14-North (UTM-14N) was used for all bathymetry data.

3.2 Vessel Dimensions

The design vessel for the channel deepening project is a 306k DWT VLCC laden to a draft of 68 ft. However, loading of the VLCC to the 68 ft draft will at times rely on a reverse lightering operation using a combination of Suezmax and VLCCs from the MODA terminal at Ingleside that will be limited in draft to 52ft due to the 54ft channel depth along the Corpus Christi channel. As such, two vessels were assessed in this vessel wake study with their dimensions summarized in Table 3.1.

Table 3.1: Vessel Dimensions

Dimension	Suezmax	VLCC
Length Over All (ft)	866.1	1089.2
Width (ft)	157.5	190.3
Ballast Draft (ft)	26.2	31.2
Laden Draft (ft) *	52.0	52.0

* Laden draft is depth restricted due to 54ft channel

3.3 Vessel Tracks and Speeds

Automatic Identification System (AIS) data of 50 large tanker inbound and outbound transits between the years 2019 and 2020 to/from the terminal at Ingleside were analyzed to quantify typical vessel tracks and speeds under existing operations. The inbound tracks with vessel speed (over ground) are shown in Figure 3.3. Vessel speed is generally maintained on an inbound transit around the channel bend before a slight reduction in speed past Port Aransas and then increasing speed down the length of the channel until again reducing for berthing at Ingleside. Departure tracks are presented in Figure 3.4, showing slower speeds along the channel and bend, with a more pronounced slow down past Port Aransas. It is noted that since these are historic data the maximum draft would be 45 ft for outbound transits.

The AIS track data was further analyzed at a point approximately halfway along the Corpus Christi channel to define lower, mean and maximum vessel speeds, as presented in Table 3.2. Vessel tracks that matched the lower, mean and maximum vessel speeds at the analyzed point were then selected as a basis for the FUNWAVE passing vessel analysis. That is, the vessel tracks and speed profiles applied in the modeling were based on actual measured track data.

Figure 3.3: Tracks and speed profiles of inbound transits to the Ingleside terminal from AIS data for VLCCs and Suezmaxs (2019 – 2020)

Figure 3.4: Tracks and speed profiles of outbound transits from the Ingleside terminal from AIS data for VLCCs and Suezmaxs (2019 – 2020)

Table 3.2: Vessel Speeds (kts) at Channel midpoint from analyzed AIS data for VLCC and Suezmax (2019-2020)

Direction of Travel	25th %tile	Mean	Maximum
Inbound	8.0	8.9	12.0
Outbound	7.5	8.1	10.5

3.4 Metocean Conditions

It is noted that the results from the modeling within this assessment are intended to provide an estimate of potential shoreline and channel bed level changes as a result of the project, and therefore will not quantify other processes (i.e., wind waves, storm surge etc.) which are not altered by the project but still contribute to the overall shoreline and sediment transport dynamics over short, medium and long time periods. As such, no wind, waves or currents have been applied in the FUNWAVE or XBEACH modeling.

Tides in the Corpus Christi channel have a tidal range of 1.04 ft, with a typical diurnal range of 0.9ft (MLW to MHW at Port Aransas, gauge 8775237). Given the relatively small tidal range, a fixed water level of Mean Sea Level (MSL), being +0.5ft relative to NAVD88, was applied to all modeling.

3.5 Sediment Data

A suite of sediment sampling data was obtained by Baird along the length of the Corpus Christi Channel. An example of the available data is presented in Figure 3.5. From the channel sedimentation study (also performed by Baird and documented in a separate report) it is noted that this section of the channel is not the main area for sedimentation, and therefore samples are more likely to represent the native sediment which appear to be approximately 50% sand, 25% silt and 25% clay.

Based on this assessment the following sediment parameters were specified in the FUNWAVE and XBEACH modeling, noting the bed was described by single sediment fraction with shear stress values representative of mixed beds:

- Medium Sediment Diameter, D_{50} = 0.12mm
- Dimensionless Sediment Size = 3
- Critical Shields parameter for suspended load, θ_{cr} = 0.091 (dimensionless)
- Critical Shields parameter for bedload, θ_{bcr} = 0.08 (dimensionless)
- Porosity of sediment, n = 0.37
- Settling velocity, wf = 0.02m/s

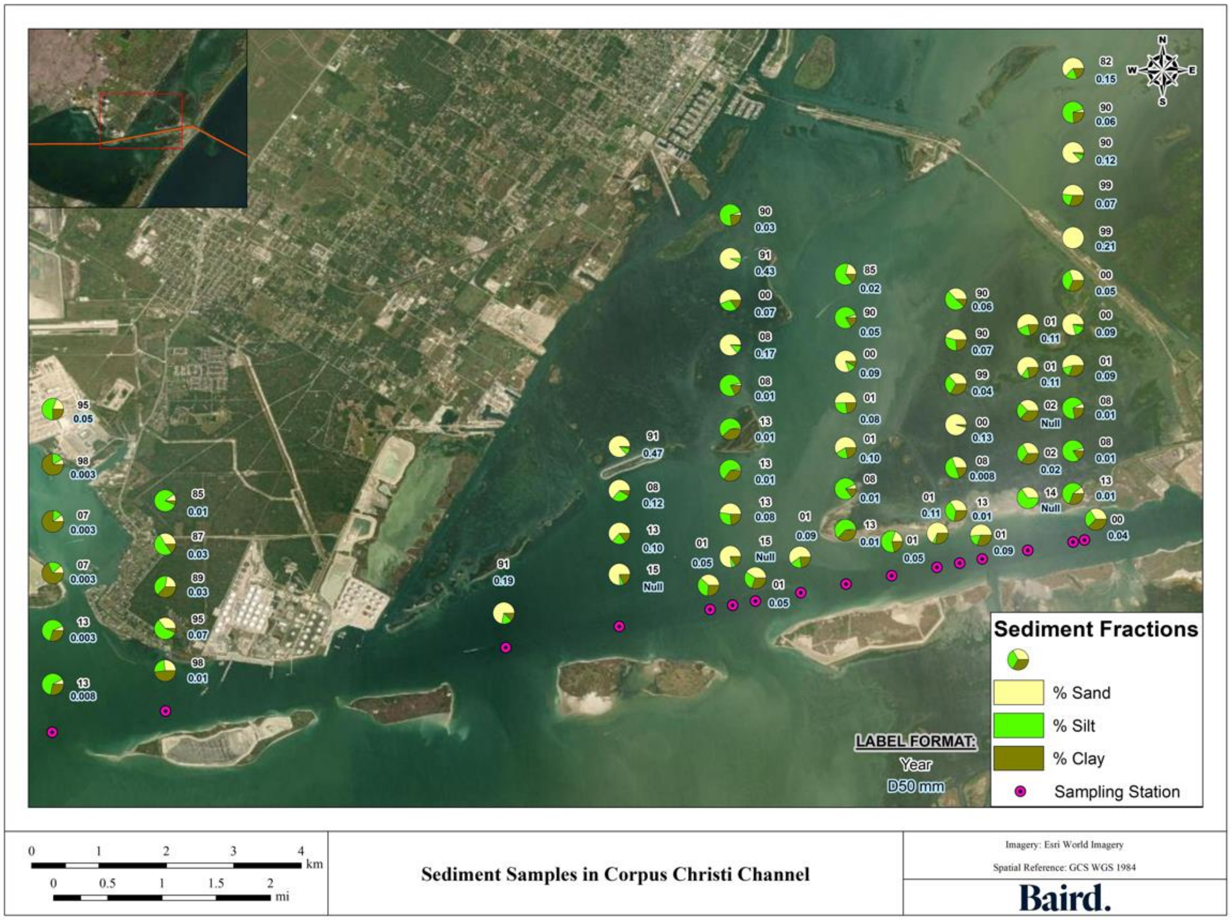


Figure 3.5: Example summary of available sediment sampling data in the Corpus Christi Channel

3.6 Pilot Workshop (May 2021)

To confirm the vessel and tug maneuvering on typical inbound and outbound transits and validate the analyses of vessel speeds, Baird facilitated a workshop with pilots from the Port of Corpus Christi. The pilots provided invaluable insight into vessel maneuvering and the navigation hazards that are dealt with at the port. At the conclusion of that meeting the pilots endorsed the assumptions made by Baird. One notable clarification from the pilots was the vessel speeds that would likely be achieved with a partially laden (to 52 ft) VLCC and Suezmax on an outbound transit, the maximum value from the AIS data was considered unrealistic for these design vessels with a 52ft draft. As such, Baird capped the outbound speed of the Suezmax and VLCC to the mean value (8.1kts) for the vessel wake analyses.

4. Vessel Wake Modeling

As noted previously, vessel wakes have been quantified using the FUNWAVE model system. Due to inherent limitations of the Boussinesq equations in propagating short period waves in deep water, a decoupled modeling approach has been adopted for this study, whereby the primary and secondary waves are modeled in separate simulations and the results combined into a post-processed result (see Section 2.1 for discussion). The following section provides a summary of the results for primary and secondary waves, including a benchmarking of the FUNWAVE model outputs.

4.1 Benchmarking of FUNWAVE Model Results

No water level data, of sufficient temporal resolution, for passing vessel effects was available to this study that would allow a direct validation of vessel wakes from the FUNWAVE model outputs. To this end, a benchmarking exercise was completed where the FUNWAVE model results were compared to commonly applied empirical and numerical models for vessel wakes. The intention of this exercise was to provide assurance as to the accuracy of the FUNWAVE model results. Additionally, the results were reviewed by local pilots and mariners to qualitatively validate the results.

Primary (drawdown) wave results from FUNWAVE were compared against results from the PASSCAT (potential flow) model and empirical relationships of Schiereck (2001) and Almstrom & Larson (2020). The results are summarized in Table 4.1, with a comparison in the water level surface around the vessel visually compared in Figure 4.1 from the FUNWAVE and PASSCAT model. Good agreement of the FUNWAVE model was found against approaches that define the confined channel in their estimate (i.e., PASSCAT, Almstrom & Larson, 2020).

Table 4.1: Comparison of Primary Wave Estimates using alternate empirical and numerical methods (in feet below SWL at 165ft from vessel hull)

Method	Vessel Speed	
	8 knots	12 knots
Schiereck (2001)	0.98	2.62
Almstrom & Larson (2020) ^	1.92	4.87
PASSCAT	1.41	3.77
FUNWAVE	1.31	3.94

^ derived from passenger vessels

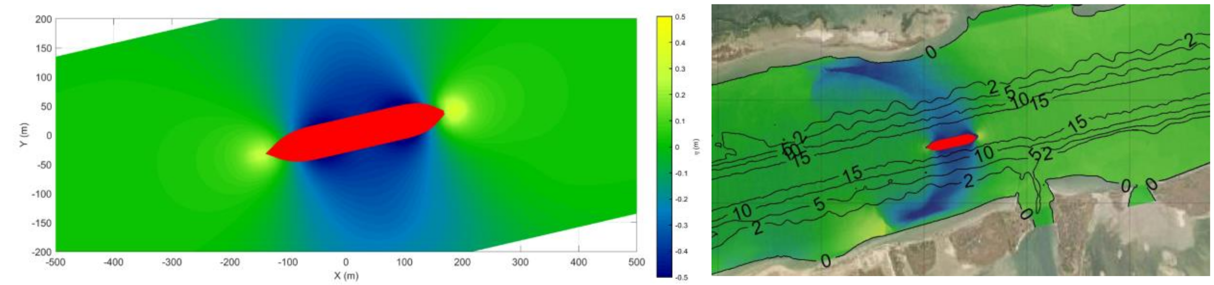


Figure 4.1: Visual Comparison of the Primary Wave Field around a VLCC vessel at a speed of 8 knots in the Corpus Christi Channel using the PASSCAT (left) and FUNWAVE (right) models

Secondary wave results from the FUNWAVE model were compared against the MICHLET potential flow solver (Cyberiad, 2015) and empirical relationships of Sireli (2002) and PIANC (1987), for a flatbed idealized case. Reasonable agreement was achieved when adopting a depth limited FUNWAVE model setup (as described in Section 2.1), as summarized in Table 4.2. A visual comparison of the FUNWAVE and MICHLET results are presented in Figure 4.2. It is noted that at speeds of 8-9 knots, the primary wave estimates (Table 4.1) are notable larger than the secondary waves (Table 4.2).

Table 4.2: Comparison of Secondary Wave Estimates using alternate empirical methods (in feet below SWL at 165ft from vessel hull)

Method	Vessel Speed		Wave Period
	8 knots	12 knots	
Sireli (2001)	0.16	1.05	2-4 sec
PIANC (1987)	0.20	1.31	3-4 sec
MICHLET	0.26	2.76	3-4 sec
FUNWAVE ^	0.15	1.02	3-4 sec

^ depth-limited model setup

In addition to the benchmarking exercise, FUNWAVE model results specific to the Corpus Christi channel were presented and discussed with Captain Jay Rivera (Riben Marine), a former pilot at the Port of Corpus Christi, to provide a sense check and anecdotal validation of the model outputs. Captain Rivera's review noted the realistic nature of the primary wave, in terms of both drawdown magnitude next to the vessel and the shoaling, propagation, breaking and reflections along the shorelines adjacent to the channel.

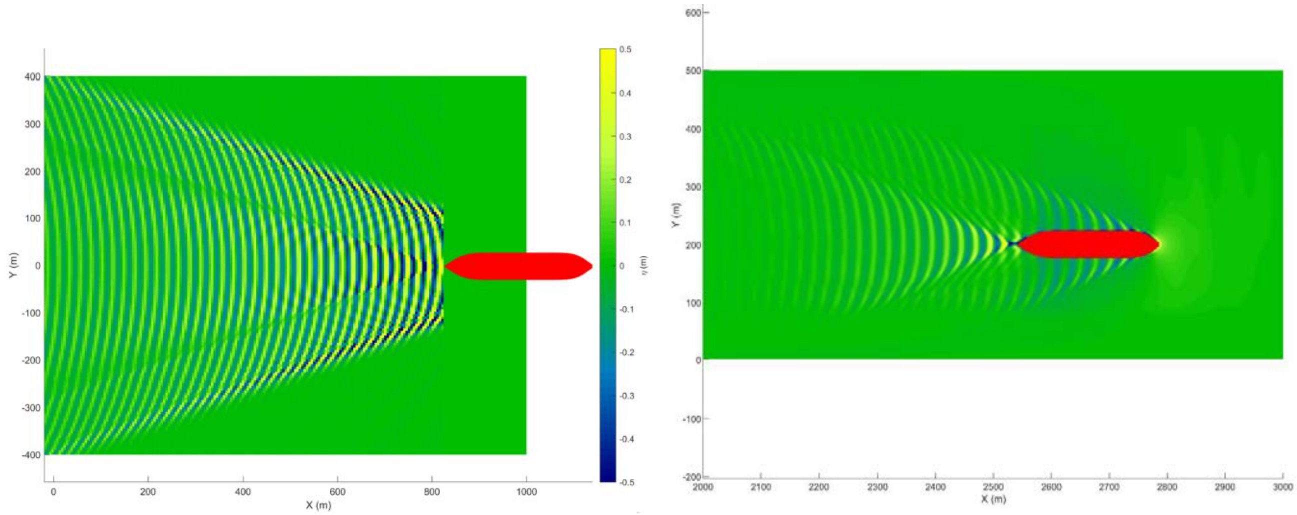


Figure 4.2: Visual Comparison of the Secondary Wave generated from a VLCC vessel at a speed of 12 knots over an idealized flatbed using the MICHLET solver (left) and FUNWAVE model (right)

4.2 Model Scenarios

A suite of model scenarios was completed in FUNWAVE, each describing a single vessel transit of the Corpus Christi channel. Table 4.3 provides a summary of the model scenarios, noting that each were run for a Suezmax and VLCC vessel for both the FWOP and FWP channel conditions. In total 40 simulations were completed.

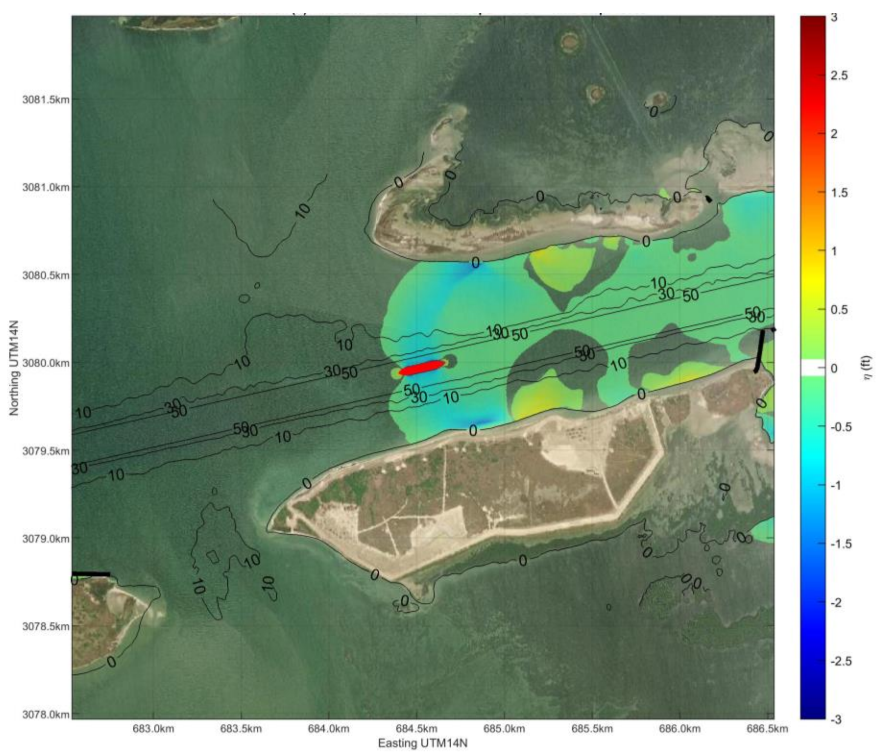
Table 4.3: Summary of FUNWAVE model scenarios. Each scenario was modeled for Suezmax and VLCC Vessels for the FWOP and FWP channel conditions.

Vessel Wake Type	Sediment Transport / Morphology	Direction of Travel	25^{th} %tile	Mean	Maximum
Primary	Yes	Inbound	Y	Y	Y
		Outbound	Y	Y	Y
Secondary	No	Inbound	-	Y	Y
		Outbound	-	Y	Y

Example of spatial outputs from the FUNWAVE modeling for primary and secondary wave scenarios is presented are follows:

- Figure 4.3: Suezmax Primary Wave, Mean Speed Profile, for Inbound and Outbound.
- Figure 4.4: Suezmax Secondary Wave, Mean Speed Profile, for Inbound and Outbound.
- Figure 4.5: VLCC Primary Wave Mean Speed Profile, for Inbound and Outbound.
- Figure 4.6: VLCC Secondary Wave Mean Speed Profile, for Inbound and Outbound.

It is noted that there is a primary wave response around the vessel, albeit small, in the secondary wave simulations, which was filtered out of the timeseries results in post-processing prior to application to the XBEACH profile models.



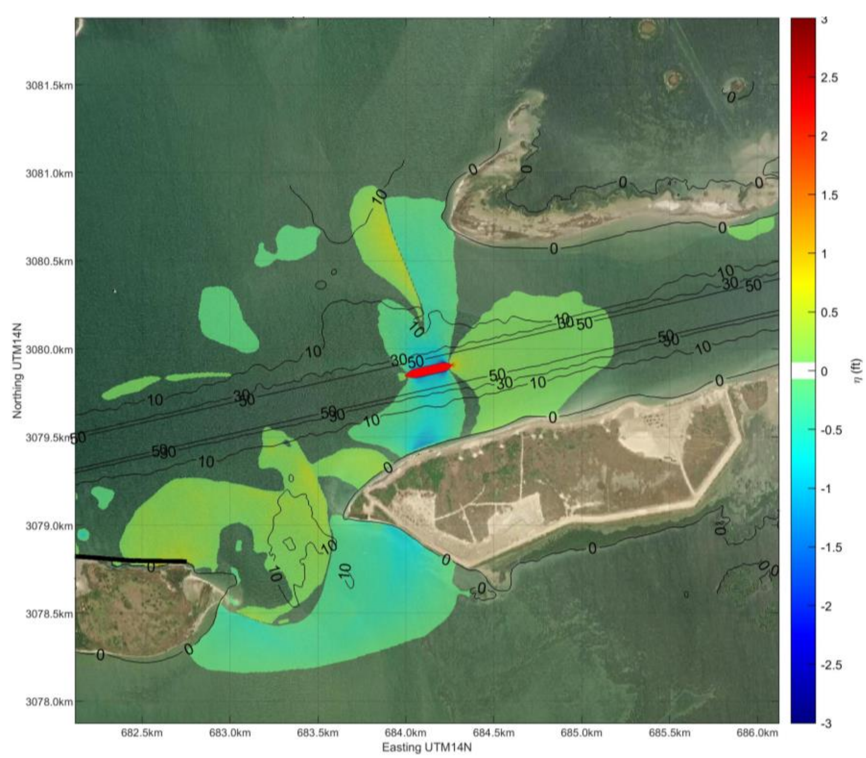


Figure 4.3: Example Primary Wave Field for an Inbound (left) and Outbound (right) Suezmax Vessel (Mean Speed) Scenario (Water Level Surface in ft relative to SWL)

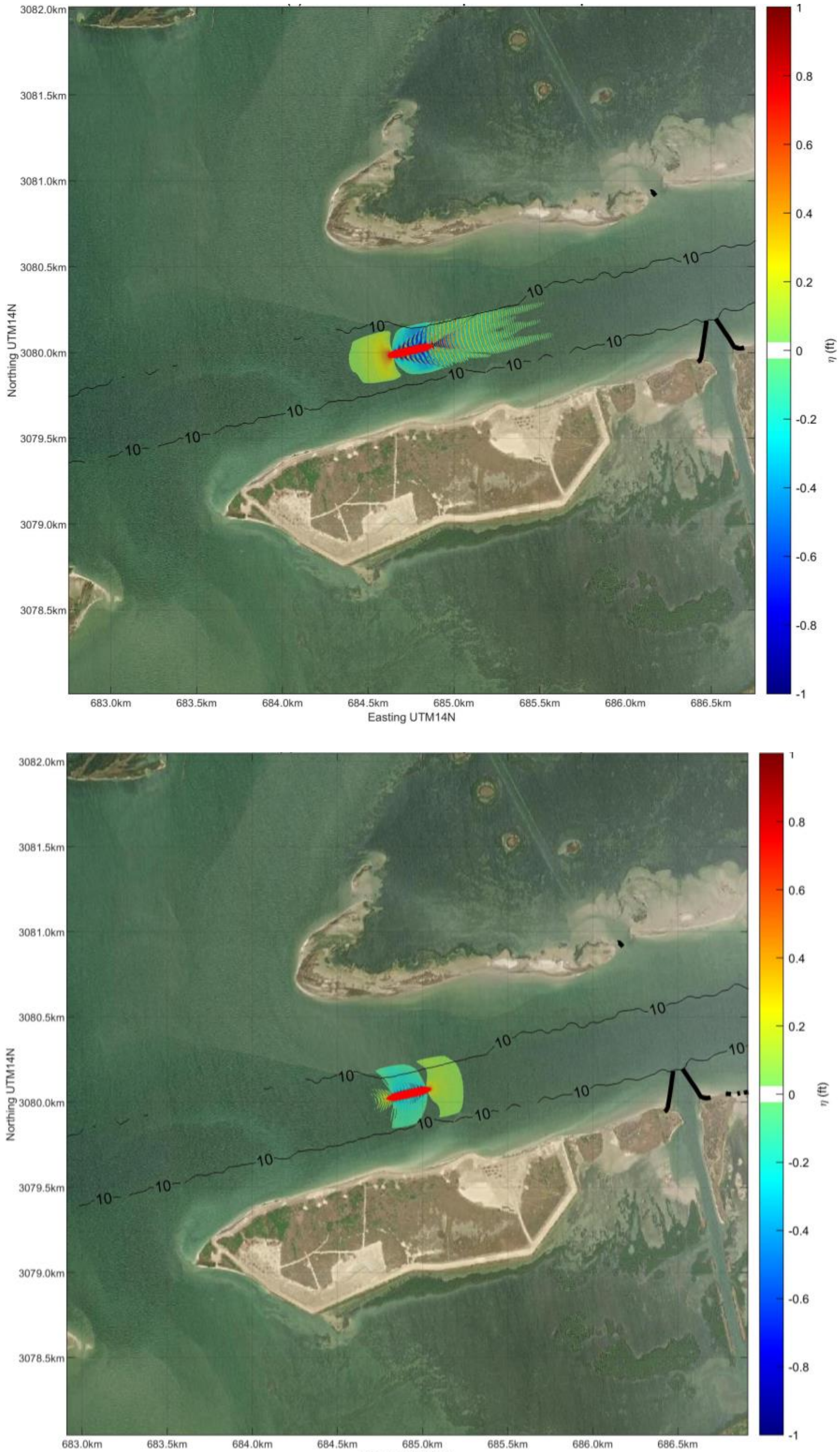


Figure 4.4: Example Secondary Wave Field for an Inbound (left) and Outbound (right) Suezmax Vessel (Mean Speed) Scenario (Water Level Surface in ft relative to SWL)

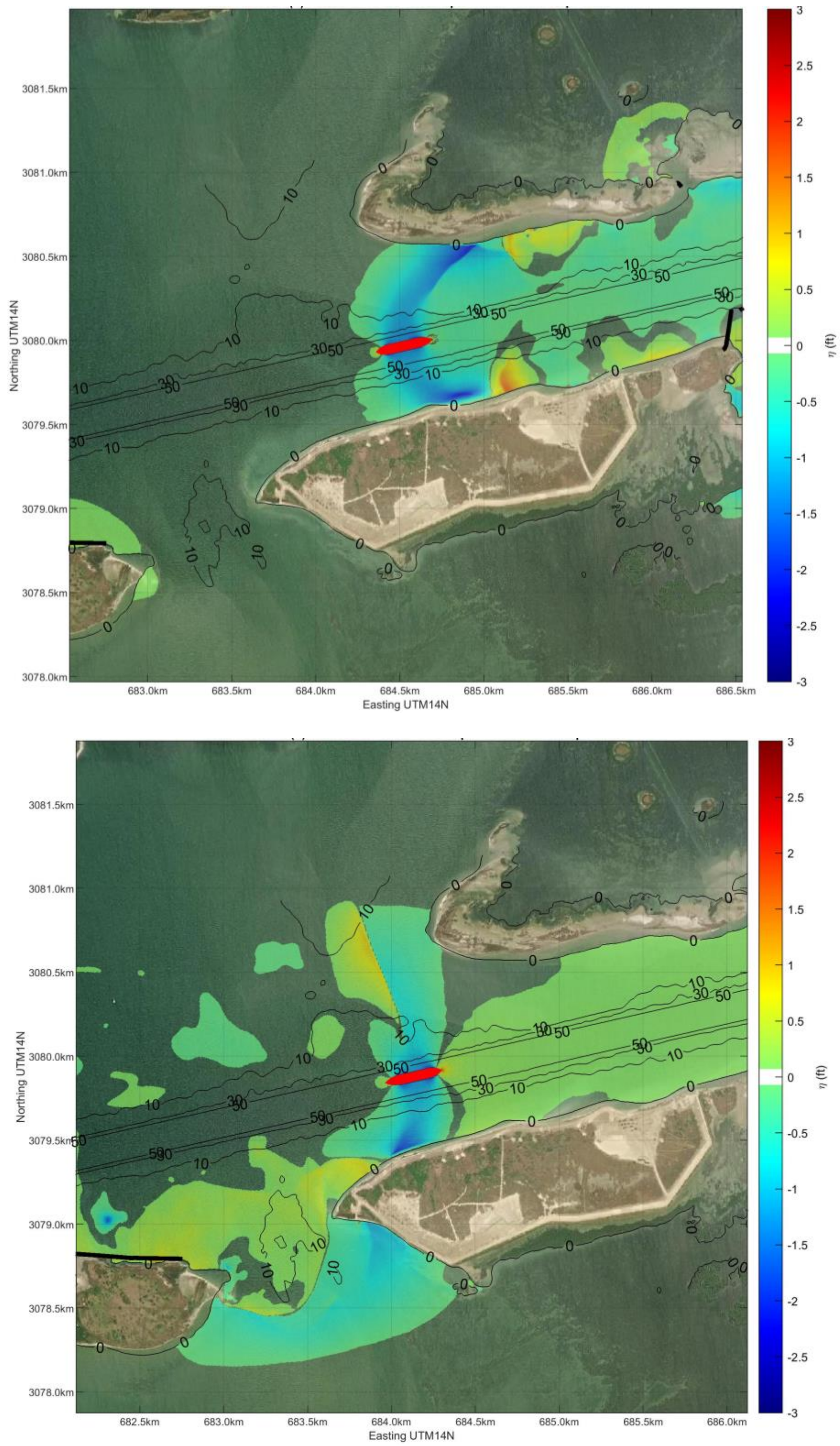


Figure 4.5: Example Primary Wave Field for an Inbound (left) and Outbound (right) VLCC Vessel (Mean Speed) Scenario (Water Level Surface in ft relative to SWL)

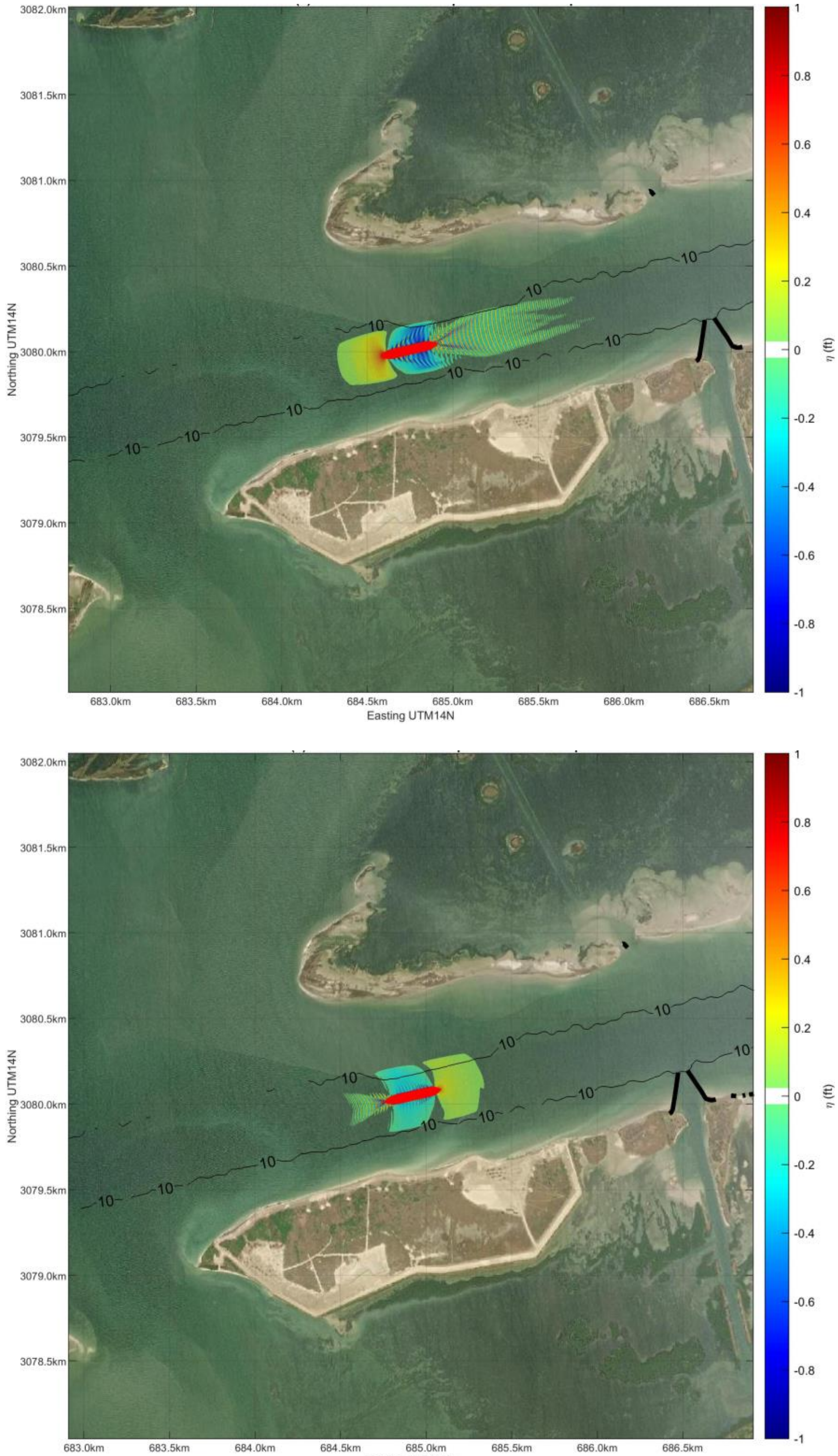


Figure 4.6: Example Secondary Wave Field for an Inbound (left) and Outbound (right) VLCC Vessel (Mean Speed) Scenario (Water Level Surface in ft relative to SWL)

5. Bed Change Analysis

To assess the impact to bed change as a result of the channel deepening project, comparison of bed change outputs from the FUNWAVE model were assess for FWOP and FWP scenarios. In addition, an assumption regarding a change in vessel traffic as a result of the project was needed. Such guidance was provided by USACE in consultation with the Port of Corpus Christi, indicating the projected vessel traffic for the year 2022 would form the basis for the FWOP scenario.

For 2022, the vessel traffic projection is as follows:

- 120 Aframax
- 95 Suezmax
- 110 VLCC

An annual growth rate of 5% to the VLCC vessel traffic is projected and the year 2023 is to be adopted for the FWP scenario. This would result in an increase in VLCC numbers to 116 per year.

5.1 Annualized Bed Change

The bed change results from the individual (single transit) primary wave simulations have been post-processed and combined based on the projected vessel traffic numbers to produce an annualized bed change outcome. The annualized results are a weighted average of the three vessel speed scenarios, with a higher weighting given to the mean speed scenario (min 20%, mean 60%, max 20%), inbound and outbound are then combined (as each vessel will make two transits of the channel; inbound and outbound) and then multiplied by the vessel count. Results are presented separately for VLCC and Suezmax. Aframax vessels have not been considered as part of this assessment, however the results would be consistent with the Suezmax vessels.

Annualized bed change results are presented in Figure 5.1 to Figure 5.4, noting:

- Suezmax results compare the FWOP channel scenario against the FWP channel scenario with no change in traffic numbers.
- VLCC results compare the FWOP channel scenario with 2022 traffic projections against the FWP channel scenario with 2023 traffic projections (5% increase in VLCCs)

A comparison of the FWOP and FWP channel scenarios for both the Suezmax and VLCC indicate that there would be very limited change in bed morphology as a result of the project. In general, the bed morphology results suggest a scouring pattern on the channel shoulders with sedimentation along top of channel bank. No sedimentation is observed within the channel width. While the annualized bed change results indicate very similar outcomes, notable differences include:

- Nearshore shallow area adjacent to Pelican Island (on the southern side of channel) shows greater deposition/erosion magnitudes for the FWP case. This outcome is considered a result of a marginal change in the characteristic of the primary wave for inbound vessels due to the channel deepening further to the east. The change is localized, and it is noted that the shoreline in this area is armored.
- Shallow areas around entranced to the new terminals at Harbor Island show localized areas of increased scour, which is a direct result of the terminal developments. This outcome should be considered as part of terminal design (i.e., armoring may be deemed necessary).

Overall, the annualized bed change results indicate that there would be minimal additional impact to seabed morphology as a result of the channel deepening project.

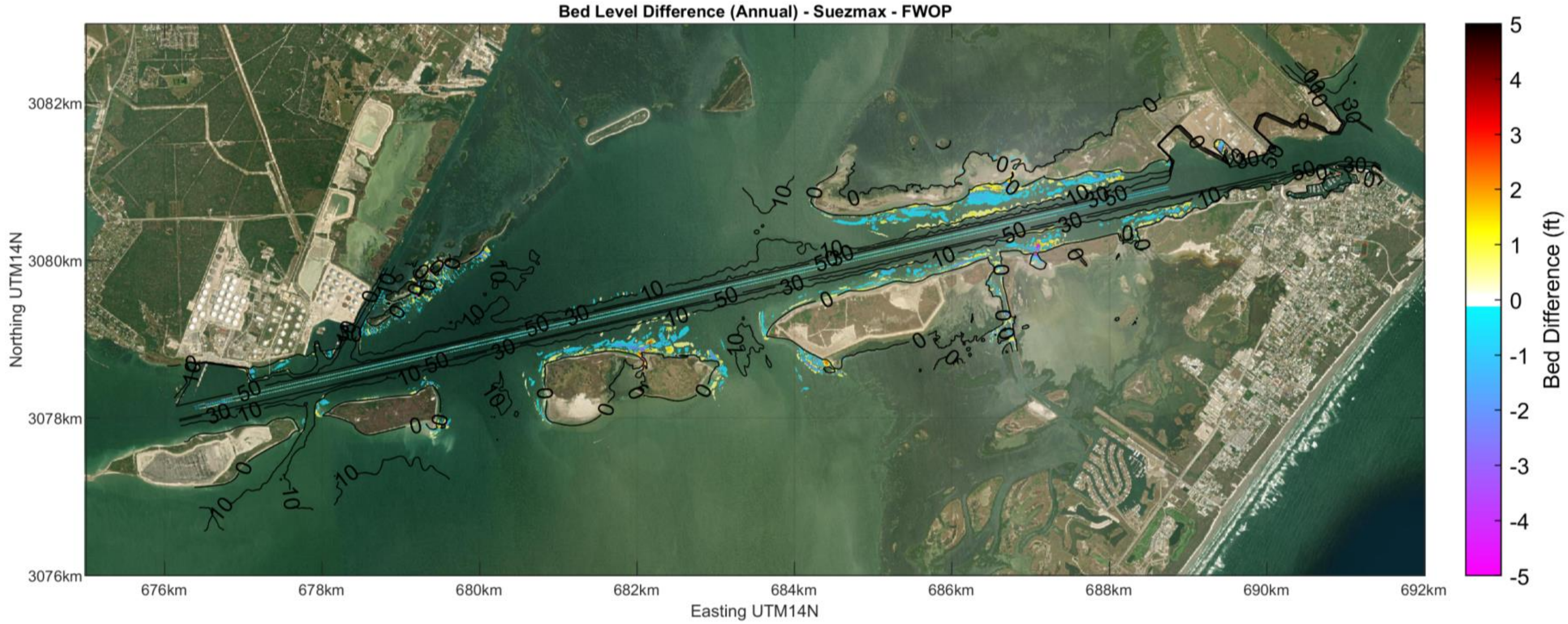


Figure 5.1: Annualized Bed Level Change under Future Without Project Channel Conditions for Suezmax vessel traffic

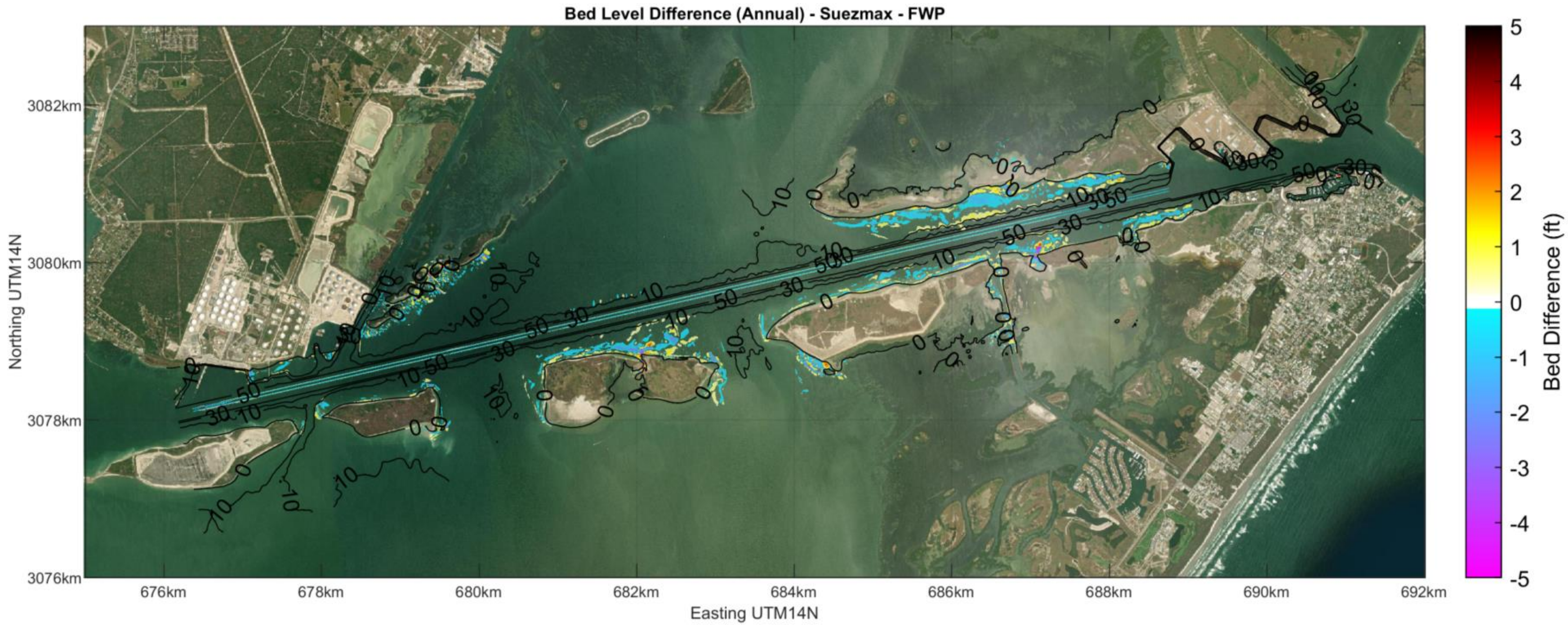


Figure 5.2: Annualized Bed Level Change under Future With Project Channel Conditions for Suezmax vessel traffic

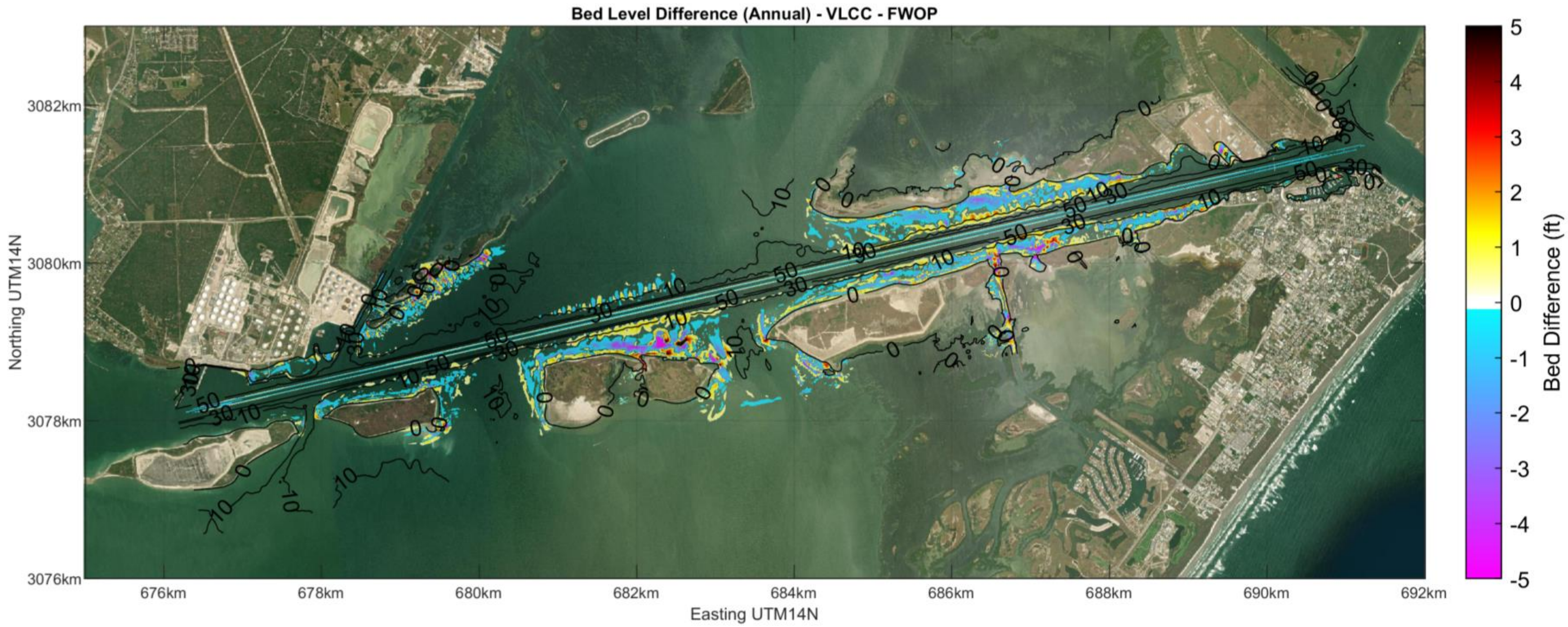


Figure 5.3: Annualized Bed Level Change under Future Without Project Channel Conditions for VLCC vessel traffic

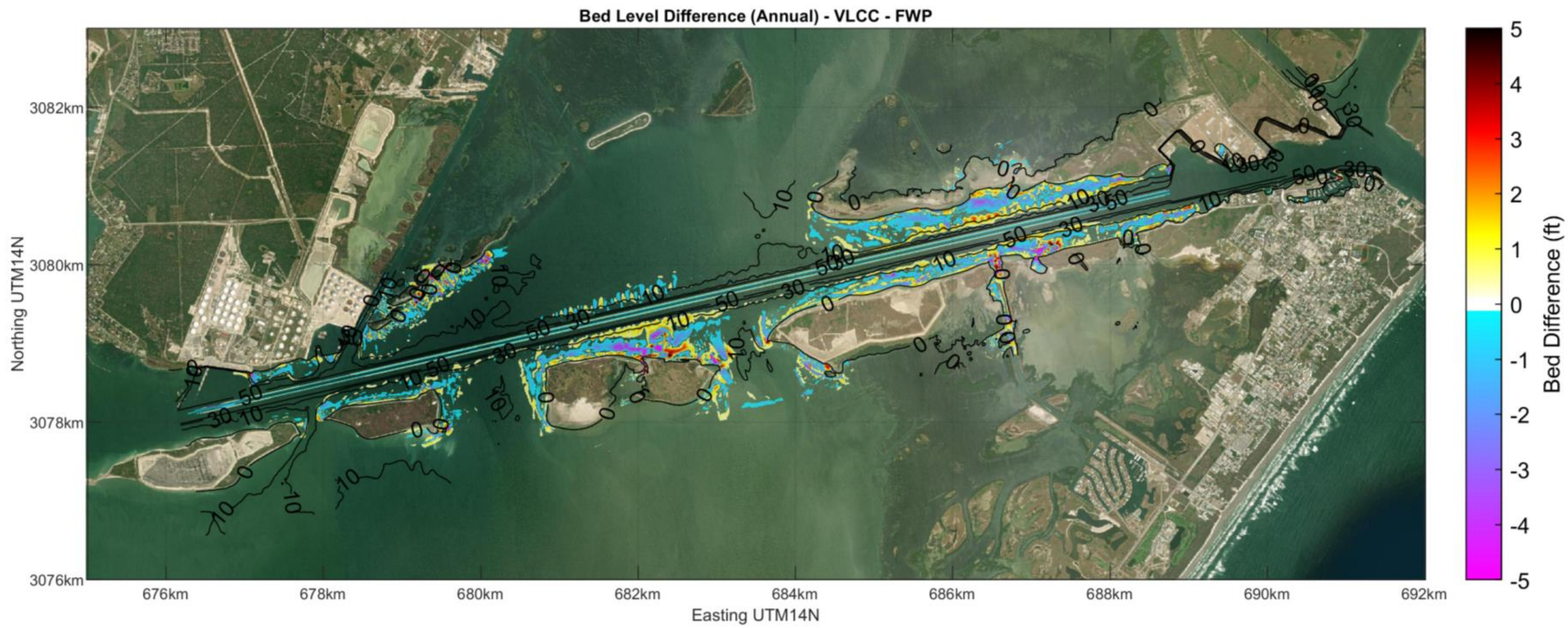


Figure 5.4: Annualized Bed Level Change under Future With Project Channel Conditions for VLCC vessel traffic

6. Shoreline Change Analysis

Shoreline changes as a result of ship generated hydrodynamics has been assessed using the XBEACH model along a series of shoreline profiles, located by identifying natural shoreline areas deemed most at risk from consideration of the vessel wake modeling outputs. Annualized shoreline change adopted the same assumptions regarding vessel traffic as done for the bed change analysis and compared the FWOP and FWP scenarios through synthesized yearlong simulations of vessel wakes. The results from the XBEACH modeling provide an estimate of potential shoreline changes as a result of the project but do not quantify other processes (i.e., wind waves, storm surge etc.), which are not altered by the project but still contribute to the overall shoreline dynamics over short, medium and long time periods.

6.1 Shoreline Trends

A preliminary analysis of historical shoreline change was completed by mapping shoreline positions over a suite of available historical imagery, obtained from Google Earth. The shoreline mapping outcomes are presented in Figure 6.1 and identify a clear recessional trend.

Figure 6.1: Shoreline Position Mapping along a Section of the Corpus Christi Shipping Channel covering the period 1956 to 2020

6.2 Shoreline Modeling Approach

Shoreline changes was modeled using the XBEACH model system in profile mode (2DV). The XBEACH model can accept the non-linear wave profile time series from the FUNWAVE simulations as boundary conditions and is well suited to describe the shoreline evolution as a result of run-up and drawdown at the shoreline from vessel wake.

Depths along each profile were extracted from high resolution survey of the area and extended from land to the relative deep water in the channel. Sediment along the profiles were described by native sediments, as presented in Section 3.5. Figure 6.2 presents the locations and naming of the XBEACH profiles.

Figure 6.2: Location of the XBEACH profile models (red) along the Port of Corpus Christi Shipping Channel

Boundary conditions for the profile models were developed by combining water level timeseries from the FUNWAVE model results (for both primary and secondary wave simulations) in a continuous series, based on the projected vessel numbers. Initially the primary and secondary wave results were combined for each vessel/speed/channel scenario. Timeseries boundary conditions were then generated by randomly repeating the timeseries from the three vessel speed scenarios, with a higher occurrence given to the mean speed scenario (min 20%, mean 60%, max 20%). For each vessel transit, an inbound and outbound timeseries was included (as each vessel will make two transits of the channel: inbound and outbound). In this way, each profile model was run for an approximately 20-day period, being the equivalent of a year's worth of vessel wakes based on the projected vessel numbers.

6.3 Annual Shoreline Change Estimates

Annual shoreline change results are presented in Figure 6.3 for all eight profiles. In general, a flattening of the profiles is observed, with most change occurring in water depths less than 4ft, close to the shoreline. This outcome is consistent with the FUNWAVE bed change results. In addition, shoreline recession is predicted at all profiles as a result of vessel wakes, ranging from 3 ft (profile 2) to 6 ft (profile 8) at MSL. The recession trend in the modeled profiles is in keeping with the observed changes in shoreline position (see Figure 6.1).

Differences in the shoreline change estimates for the FWOP and FWP scenarios are negligible with no observable difference in the annual result. It is noted that the rate of shoreline and profile change slows over the course of the simulations and as such the additional 6 VLCC transits make very little difference to the final outcome for the FWP scenario. While this observation may point to a limitation in the model, the outcome is considered valid and reasonable and consistent with outcomes from the FUNWAVE bed change modeling.

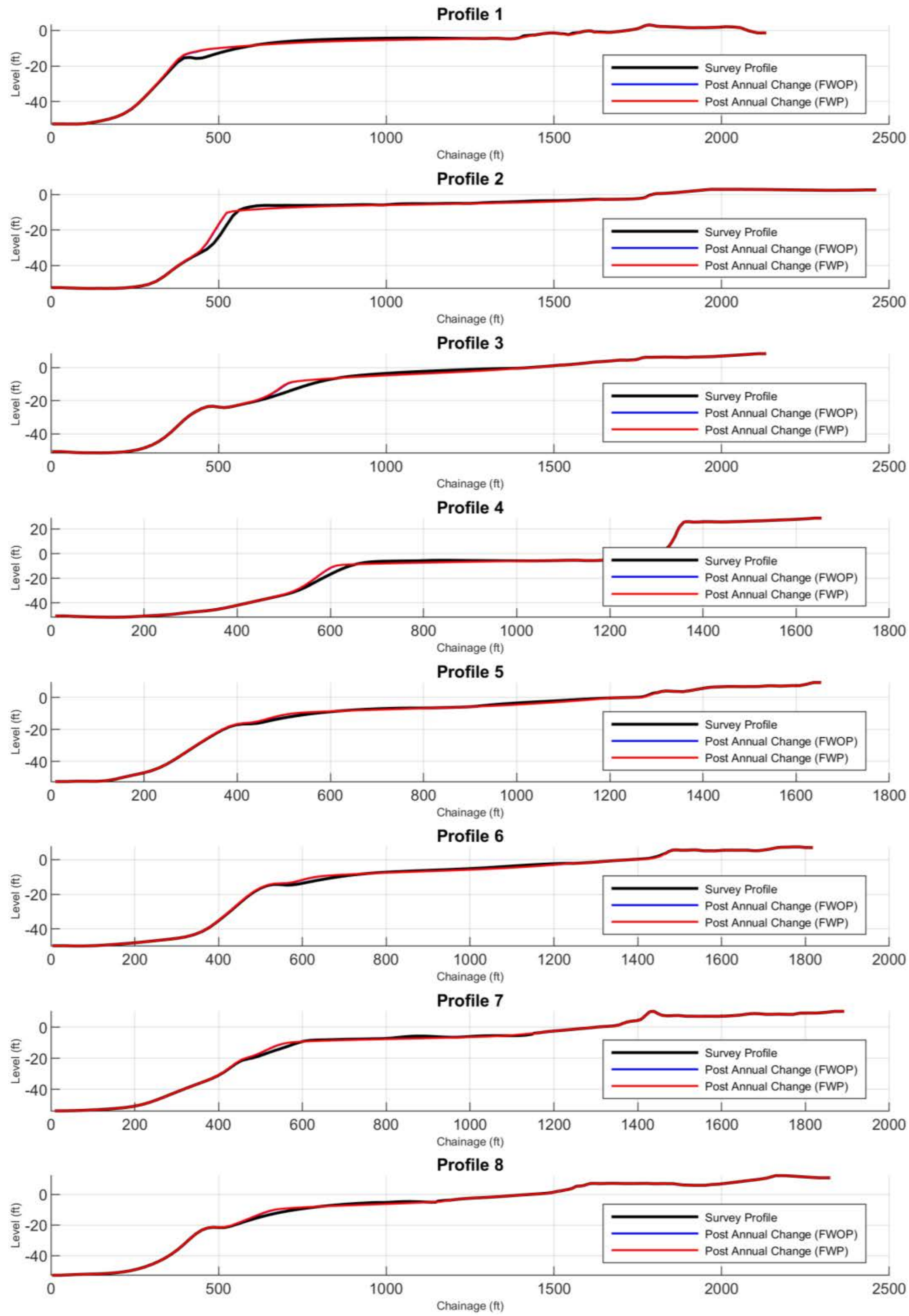


Figure 6.3: Annual Shoreline Change Results as a result of vessel wakes for the FWOP and FWP scenarios at Profile 1 (top) to Profile 8 (bottom).

7. Conclusions

Baird has conducted a vessel wake analysis as part of the modeling services for the Corpus Christi Channel Deepening project. The project will comprise deepening of the Outer and Approach Channels to 77 ft, and the Jetty Channel and seaward-most portion of the Corpus Christi Ship Channel to 75 ft. The channel will be used by laden VLCC's at a maximum draft of 68 ft departing from the planned Axis and Harbor Island terminals. In addition, growth in the reverse lightering operations between the MODA terminal at Ingleside and the Harbor Island terminals would be more VLCC vessel utilize the Corpus Christi Ship Channel.

The vessel wake study consisted of the following tasks:

- Assessment of vessel speeds in the channel.
- Modeling and assessment of vessel induced wakes for Suezmax and VLCC vessels.
- Modeling and assessment of bed morphology along the Corpus Christi Ship Channel as a result of vessel hydrodynamics.
- Modeling and assessment of shoreline response at selected locations along the Corpus Christi Ship Channel as a result of vessel hydrodynamics.

Vessel induced wakes consist of both a primary and secondary wave and the magnitude of each (both absolute and reliative) are a function of the vessel characteristics, speed through water and channel geometry. Being a constrained deep dredged channel with vessels traveling at relatively low speeds, the primary wave is dominant along the Corpus Christi channel for large tanker vessels. The constrained channel increases the primary drawdown wave, while typical vessel speeds result in relatively small secondary waves that reduce in magnitude as they propagate away from the vessel. As a result, the primary wave is the predominant driver for bed and shoreline change.

An estimate of annualized bed and shoreline change as a result of vessel wakes was made with a comparison of the following:

- Suezmax results compare the Future Without Project (FWOP) channel scenario against the FWP channel scenario with no change in traffic numbers.
- VLCC results compare the Future With Project (FWP) channel scenario with 2022 traffic projections against the FWP channel scenario with 2023 traffic projections (5% increase in VLCCs)

A comparison of the FWOP and FWP channel scenarios for both the Suezmax and VLCC indicate that there would be very limited change in bed morphology as a result of the channel deepening project. In general, the bed morphology results suggest a scouring pattern on the channel shoulders with sedimentation along top of channel bank and no sedimentation within the channel width for all scenarios. Some localized changes are observed for the FWP channel scenario; however, these are not considered significant.

Consistent with the bed change results, shoreline change modeling indicates that changes in vessel wakes as a result of the channel deepening project will have minimal impact on the future evolution of natural shorelines along the length of the Corpus Christi Shipping channel. A general recession trend is observed in analysis of historical shoreline positions and the annual shoreline change modeling, and no discernable increase in the recessional trend as a result of the project could be identified. Further, the project is not likely to contribute to an increase in sedimentation within federal navigation channels as a result of a change in vessel hydrodynamics.

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Appendix I

Hydrodynamic and Salinity Modeling Study

Note: The Section 508 amendment of the Rehabilitation Act of 1973 requires that the information in Federal documents be accessible to individuals with disabilities. The USACE has made every effort to ensure that the information in this appendix is accessible. However, this appendix is not fully compliant with Section 508, and readers with disabilities are encouraged to contact Mr. Jayson Hudson at the USACE at (409) 766-3108 or at SWG201900067@usace.army.mil if they would like access to the information.

Environmental Impact Assessment for Channel Deepening, Port of Corpus Christi

Hydrodynamic and Salinity Modeling Study

March 17, 2022 | 13242.102.R3.RevB

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Environmental Impact Assessment for Channel Deepening, Port of Corpus Christi

Hydrodynamic and Salinity Modeling Study

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Revision	Date	Status	Comments	Prepared	Reviewed	Approved
RevA	2022-01-25	Draft	Draft for Review	QL	LAW/RBN	LAW
RevB	2022-03-17	Draft	Draft for Review	QL	LAW	LAW

Executive Summary

W.F. Baird & Associates Ltd. (Baird) was retained by Freese & Nichols, Inc. (FNI) to perform the third-party environmental impact study (EIS) for the Corpus Christi Ship Channel Deepening Project (CDP). The project is the proposed deepening of the offshore channel, entrance channel, and seaward most portion of the Corpus Christi Ship Channel to a nominal depth of 75 ft. The main objectives of this modeling study are to assess the impacts of the CDP on tides, currents, and salinity on the surrounding bays using a three-dimensional (3D) hydrodynamic and salinity model, mainly focused on Corpus Christi Bay, Nueces Bay, and Redfish Bay. It also provides the hydrodynamic information for all other EIS and/or Sec. 408 required assessments and for navigation simulation.

Corpus Christi Bay connects to several subtropical bays, such as Nueces Bay to northwest, Aransas Bay and Copano Bay on the northeast side, and Baffin Bay on the southwest side. It is separated from the GOM by the longshore barrier islands, such as Mustang Island, Padre Island, and San Jose Island. These bays are connected to the GOM by a narrow entrance channel, Aransas Pass, where the navigation channel will be deepened in the CDP. There is a secondary pass, Packery Channel.

The tides in the GOM are primarily diurnal or mixed diurnal-semidiurnal with the tide range of about 0.7 m. The tidal exchange between the GOM and these bays is mainly through Aransas Pass, resulting in strong currents in the pass. The peak current speed in the pass reaches approximately 1.5 m/s. Beside tides, the water levels in the bays are also driven by the seasonal variation of water level in the GOM which likely results from sustained seasonal winds and the other related oceanographic circulation. Tropical storms (or hurricanes) periodically cause large fluctuations in water level in the bays.

Salinity in the bays is mainly driven by tide currents and river inflows and influenced by many physical processes. The saltwater carried by tidal currents from the GOM is the origin of salinity in the bays. Evaporation in dry season becomes important to drive salinity in shallow water areas to higher levels and sometimes even higher than in the GOM. The freshwater from the rivers and rainfalls results in significant decline of salinity in Nueces Bay.

A three-dimensional numerical model was developed to simulate hydrodynamics and salinity for this impact assessment. The model domain extends to offshore about 50 km into the Gulf of Mexico to the -50 m (NAVD88) contour, about 50 km north to Interstate Highway 37 including Nueces River Delta, and about 100 km along the GIWW. The two narrow connecting channels, Aransas Pass and Packery Channel, were included.

Three simulation periods were selected for the model calibration and validation, based on the data availability and driving force conditions. Each period has three-month duration which is sufficiently long to cover the full variation of tides. Each period represents the selected scenario of river inflow conditions, wind conditions, and salinity mixing in the Corpus Christi Bay. Model calibration shows that the model predicts water level, current speed and direction, and salinity reasonably well. The overall prediction error root mean square error (RMSE) is less than 0.07 m for water levels, less than 0.25 m/s for current speed, and 5 PSU for salinity, respectively.

The impact of the CDP was assessed by comparing the model results between Future With Project (FWP, i.e., this CDP) with Future Without Project (FWOP) which is currently in construction. The navigation channel in the FWOP is being dredged from the Port of Corpus Christi to the GOM to -54 ft MLLW, including Humble Basin and the Turning Basin. The FWP is the proposed project to dredge the Corpus Christi navigation channel to -

75 ft MLLW from approximately Light #1 near Port Aransas to the GOM. These two project scenarios were simulated by using the developed 3D model in these three selected periods.

The changes in water level caused by the FWP were evaluated. The model predicted that the FWP cause the drop of mean water level less than 1 cm, the rise of high tide less than 2 cm, and the drop of low tide less than 4 cm in Corpus Christi Bay. The FWP unlikely cause any risks of flooding and navigations. The tide range will increase about 1 to 2 cm in Corpus Christi Bay and Redfish Bay after the FWP is constructed. The largest increase in tide range occurs in the navigation channel from Point Mustang to the inner basin. There is no significant change in tidal range in Aransas Pass and the outer channel. The impact of FWP on current speed was also analyzed by comparing the model results predicted in the FWP scenario with the model results predicted in the FWOP scenario. Overall, the impact of FWP on the current speed is limited to the proposed dredge areas and the navigation channel extending about 15 km to Ingleside from the proposed dredge area near Port Aransas. There is no significant impact on currents in Corpus Christi Bay, Redfish Bay, and Nueces Bay. Deepening the navigation channel in Aransas Pass will result in the increase of conveyance capacity in the pass. As a result, tidal exchange between the bays and the GOM increases by about 8% The impact of FWP on salinity was assessed by comparing the salinity predicted in the FWP scenario with that predicted in the FWOP scenario in time and 3D space. The average change in salinity caused by FWP is less than 1 PSU. The range of salinity change was also calculated as the maximum salinity change minus the minimum salinity change, which represent the disturbing in salinity caused by the FWP. Figure E.1 shows the range of salinity change which is less than ±3 PSU in the proposed dredge area and the connected navigation channels.

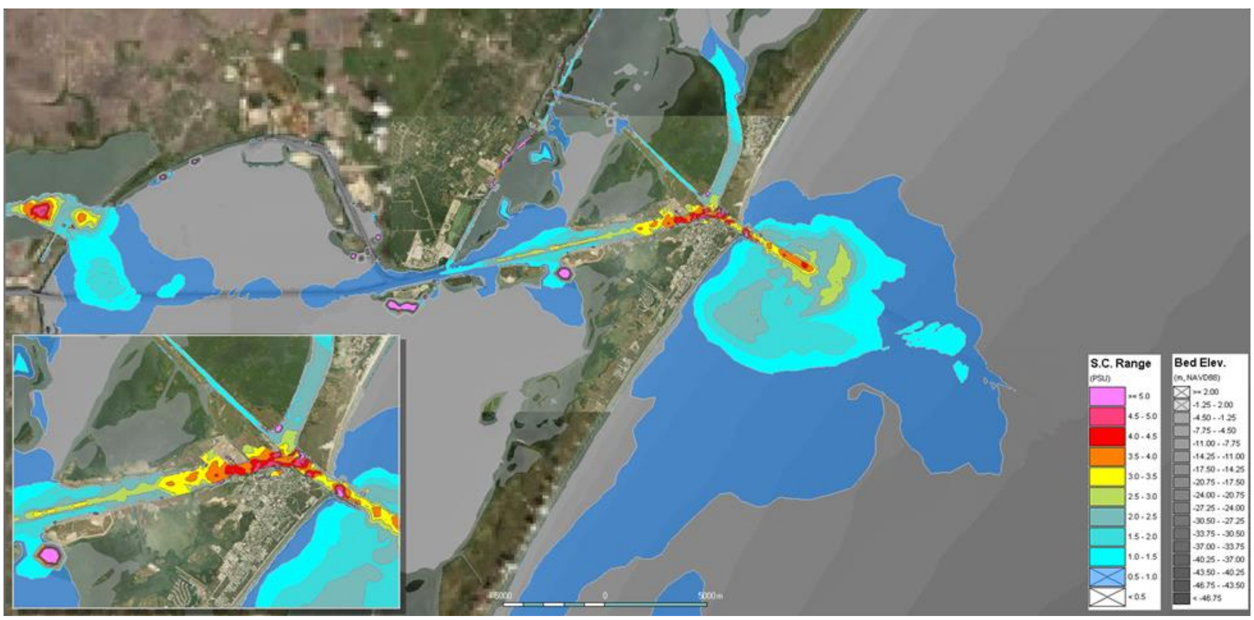

Figure E.1: Range of salinity change (maximum change minus minimum change) caused by FWP in Period 2.

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1. Introduction

W.F. Baird & Associates Ltd. (Baird) was retained by Freese & Nichols, Inc. (FNI) to perform the third-party environmental impact study (EIS) for the Corpus Christi Ship Channel Deepening Project (CDP). The project is the proposed deepening of the offshore channel, entrance channel, and seaward most portion of the Corpus Christi Ship Channel to a nominal depth of 75 ft. Baird has provided consulting services for the past 11 months on the project to FNI as part of the 3rd Party EIS contract with the Port of Corpus Christi Authority (PCCA). The work has been coordinated by the US Army Corps of Engineers (USACE) Galveston District Regulatory Branch. The main purpose of this hydrodynamic and salinity modeling study is to provide a direct response to the data gaps identified in the PCCA CDP Recommended Actions Plan developed by FNI on 30 September 2020 (Freese and Nichols, Inc., 2020).

The objectives for this modeling study are:

- To assess the impacts of deepening the navigation channels to Port of Corpus Christi (PCC) on tides (tidal prism and datum) on the surrounding bays, mainly focused on Corpus Christi Bay, Nueces Bay, and Redfish Bay including effects of wind driven changes to Gulf of Mexico (GOM) water levels.
- To access the impacts of deepening the navigation channel on tidal currents and Gulf wide circulation driven currents in the entrance channel, navigation channels (in the bays and jetty channel), and surrounding bays including assessment of offshore currents.
- To provide the base hydrodynamic model for all other EIS and/or Sec. 408 required assessments, for example, salinity model, sediment transport model, and water quality modeling (if required).
- To provide the necessary inputs for navigation simulation including offshore currents, three-dimensionality of currents, and current changes within the jetty channel and turning basin.
- To access the impacts of channel deepening on the salinity in the bays, particularly under high inflow events, using a three-dimensional physics-based model including the effects of varying offshore boundary conditions.

This report documents the data collected and used for the study, the model development, and the assessment on the impacts of CDP on hydrodynamics and salinity. The report consists of:

Section 1. Introduction (this section);

Section 2. Data collection and analysis – to document all data used in this study, including data sources, data gaps, data processing, and the understandings of physical processes from the data analysis;

Section 3. Hydrodynamic and salinity model development – to document the setup, calibration, validation, and uncertainties of the hydrodynamic and salinity model;

Section 4. Impact assessment – to document the modeling assessment of the impacts of channel deepening on hydrodynamics and salinity;

Section 5. Conclusions and uncertainty – to document the conclusions made from this study. The evaluation of uncertainties is also provided; and

Section 6. References.

2. Data Collection and Analysis

2.1 Data Collection

The collected data used in this modeling study includes the shorelines, topographic data and bathymetry, watershed and runoff, hydrological and meteorological information in the bays, the Intracoastal Waterway, and the Gulf of Mexico. Many of the datasets were collected from the publicly accessible data servers as detailed below.

2.1.1 Geospatial Data

Several geospatial datasets were acquired in support of the numerical modeling study. Elevation datasets were downloaded to cover the model domain and navigation channel boundaries in the study area.

2.1.1.1 Elevation Data

Four elevation datasets were acquired for use in the model grid, listed in hierarchical order within the model domain below. Figure 2.1 shows the spatial coverage within the model domain of each elevation source.

- United States Army Corps of Engineers (USACE), Galveston District, Sea Bar Channel Survey, 2018/07/17;
- Cooperative Institute for Research in Environmental Sciences (CIRES), Continuously Updated Digital Elevation Model (CUDEM) - 1/9 Arc-Second Resolution Bathymetric-Topographic Tiles (v2020);
- NOAA National Geophysical Data Center, 2007, Corpus Christi, Texas 1/3 arc-second MHW Coastal Digital Elevation Model;
- NOAA National Geophysical Data Center, 2001, U.S. Coastal Relief Model Vol.5 - Western Gulf of Mexico.

All elevations were converted to the North American Vertical Datum of 1988 (NAVD 88) at Port Aransas. The horizontal coordinate system of Universal Transverse Mercator 14-North (UTM-14N) was used for all bathymetry data.

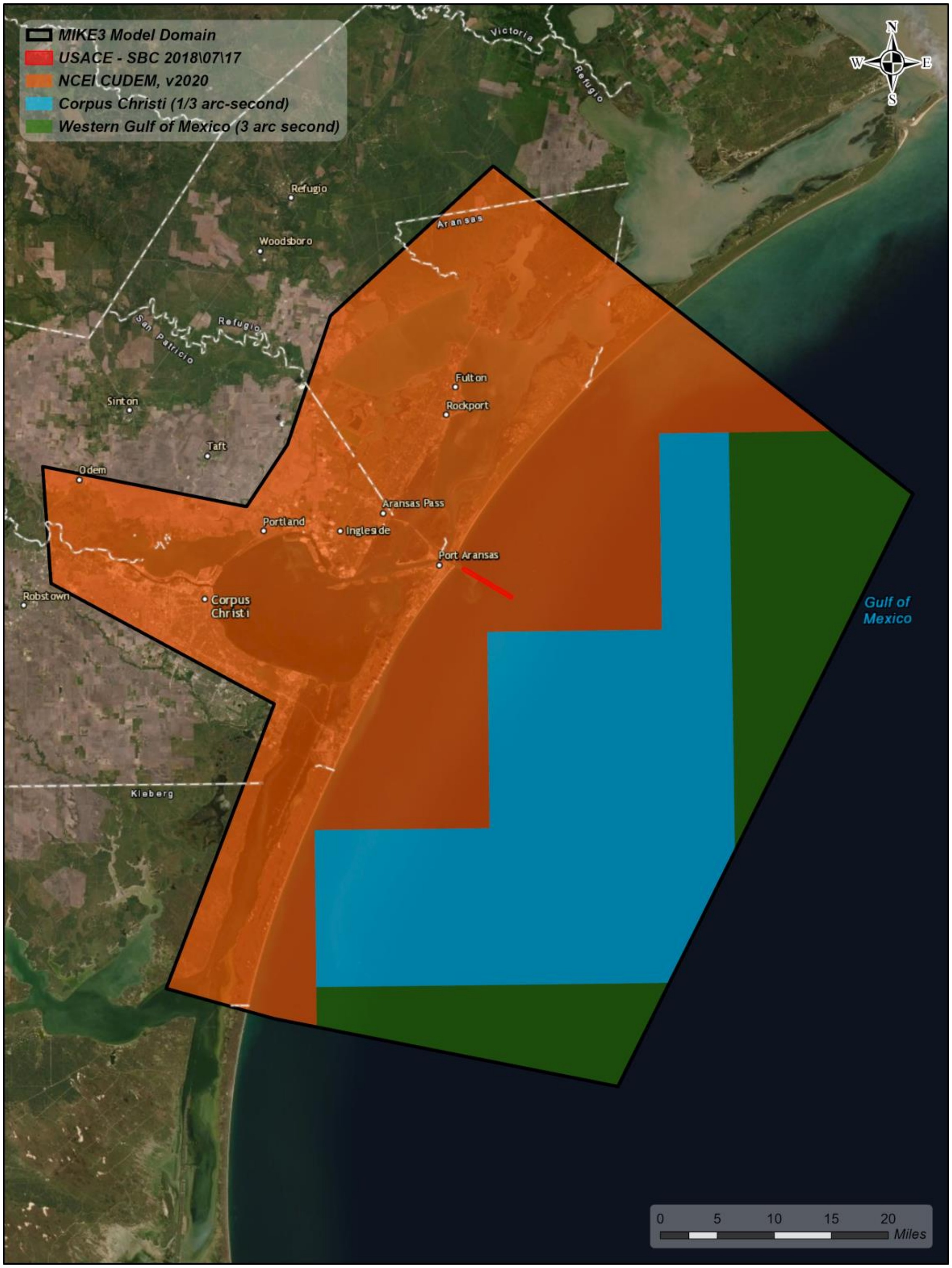


Figure 2.1: Bathymetry data collected for this modeling study

2.1.1.2 Navigation Channel Data

The extents of the navigation channels within the study area were downloaded from the USACE Geospatial National Channel Framework (NCF) portal. The data included channel areas, reaches, and lines.

2.1.2 Meteorological Data

2.1.2.1 Winds

Wind data was collected from in-situ observation stations in the Corpus Christi area (see locations in Figure 2.2). These stations, listed in Table 2.1, are operated by the National Oceanic and Atmospheric Administration (NOAA) with hourly data available online (https://tidesandcurrents.noaa.gov). Wind speed and direction was collected from January 2018 to June 2021 in hourly increments. Observed wind speeds were converted to wind speeds at 10 m above the ground using the log law:

$$u_2 = u_1 * \left(\frac{ln\frac{z_2}{z_0}}{ln\frac{z_1}{z_0}} \right)$$

where u_2 is the wind speed at the desired elevation, u_1 is the observed wind speed at the station elevation, z_2 is the desired elevation (10 m), z_1 is the station instrument elevation and z_0 is the roughness length coefficient. Figure 2.3 displays an example 10 m wind speed plot for Bob Hall Pier.

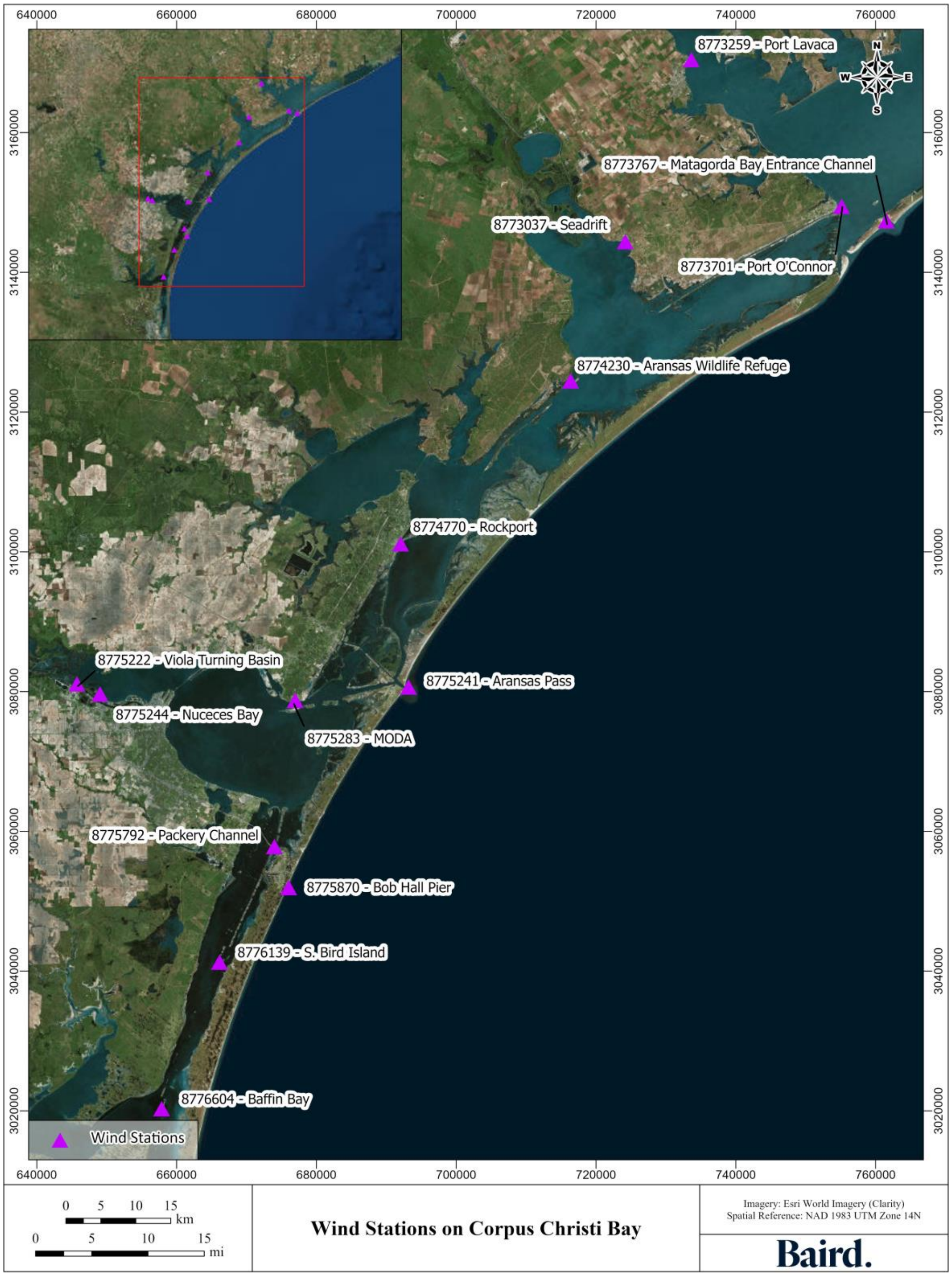


Figure 2.2: Locations of NOAA wind stations collected for this modeling study

Table 2.1: Summary of Wind Data Available from NOAA

Station Name	Station ID	Start Date	End Date
Matagorda Bay Entrance Channel	8773767	2016-06-18	Present
Port O'Connor	8773701	2004-06-24	Present
Port Lavaca	8773259	2007-06-06	Present
Seadrift	8773037	2004-04-06	Present
Aransas Wildlife Refuge	8774230	2014-03-28	Present
Rockport	8774770	2007-07-31	Present
Viola Turning Basin	8775222	2021-01-07	Present
Aransas Pass	8775241	2016-09-21	Present
Nueces Bay	8775244	2011-03-20	Present
MODA	8775283	1992-10-29	Present
Packery Channel	8775792	2007-06-06	Present
Bob Hall Pier	8775870	1995-06-19	2021-12-22
South Bird Island	8776139	2004-04-06	Present
Baffin Bay	8776604	2004-04-09	Present

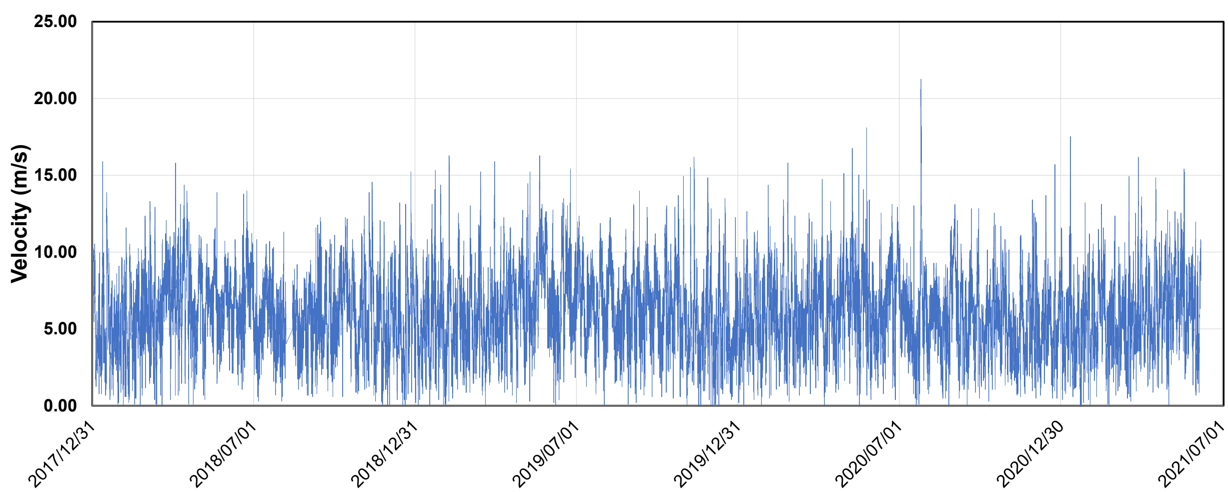


Figure 2.3: Wind speed measured at Bob Hall Pier which was corrected to an elevation of 10 m above the ground

2.1.2.2 Air Temperature

Air temperature data was collected from the National Centers for Environmental Information (NCEI), an agency under NOAA. The in-situ data (Figure 2.4) was collected via observations stations (https://gis.ncdc.noaa.gov/maps/ncei/summaries/daily), listed in Table 2.2. Observed air temperature data from the Corpus Christi airport were used to initially calculate evaporation rates utilizing methods outlined by Linacre

(1977). The sub-hourly temporal frequency provided by the Corpus Christi airport was favorably compared to the daily evaporation data sets provided by the Choke Canyon Dam and Mathis stations. However, upon further analysis, it was determined that the calculated evaporation rates, utilizing air temperature data from the Corpus Christi airport, underpredicted evaporation in the summer seasons. Therefore, it was decided that direct measurements of daily evaporation rates from Mathis were preferable compared to the calculated data sets. No additional air temperature data was utilized for modeling.

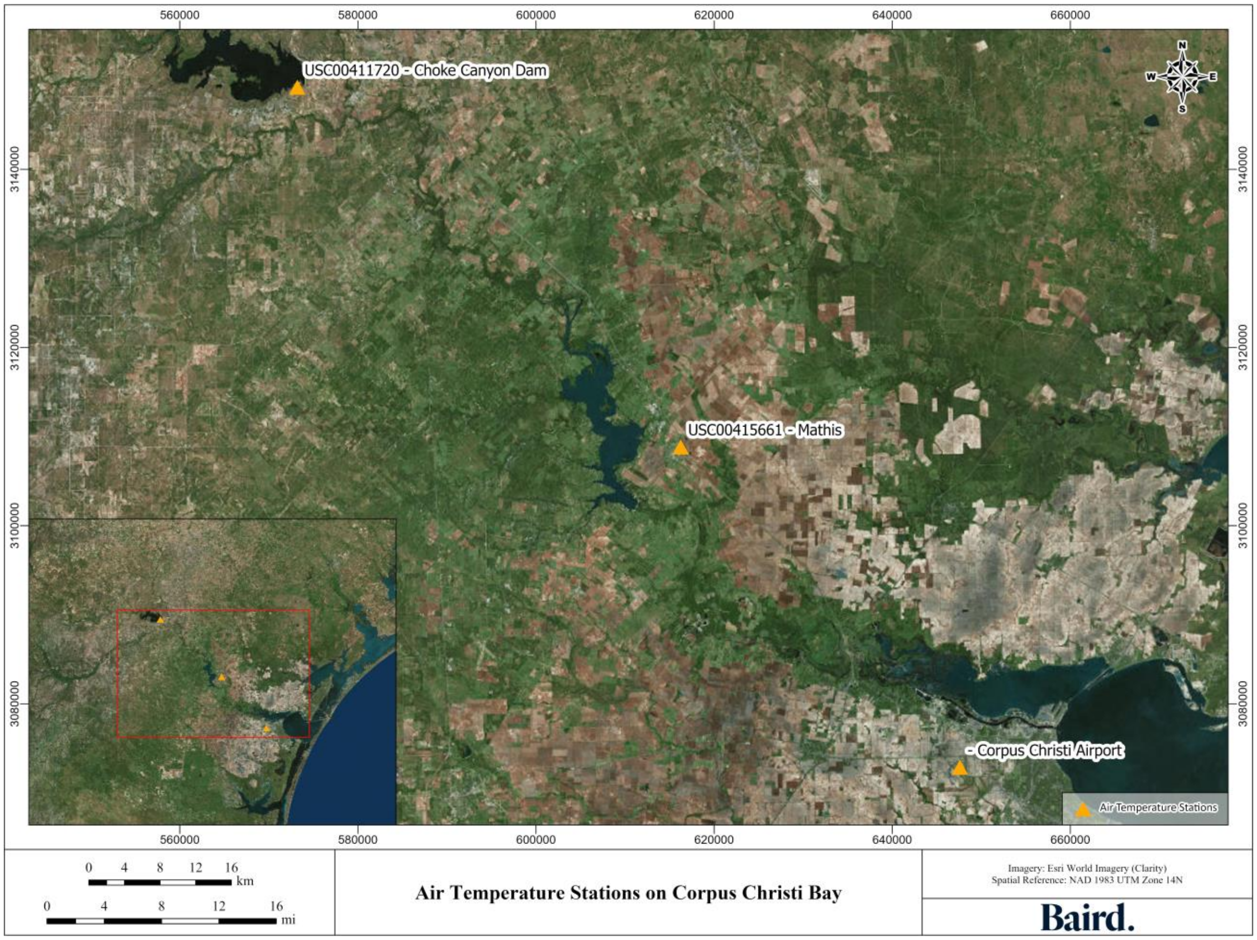


Figure 2.4: Location of NOAA Temperature Stations

Table 2.2:Summary Temperature Data Available from NOAA

Station Name	Station ID	Start Date	End Date
Mathis	USC00415661	1964-07-01	Present
Corpus Christi Airport	-	1946-08-01	Present
Choke Canyon Dam	USC00411720	1983-10-01	Present

2.1.2.3 Precipitation

Precipitation data was initially collected using the NCEI stations Mathis and Choke Canyon Dam with hourly sampling frequency. However, inconsistencies were discovered with the hourly data when compared to the same station's daily data. Additionally, daily precipitation data obtained from NOAA stations Rockport and Port Aransas depicted larger amount of precipitation when compared to the NCEI stations. Therefore, it was decided that the two NOAA stations with daily precipitation observations would be utilized. All four stations are shown in Figure 2.5 and listed in Table 2.3. Data was collected from January 2018 to June 2021 (https://tidesandcurrents.noaa.gov). The precipitation rates for Rockport and Port Aransas are shown in Figure 2.6.

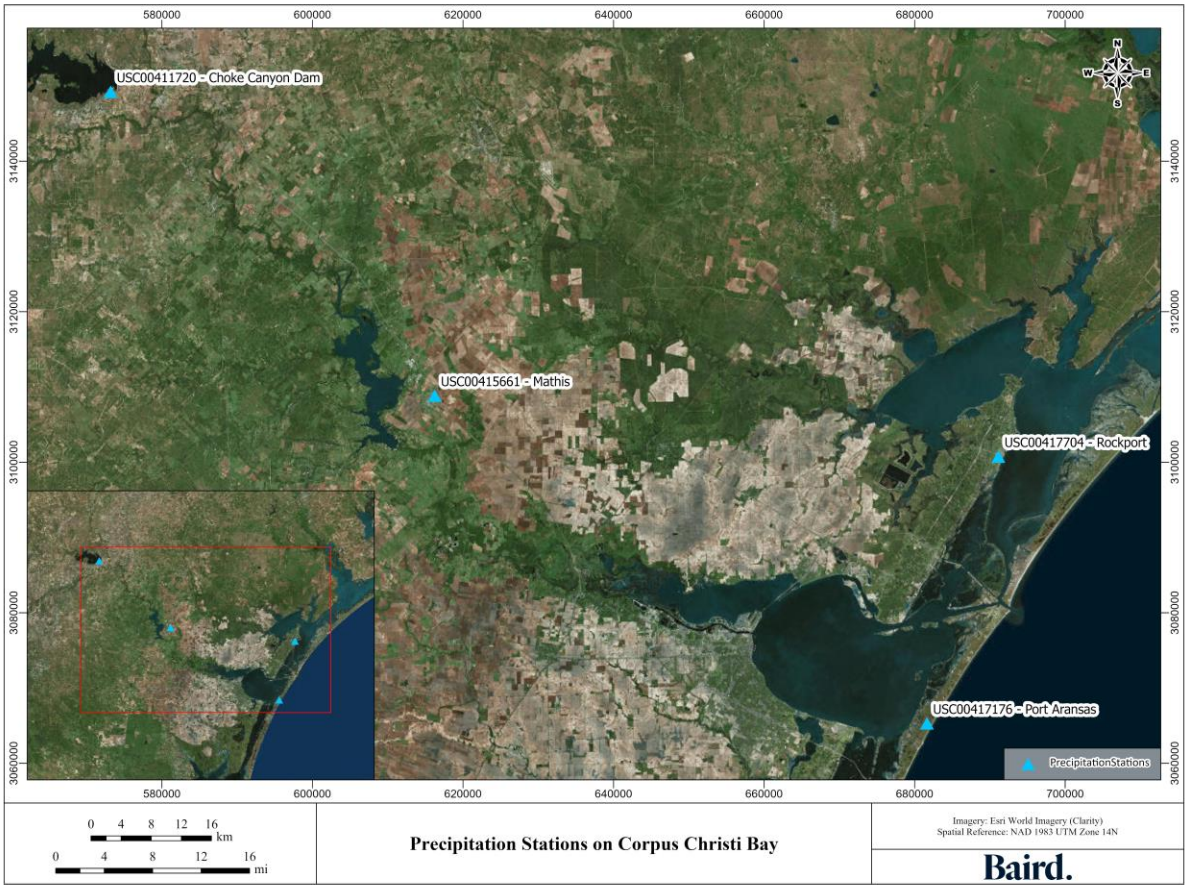


Figure 2.5: Location of NOAA Precipitation Stations

Table 2.3: Summary of precipitation data available from NOAA

Name	Station ID	Start Date	End Date
Mathis	USC00415661	1964-07-01	Present
Port Aransas	USC00417176	2007-11-18	Present
Choke Canyon Dam	USC00411720	1983-10-01	Present
Rockport	USC00417704	1959-01-01	Present

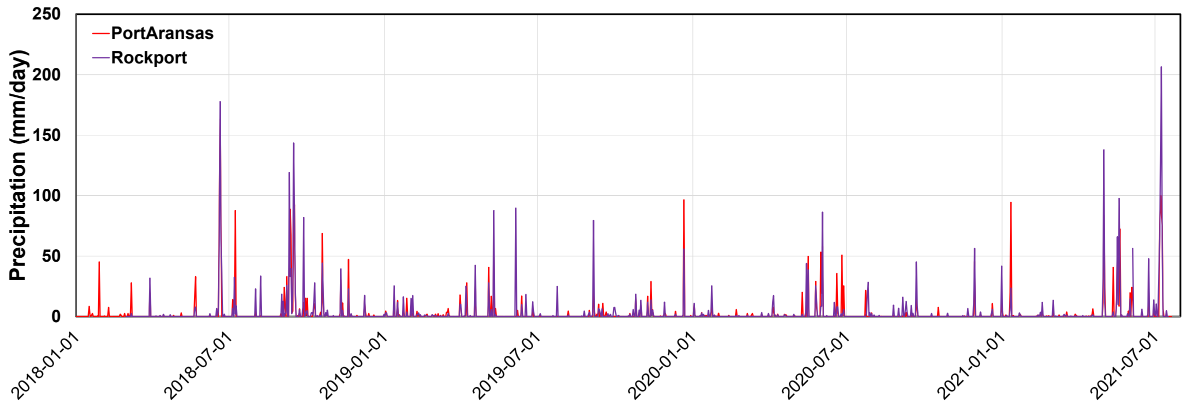


Figure 2.6: Daily precipitation rates

2.1.2.4 Evaporation

As previously mentioned in Section 2.1.2.2, daily evaporation rates were collected from two stations: Choke Canyon Dam and Mathis (Figure 2.5 and Table 2.3) from January 2018 to June 2021. Data from Mathis station was primarily used; however, data from Choke Canyon station was substituted if data from Mathis was unavailable. Evaporation rates for the two stations are shown in Figure 2.7.

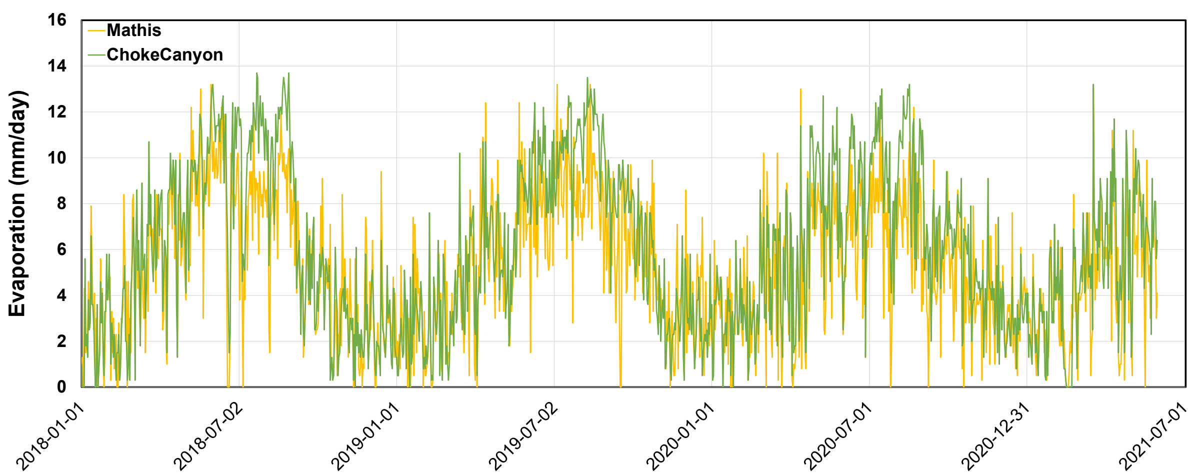


Figure 2.7: Daily evaporation rates measured at Mathis and Choke Canyon Dam

2.1.3 River Flows and Runoffs

2.1.3.1 Watersheds

Watershed boundaries and data were obtained from the United States Geological Survey (USGS) Watershed Boundary Dataset (WBD, https://apps.nationalmap.gov/downloader/#/). The watersheds surrounding Corpus Christi Bay are Nueces, South Corpus Christi Bay, and North Corpus Christi Bay watershed. The entirety of Nueces watershed (HUC6 121101) was used, while only specific catchments of the South and North Corpus Christi Bay watersheds were isolated, which are those surrounding Corpus Christi Bay and Oso Creek. The catchments of interest are illustrated in Figure 2.8, where the blue represents those directly draining into

Corpus Christi Bay or partially into Oso Bay, orange represents those contributing to the Nueces River flow, and purple represents those contributing to the Oso Creek flow.

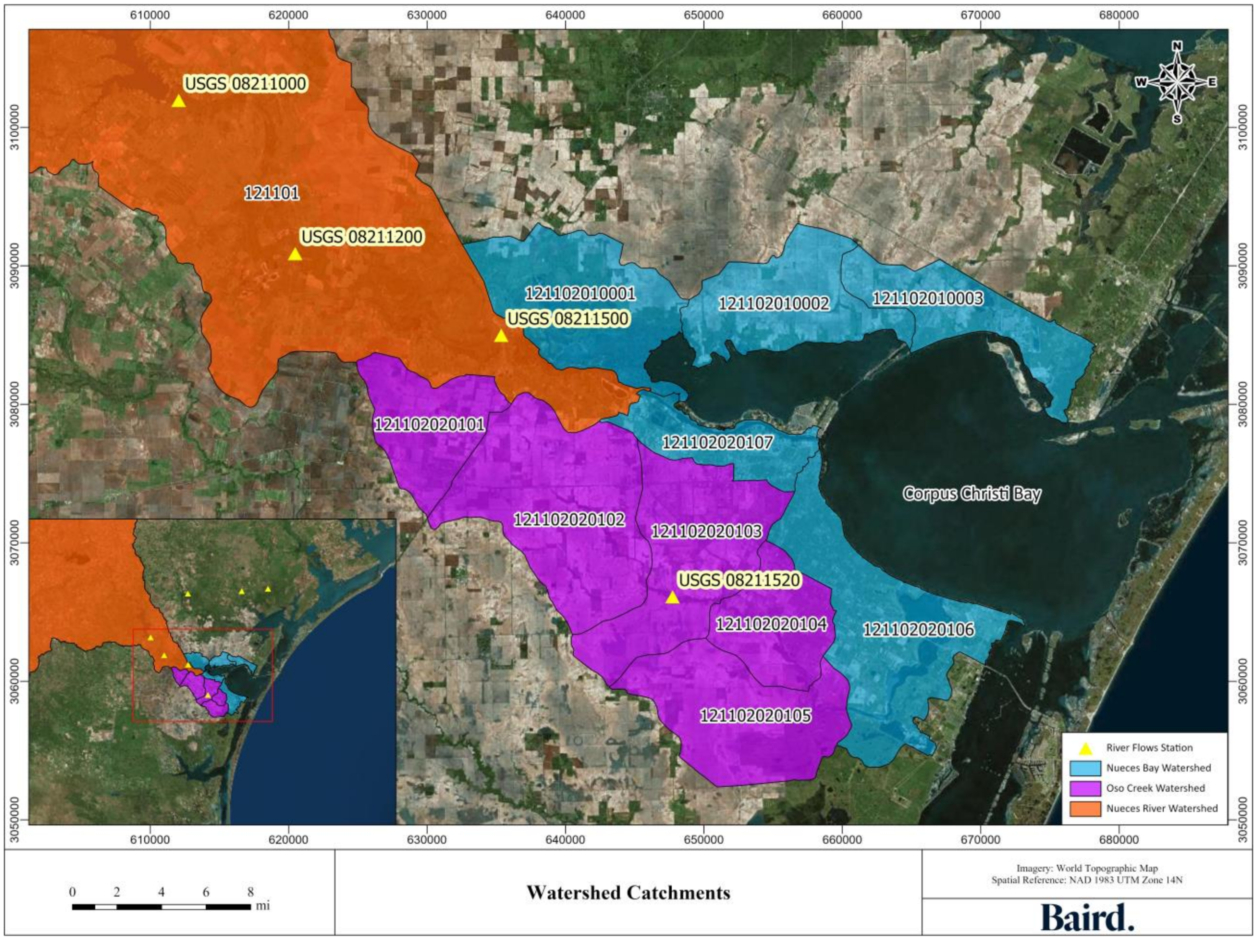


Figure 2.8: Watershed catchments for Nueces River, Oso Creek, and direct drainage

For the sub catchments of the South and North Corpus Christi Bay watersheds, present at HUC 12 (see below table), the areas were clipped and reviewed from the WBD using QGIS, an open-source geographic information system. The individual areas for each sub catchment are summarized in Table 2.4 and discussed in the following sections.

Table 2.4: North and South Corpus Christi Bay Watershed Sub catchment areas

HUC12	Area (Km^2)	Drained to
121102010001	114.96	Nueces Bay
121102010002	91.20	Nueces Bay
121102010003	74.28	Corpus Christi Bay
121102020101	67.66	Oso Creek
121102020102	156.88	Oso Creek

HUC12	Area (Km^2)	Drained to
121102020103	120.67	Oso Creek
121102020105	61.84	Oso Creek
121102020106	110.66	Oso Bay & Corpus Christi Bay
121102020107	49.71	Corpus Christi Bay

2.1.3.2 River Flows

River flows draining into Corpus Christi Bay and Aransas Bay were retrieved from seven USGS gages (https://maps.waterdata.usgs.gov/mapper/index.html). Nueces River, in which there are three gages, drains to Nueces Bay. There is one gage in Oso Creek which empties into Oso Bay. The remaining stations drain into Copano Bay. The data availability for each gage is summarized in Table 2.5. Figure 2.9 shows the location for each gage.

Table 2.5: Summary of river flow gages from USGS

Gage Name	Gage ID	Start Date	End Date
Nueces River nr Mathis	08211000	1987-09-01	Present
Nueces River at Bluntzer	08211200	1992-04-01	Present
Nueces River at Calallen	08211500	1989-10-02	Present
Oso Creek at Corpus Christi	08211520	1995-10-01	Present
Aransas River nr Skidmore	08189700	1964-03-27	Present
Mission River at Refugio	08189500	1939-07-01	Present
Copano Creek nr Refugio	08189200	1970-06-17	Present

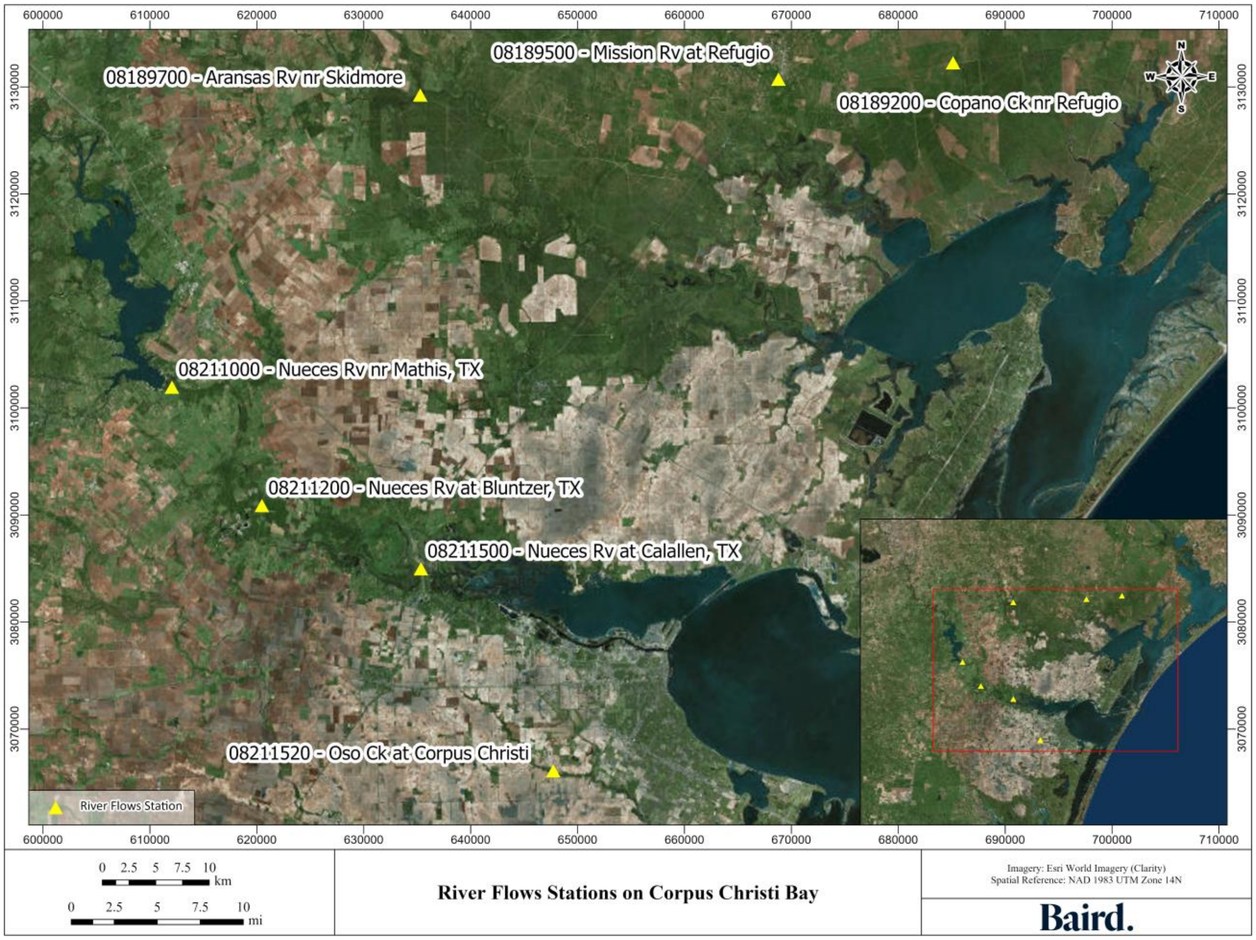


Figure 2.9: Location of USGS gages

A sample of the gaged flow is illustrated in Figure 2.10 from the period of August 2018 to the end of February 2019 for flows draining into Nueces Bay. Figure 2.11 displays a sample of the gage flows draining into Copano Bay. The upstream gages (08211000 and 08211200) were used to fill the data gaps at the most downstream gage in Nueces River.

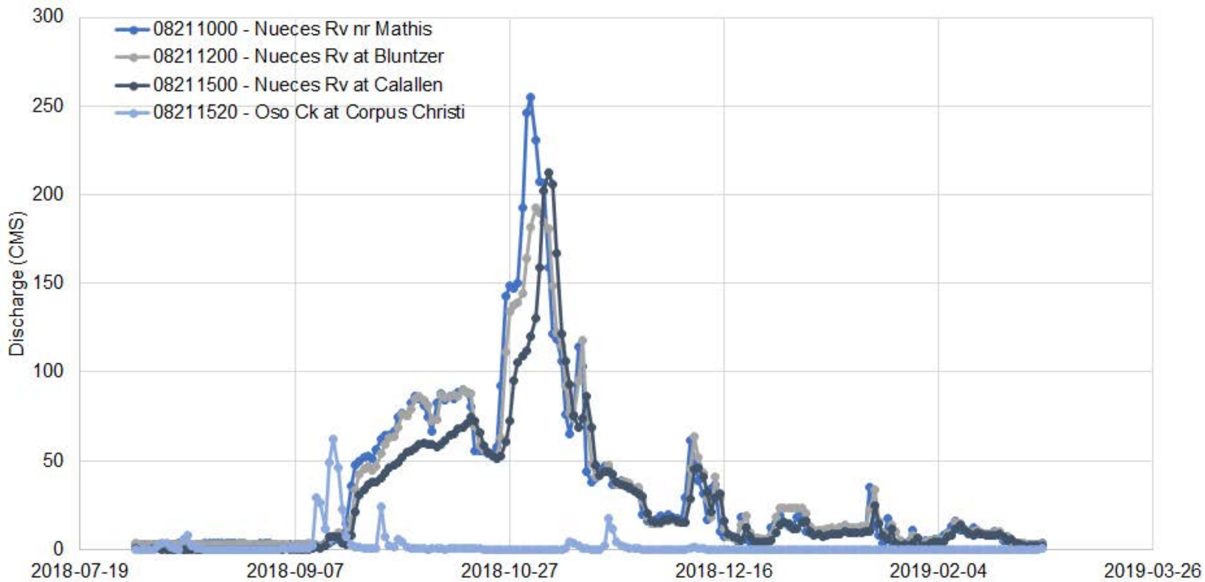


Figure 2.10: USGS River flows into Corpus Christi Bay

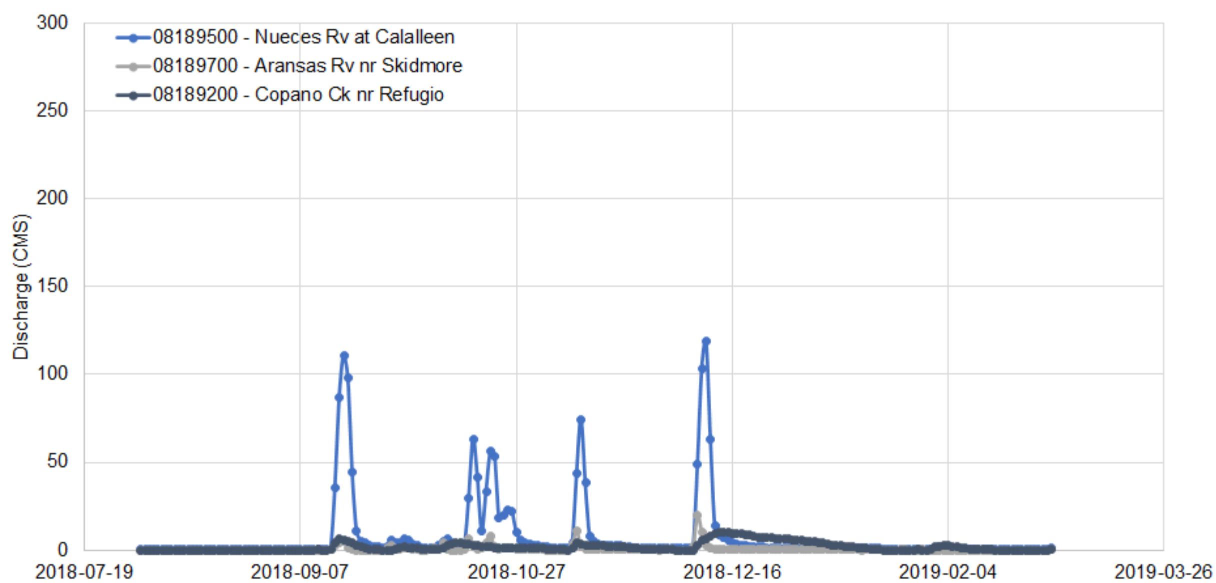


Figure 2.11: USGS River flows into Aransas Bay

It was concluded that the inflow from the Nueces River would be the combination of the gaged flows at 08211500 and the discharge from the Allison Waste Water Treatment Plant, which is estimated using return values obtained by the Texas Water Development Board (TWDB), discussed in Section 2.1.3.3. Oso Creek was determined to have unaccounted inflows from the surrounding watershed and was adjusted using a scale factor, which was estimated using the sub catchment areas. Figure 2.12 displays the final discharge estimates for Nueces River and Oso Creek after adjustments.

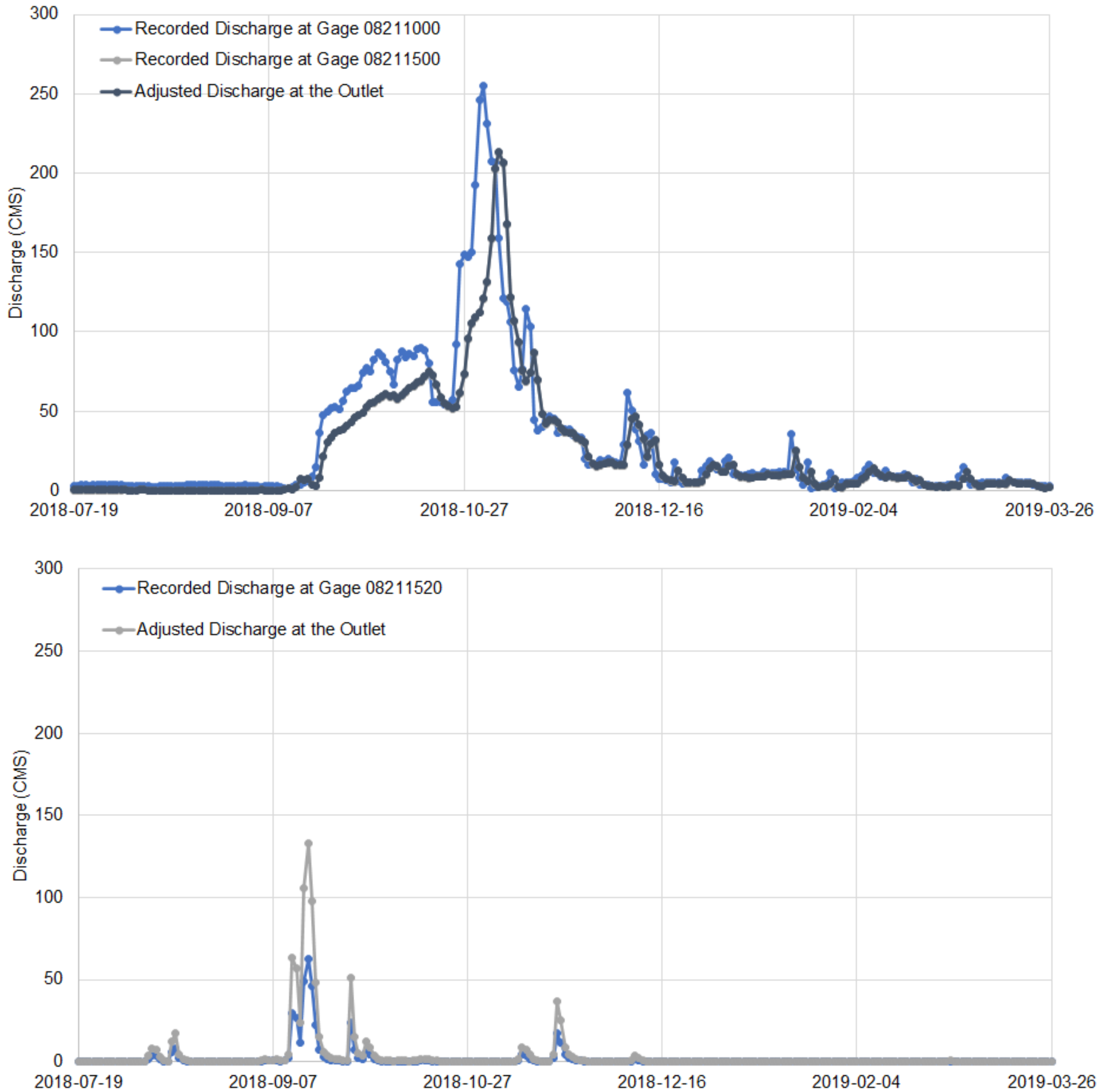


Figure 2.12: Adjusted discharge for Nueces River (top) and Oso Creek (bottom)

2.1.3.3 Runoffs from Ungagged Watershed

In addition to river flows, ungaged flows were estimated for the sub catchments draining directly into Corpus Christi Bay, which were identified in Section 2.1.3.1. To estimate the flows for the sub catchments, runoff data modeled with the Texas Rainfall-Runoff Model (TxRR) (Perales, *et al*, 2000) was obtained from the Texas Water Development Board (TWDB, https://waterdatafortexas.org/coastal/hydrology/corpus_christi). Data was available from 1940 to the end of 2019. Precipitation data used in the TxRR model was also provided for the period of 1900 to the end of 2019 and returns (from water usage facilities), and diversions were provided for the period from 2000 to 2019. The modeled precipitation was comparable to precipitation retrieved from NOAA.

A report released by the TWDB in 2011 (Schoenbaechler*, et al*, 2011) documents the procedures involved with estimating the inflows and provides an overview of the associated catchments, shown in Figure 2.13, which was used to relate the TWDB data to the watersheds highlighted in Section 2.1.3.1. TWDB modeled the total freshwater inflows as a combination of the gaged inflows, ungaged inflows, return flows, modified precipitation, diversions, and evaporation. By relating the areas of Figure 2.8 to those in Figure 2.13, the discharges for the five highlighted catchments are estimated. A brief description of how each catchment's runoff flows are estimated are that:

- HUC 121102010001 is estimated as the total runoff from TWDB's watershed #21010 and #22012 combined with the flow at USGS 08211000, and removing the percentage of flows in the at gage 08211500 after adjustments.
- HUC 121102010002 and 121102010003 make up the total area of TWDB's watershed #20005, and thus are each a portion of the modeled runoff according to their areas.
- HUC 121102020107 is directly linked with TWBD's watershed #22013, and thus is recorded as having the same runoff.
- HUC 121102020106 is associated with TWBD's watershed #22014 and #22015. The runoff for HUC 121102020106 is the sum of the runoff of both TWBD watersheds.

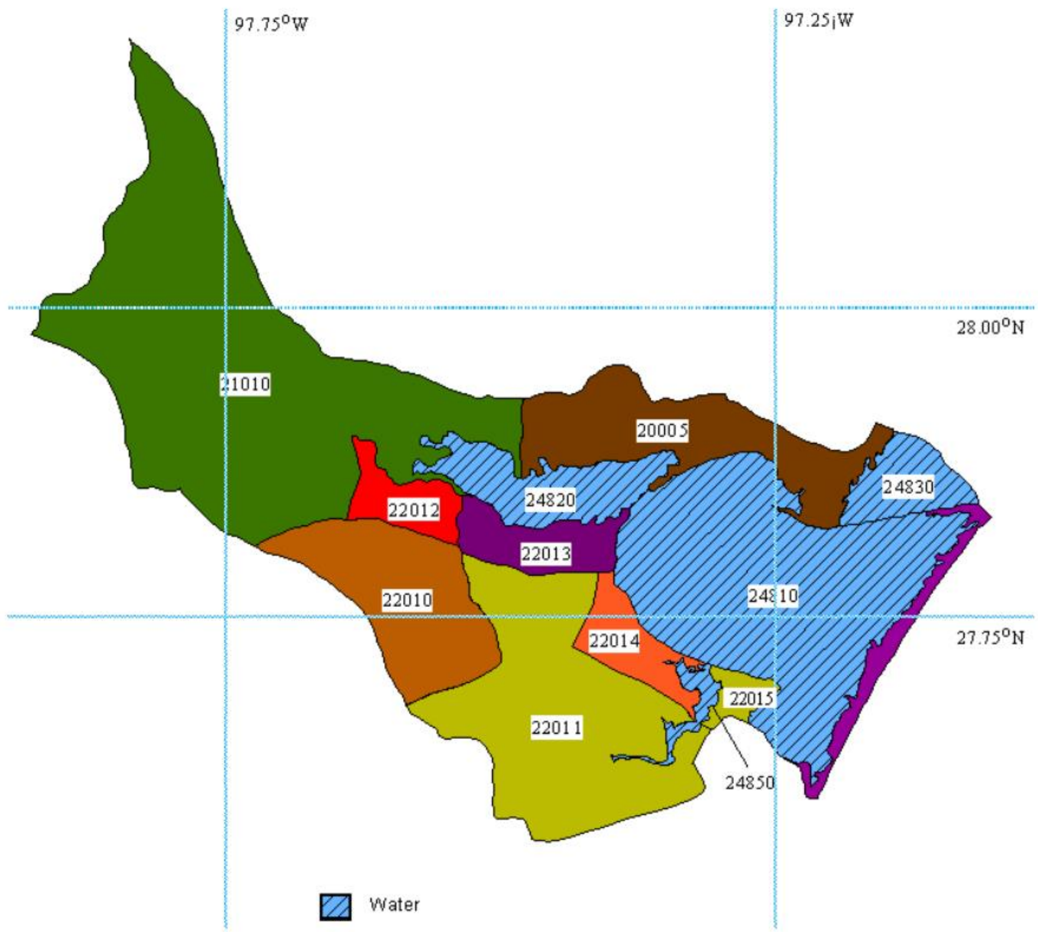


Figure 2.13: Ungaged watershed delineation (Schoenbaechler, *et al*, 2011)

2.1.4 Hydrological Data

2.1.4.1 Water Levels

Water levels from 10 stations in Corpus Christi's Bay and Aransas Bay were obtained from NOAA Tides & Currents database (https://tidesandcurrents.noaa.gov/map/index.html). Data availability at the stations is summarized in Table 2.6, and the locations are illustrated in Figure 2.14. Data gaps exist for four stations during the period of interest: Aransas Wildlife Refuge, Rockport, USS Lexington, and South Bird Island. Of these stations, Rockport has the greatest number of data gaps, representing approximately 14% of the available data. The other three stations have data gaps representing less than 2% of the available data for the period of interest.

Table 2.6: Summary of hourly data available from NOAA stations

Station Name	Station ID	Start Date	End Date
Aransas Wildlife Refuge	8774230	2012-11-01	Present
Rockport	8774770	1937-03-01	Present
Aransas Pass	8775241	2016-12-20	Present
Port Aransas	8775237	2002-06-26	Present
Nueces Bay	8775244	2012-01-01	2012-12-31
USS Lexington	8775296	2012-01-01	Present
Packery Channel	8775792	1996-01-01	Present
Bob Hall Pier	8775870	1983-11-30	Present
South Bird Island	8776139	2012-10-01	Present
Baffin Bay	8776604	2012-10-01	Present

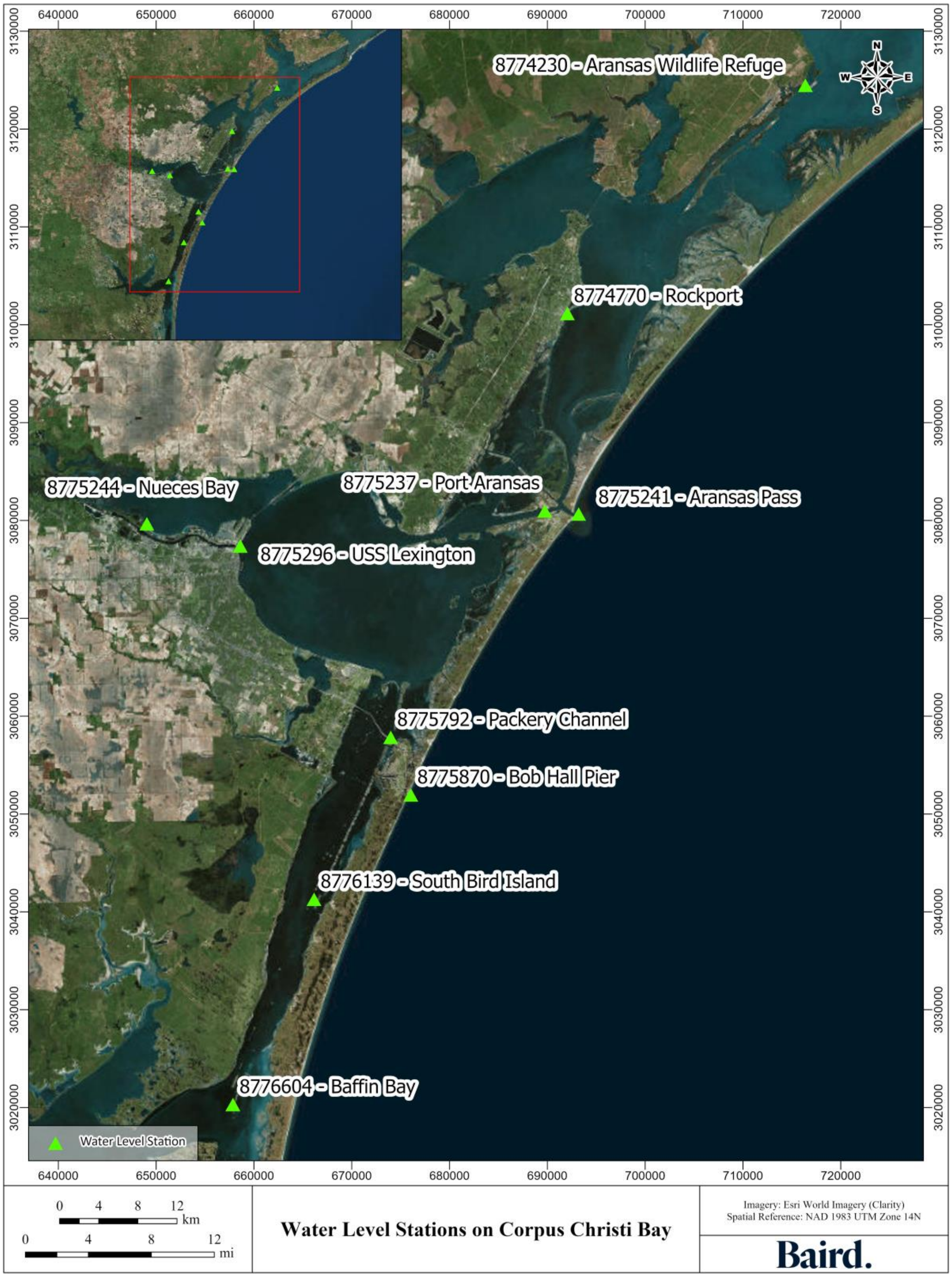


Figure 2.14: Location of NOAA water level stations

2.1.4.2 Currents

Currents data was obtained for 12 stations, available from NOAA's Center for Operational Oceanographic Products and Services online database (https://tidesandcurrents.noaa.gov/) and the National Data Buoy Center (NDBC, https://www.ndbc.noaa.gov/). The availability of the 12 stations is listed in Table 2.7, and their locations are shown in Figure 2.15. The data was processed to fill gaps through interpolation and relation to nearby stations. All stations possess long gaps in their data, with Station TABS-D having the longest record of measurements available.

Table 2.7: Summary of currents data available from NOAA and NDBC

Station Name	Station ID	Start Date	End Date
AP Buoy	CC0101	2018-01-31	2019-07-23
Aransas Pass LB6	CC0201	2019-07-12	Present
Port Aransas, Channel View	CC0301	2018-10-31	Present
MODA Currents	CC0401	2018-03-27	Present
UTMSI Fisheries and Marine Lab	CC0601	2021-04-23	Present
Texas Automated Buoy System Buoy D	42048	2010-03-01	Present
Corpus Christi Channel (moved)	STX1804	2018-12-01	2019-01-31
La Quinta Channel	STX1803	2018-12-01	2019-01-31
ICW - CC Bay Light 51	STX1806	2018-12-01	2019-01-31
ICW - CC Bay Southern Ent	STX1807	2018-12-01	2019-02-01
Lydia Ann Channel, S end	STX1801	2018-12-1	2019-01-30
Murray Shoal	STX1802	2018-12-01	2019-01-30

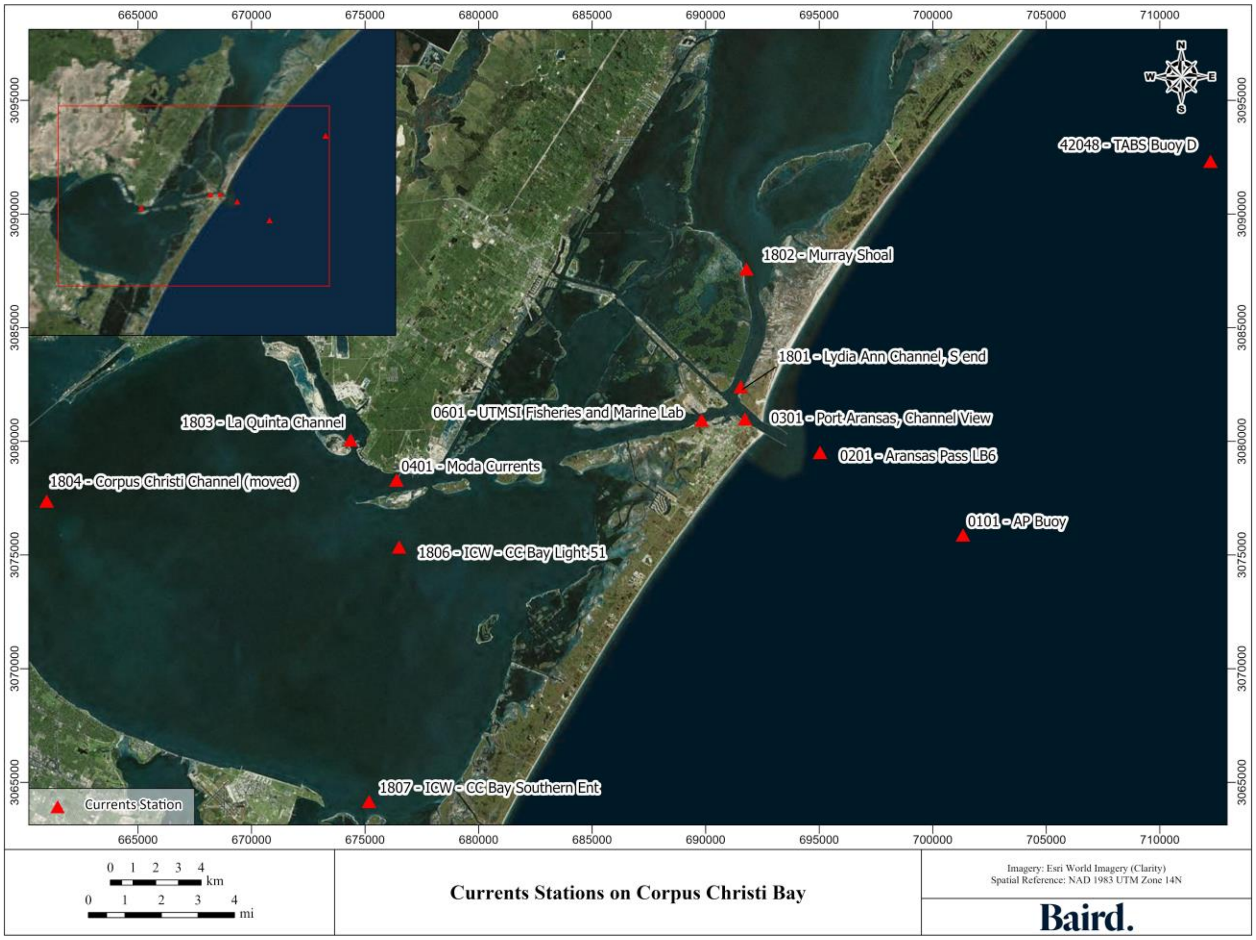


Figure 2.15: Currents monitoring locations by NOAA and NDBC

2.1.4.3 Salinity

Salinity data is available for six long term stations in and near Corpus Christi Bay. Salinity data was obtained from two sources: the Texas A&M University CBI (http://cbi.tamucc.edu) and the TWDB (https://www.waterdatafortexas.org/coastal). Outliers were manually removed from the salinity dataset prepared for the model. The data availability is presented in Table 2.8. Data processing involved removing outliers and filling in gaps through interpolation or relation to a nearby, similar station if large gaps were present, such as for MANER4, INPT and TABSD. Station further north, CHKN and GBRA#1, were used to fill in gaps for MANER4, and TABSW was used for the gaps in TABSD. Final adjustments were made through visual inspection to remove any persisting outliers.

Table 2.8: Summary of salinity data available from Texas A&M University CBI and TWDB

Station Names	Station ID	Start Date	End Date
National Park Service – Bird Island	171-NPSBI	2008-06-02	Present
MANNER Station #4 (Aransas Bay)	148-MANER4	2007-06-21	Present
SALT 01	072-SALT01	1991-12-04	Present
SALT 03	074-SALT03	1991-12-04	Present
SALT 05	076-SALT05	1995-08-18	Present
Nueces Delta 3	043-NUDE3	2009-05-19	Present
Indian Point Pier	INPT	2017-05-15	2019-05-06
Texas Automated Buoy System Buoy D	TABSD	2010-10-15	Present

In addition to the available salinity data retrieved from the Texas A&M University CBI and the TWDB, salinity measurements were obtained from two other sources: the observed salinity from Islam, Bonner, Edge, and Page (2014), and those provided by AECOM. The observed salinity measurements from Islam, Bonner, Edge, and Page consisted of three stations, known as Platform 1, Platform 2 and Platform 3, during the period of July 7 to August 10, 2007. AECOM provided nine measurement sets recorded on September 18, 2018. The AECOM stations, along with their cast times and number of measurements, are summarized in Table 2.9.

All salinity stations are displayed in Figure 2.16.

Table 2.9: Summary of salinity data available from AECOM

Name	Station ID	Start Cast	End Cast	Number of Measurements
AECOM 01	A01	9:47 CST	9:58 CST	45
AECOM 02	A02	10:16 CST	10:29 CST	55
AECOM 03	A03	10:42 CST	10:52 CST	42
AECOM 04	A04	11:08 CST	11:20 CST	55
AECOM 05	A05	11:33 CST	11:43 CST	52
AECOM 06	A06	11:53 CST	12:04 CST	52
AECOM 07	A07	12:28 CST	12:33 CST	14
AECOM 08	A08	12:46 CST	12:52 CST	16
AECOM 09	A09	13:11 CST	13:14 CST	11

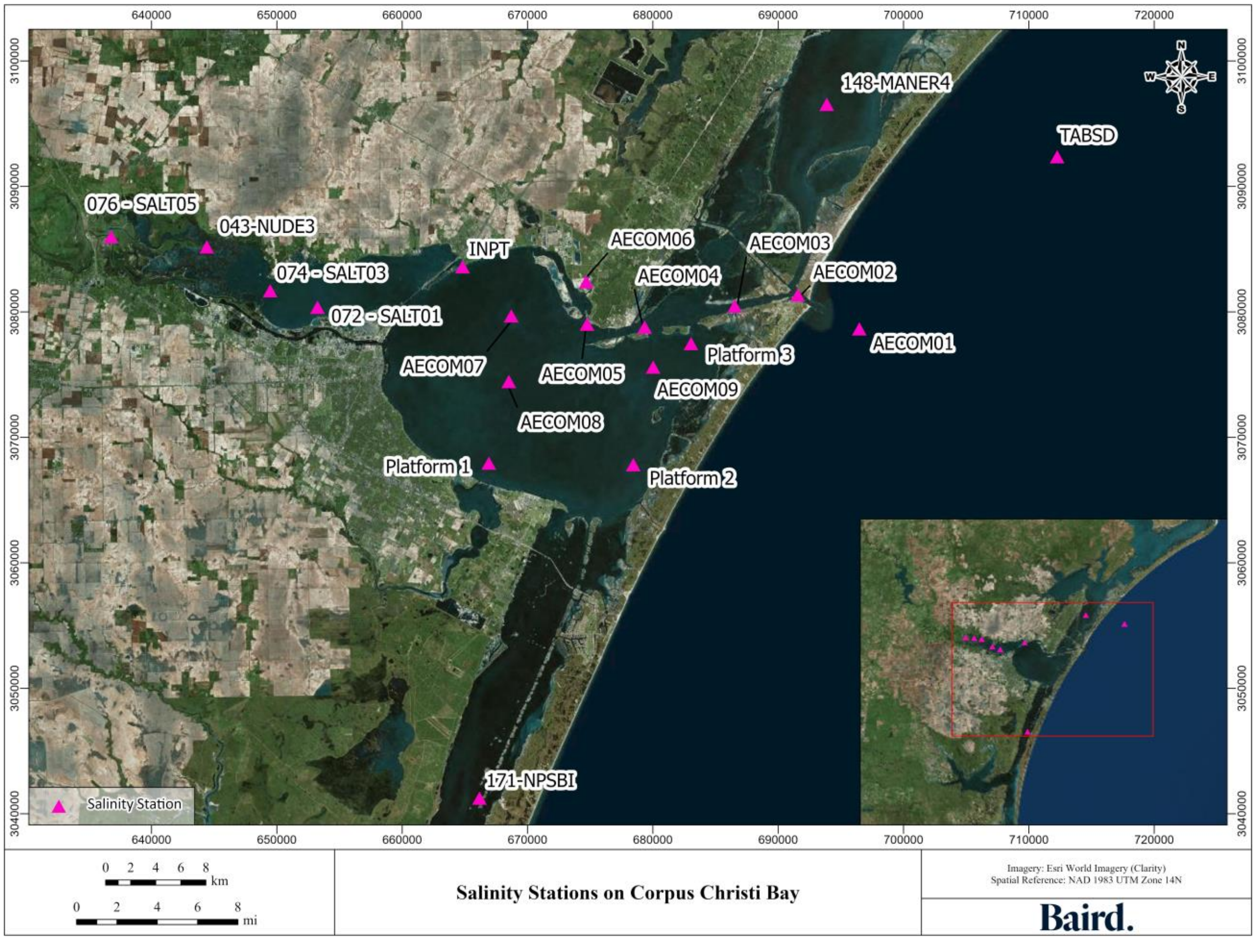


Figure 2.16: Salinity monitoring locations by the Texas A&M University CBI and TWDB

2.1.4.4 HYCOM Model

The HYCOM (Hybrid Coordinate Ocean Model) is an ocean circulation model with primitive equations that combines three types of vertical coordinates (z, sigma and isopycnal). For horizontal coordinates, HYCOM works with orthogonal rectilinear and curvilinear meshes. HYCOM efficiently solves the diapycnal diffusion, which is the interaction between layers of different densities. Also, it solves the dynamics in the stratified subsurface part of the ocean and its adjustment with the mixing layer.

The oceanic model calculates 541×385 cells in the horizontal at 1/25 degrees (~2.2 miles) in both easting and southern directions, and 27 hybrid layers (z, sigma and isopycnal coordinates) in the vertical, detailing on the surface and zone of the mixed layer with z-coordinates. From this model, the surface elevation and fluxes at the model boundary conditions were extracted.

From this source, the surface elevation and fluxes at the model offshore boundary conditions (see details in Section 3) were extracted. Figure 2.17 shows the HYCOM model nodes as black dots, the offshore boundary of the mesh as yellow dots, the northeast offshore boundary with purple lines, the southwest offshore boundary as orange dots, and the mesh elements used with blue lines. At the offshore boundary (yellow) the surface elevation was extracted from the HYCOM nodes using linear interpolation, while velocities were extracted at the northeast and southwest offshore boundary.

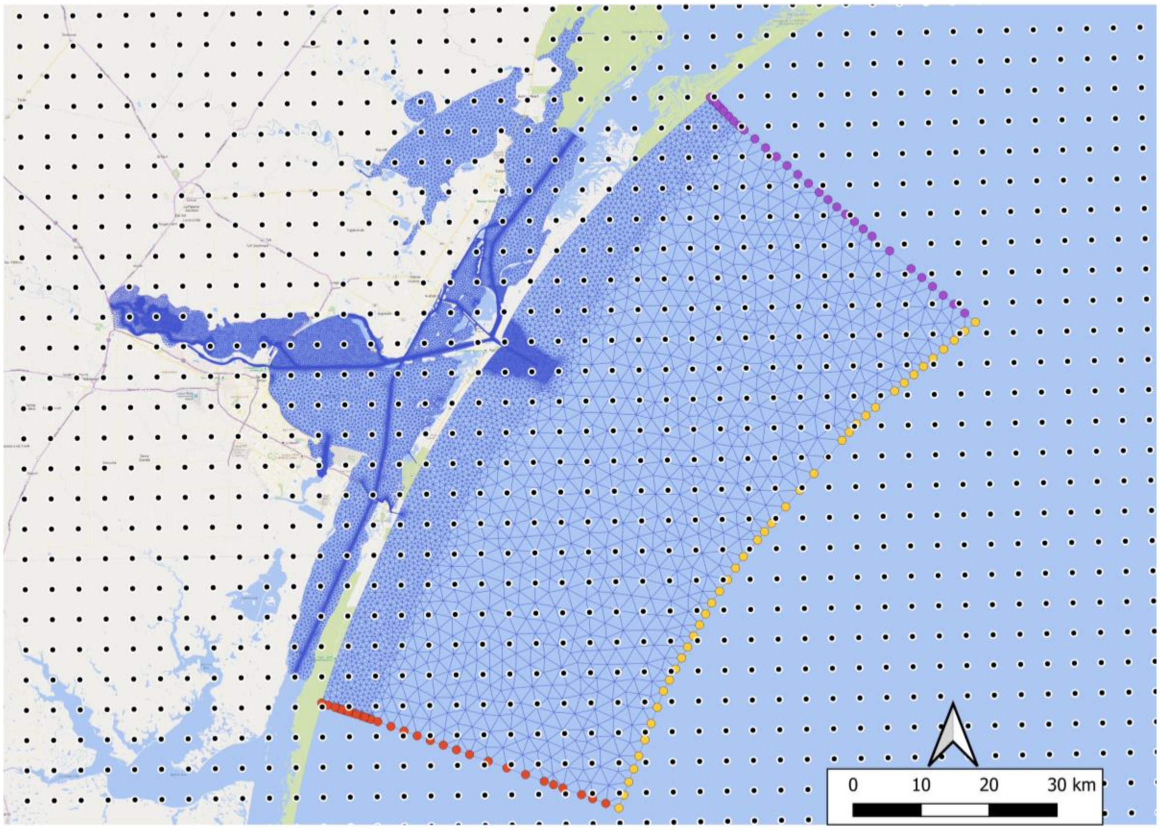


Figure 2.17: HYCOM model nodes and boundary of the computational mesh. Black dots are HYCOM model nodes, yellow dots show the offshore boundary of the mesh, purple lines show the northeast offshore boundary, orange dots show the southwest offshore boundary, and blue lines show the mesh elements.

2.2 Understandings of Physical Processes

2.2.1 Tide Propagation

This modeling study mainly focuses on Corpus Christi Bay, which connects to the other subtropical bays, such as Nueces Bay to northwest, Aransas Bay and Copano Bay on the northeast side, and Baffin Bay on the southwest side, through the Gulf Intracoastal Waterway (GIWW) (see Figure 2.18). The GIWW is a shallow water body running parallel to the shoreline of Gulf of Mexico (GOM) and has many man-made navigation channels. It is separated from the GOM by the longshore barrier islands, such as Mustang Island, Padre Island, and San Jose Island. These bays are connected to the GOM by a narrow entrance channel, Aransas Pass. There is a secondary inlet, Packery Channel. The tidal exchange between the GOM and the subtropical bays that have totally more than 1,000 km^2 in surface area is mainly through Aransas Pass, resulting in significantly strong current in the pass. The peak current speed in the pass reaches approximately 1.5 m/s (Williams et al., 1991; Brown et al., 2000, Whilden, 2015). On the other hand, this narrow channel also limits the tidal exchange between the GOM and bays, resulting in significant attenuation of tides in Corpus Christi Bay.

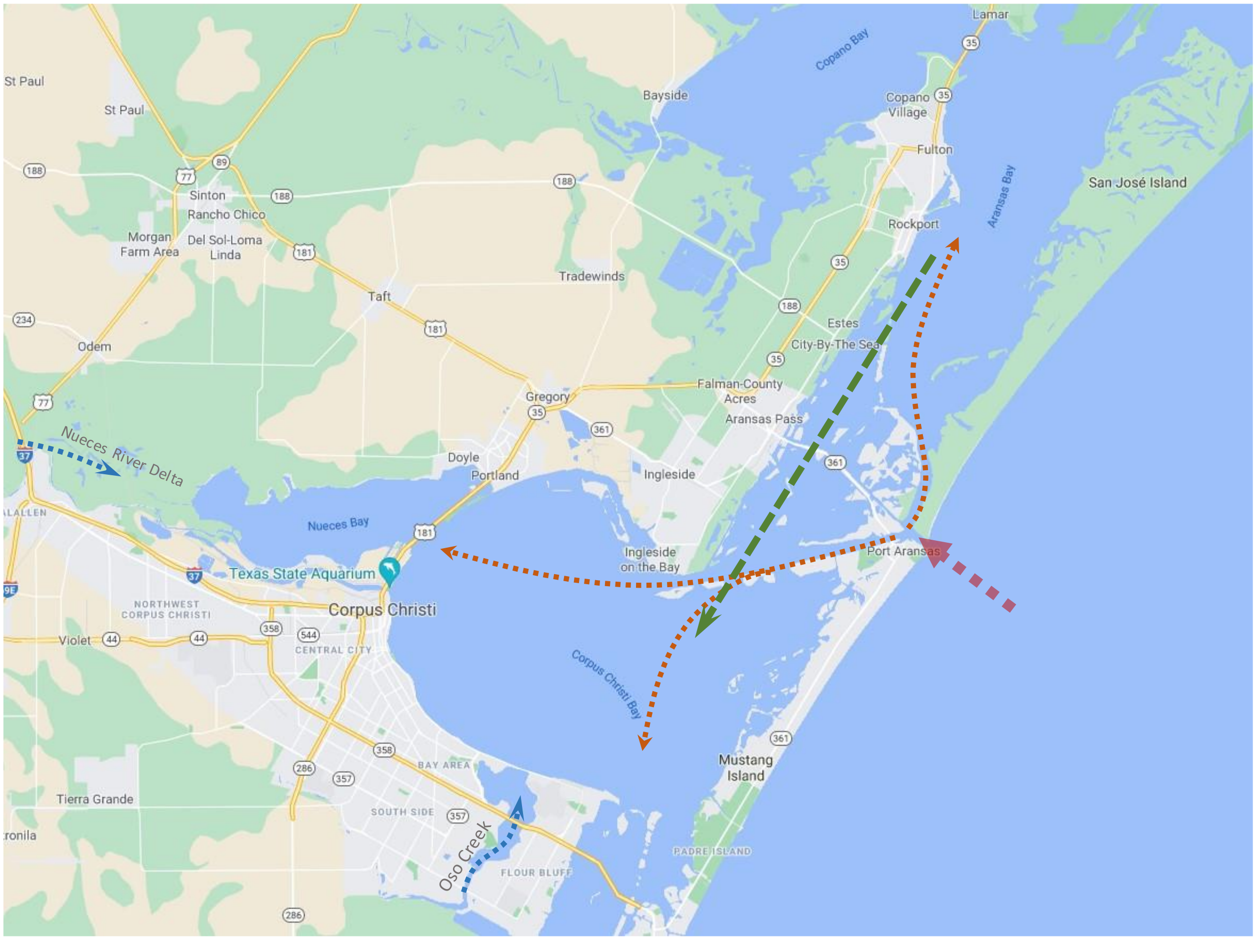


Figure 2.18: Understanding of local tide propagation. The orange arrows show the tide wave propagation directions. The green arrow shows the net flow along the intercoastal waterway. The blue arrows indicate the freshwater injections to the bays.

Data analysis of the measured water levels was carried out to understand the paths of tide propagation in the study area. Figure 2.19 to Figure 2.21 show the comparison of water levels measured at the stations (see locations in Figure 2.14) along three tide propagation paths as indicated in Figure 2.18. The Bob Hall Pier station is located in the offshore, therefore it represents the tide waves in the GOM. The tides in the GOM are primarily diurnal or mixed diurnal-semidiurnal with the tide range of about 0.7 m based on the measured water level at Bob Hall Pier.

These comparisons show three directions of tide wave propagation and the tide attenuation after the tide waves are transported from the GOM to the bays through Aransas Pass. The tide range at the Port Aransas is attenuated about 30%. The tides are further attenuated with the distance from Aransas Pass. Figure 2.19 shows the tide attenuation and phase lag along the northeast path of the intercoastal waterway, i.e., from the GOM, through Port Aransas, to Rockport and Aransas Wildlife Refuge. The lags in tide phase at these stations indicate the route of tide wave propagation in the northeast direction. The tide attenuation and the tide phase lag from the GOM to USS Lexington are shown in Figure 2.20, indicating the other middle path of tide propagation along the Corpus Christi Navigation channel towards to Nueces Bay. Figure 2.21 shows the tide attenuation and the phase lag along the southwest direction of intercostal waterway from the GOM to Port Aransas, Packery Channel, South Bird Island, and Baffin Bay. The tide signal at Baffin Bay almost disappears. This also indicates that the secondary inlet at Packery Channel Inlet has an insignificant impact on the tide in the bays.

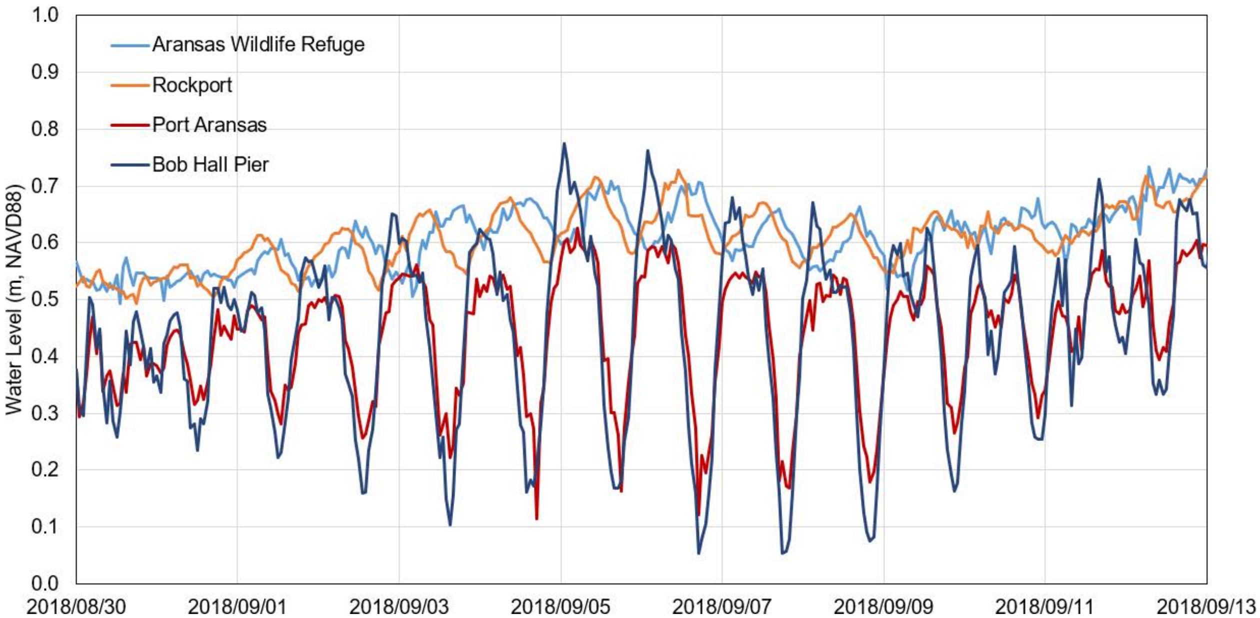


Figure 2.19: Tide propagation towards to northeast, indicated by the tide attenuation and phase lag from the GOM to Aransas Bay through Aransas Pass

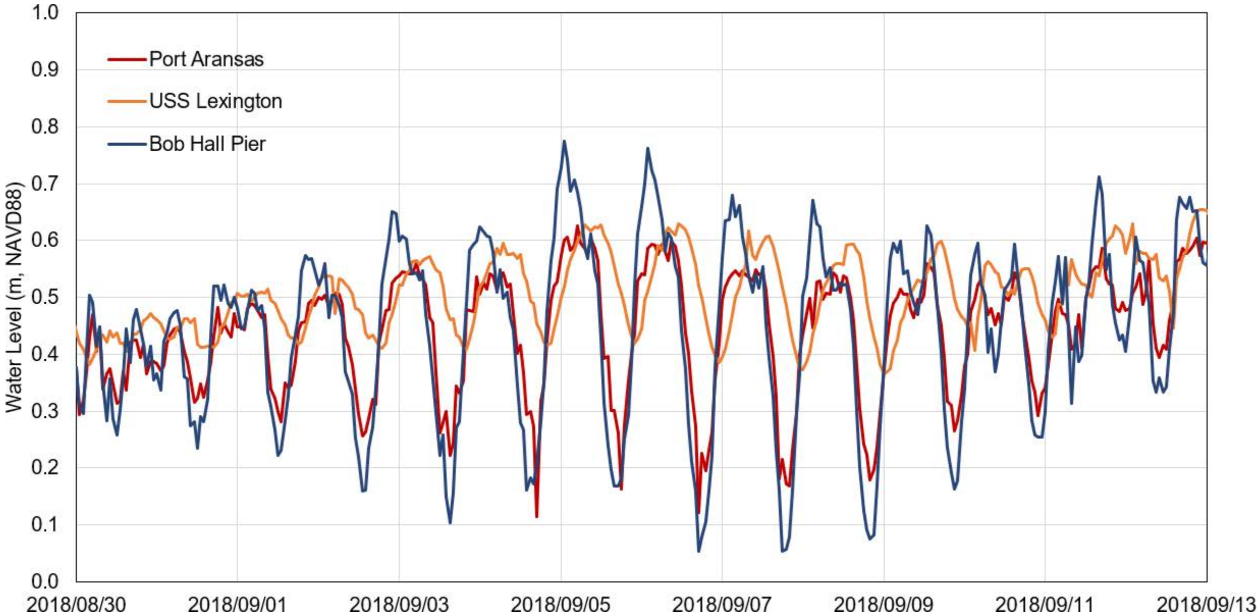


Figure 2.20: Tide propagation towards to northwest, indicated by the tide attenuation and tide phase lag from the GOM to USS Lexington through Aransas Pass

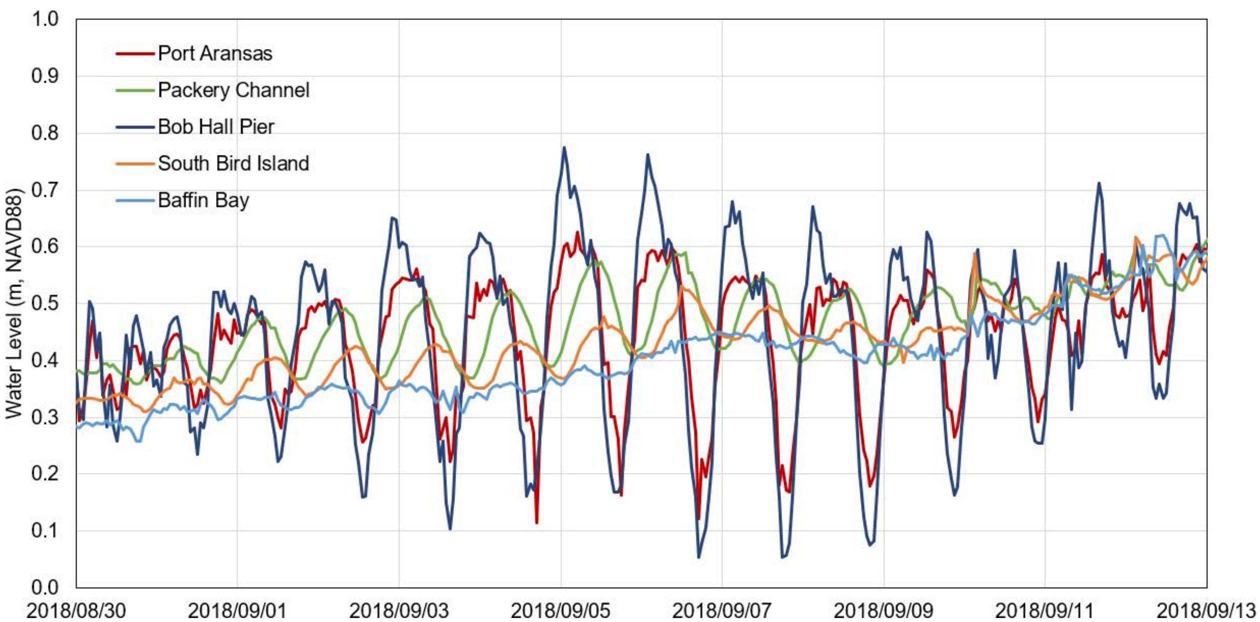


Figure 2.21: Tide propagation towards to southwest, indicated by the tide attenuation and tide phase lag from the GOM to Baffin Bay through Aransas Pass

The tide ranges at Rockport, Packery Channel, and the USS Lexington are only about 30% of the tide range in the GOM, i.e., the tides at these three stations are attenuated about 70%. It is also observed that the tide phases at these three stations are almost the same (see Figure 2.22). There is a constant water level difference between Rockport and Packery Channel, which indicates that there are likely net tide currents from Aransas Bay to Corpus Christi Bay through the GIWW as shown by the green arrow in Figure 2.18.

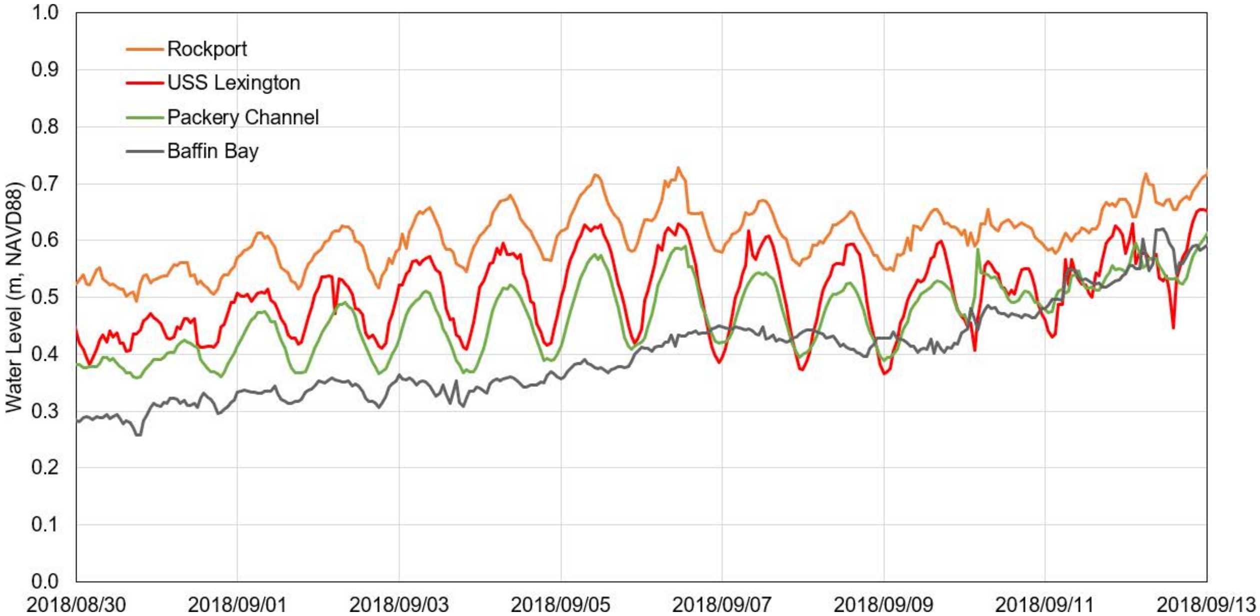


Figure 2.22: Water level difference along the Intercoastal Waterway. The water level at Rockport is always higher than that at Packery Channel.

2.2.2 Seasonal Variation of Wind

Hourly wind data measured at Bob Hall Pier was analyzed to understand the seasonal variation of local wind conditions. Figure 2.23 shows the rose plot from all wind data measured at Bob Hall Pier from 2005 to 2020. The figure indicates that the prevailing wind is from southeast. Since the study area is located on the northwest corner of the GOM, this prevailing wind likely results in the setup of water level at the study area. The monthly breakdown of the wind rose plots are shown in Figure 2.24. In the summer season from May to August, the prevailing wind is from southeast, which features the longest wind fetch in the GOM towards the project site. As a result, it likely produces the largest setup of water levels due to wind at the project site. In winter season from December to February, the prevailing wind is from north due to the frequent passages of cold fronts, which results in the set-down of water level in the GOM at the project site. In the remaining months, from March to April and from September to November, the prevailing wind is from both southeast and north which represents the transition of wind conditions between summer and winter seasons.

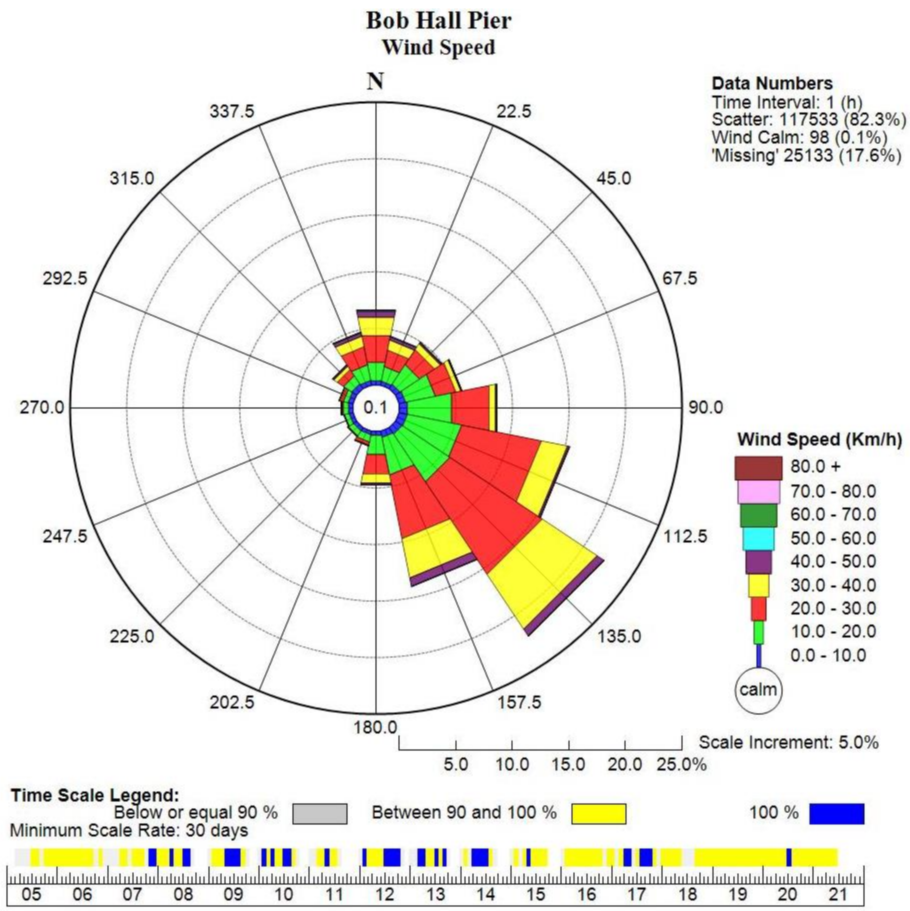


Figure 2.23: Rose plot of wind data measured at Bob Hall Pier (2005 to 2021)

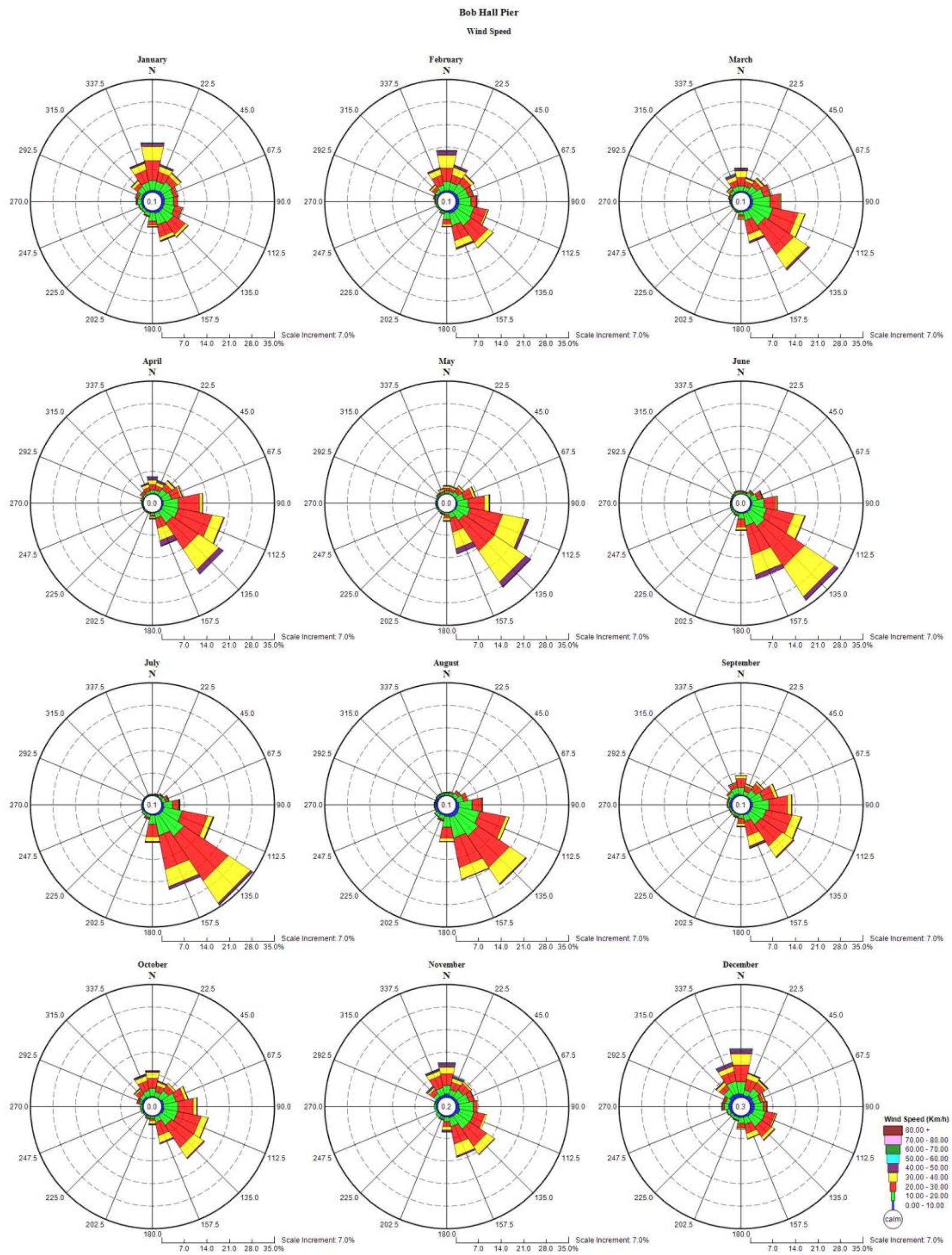


Figure 2.24: Monthly rose plot of wind data measured at Bob Hall Pier (2005 ~ 2021)

2.2.3 Seasonal Variation of Offshore Water Levels

Beside tides, the seasonal variation of water level in the GOM resulting from wind and the related oceanographic circulation has great contribution to the fluctuation of water level in these subtropical bays. As described in the previous section, the seasonal variation of water level at the offshore of the study area is driven by the seasonal sustained winds. The tropical storms (or hurricanes) cause large fluctuation of water level in the bays, but it is not sustainable. To understand the seasonal variations of offshore water level in the study area, tide signal was removed by subtracting water levels predicted using the selected major tide constituents from the measured water levels. The results are shown in Figure 2.25. The monthly averaged water level resulting from the sustained winds are shown in Figure 2.26. The seasonal variation of water level can be well explained by the seasonal changes of the prevailing wind direction in seasons in the GOM as described in Section 2.2.2 along with the related oceanographic circulation patterns. The water levels at the offshore of the project site are higher in late spring and fall. The highest offshore water level occurs in October, which is about 0.4 m ranging from 0.2 m to 0.7 m above mean sea level. The offshore water levels in winter season are low, which likely results from the predominant north winds associated with the passage of frequent cold fronts.

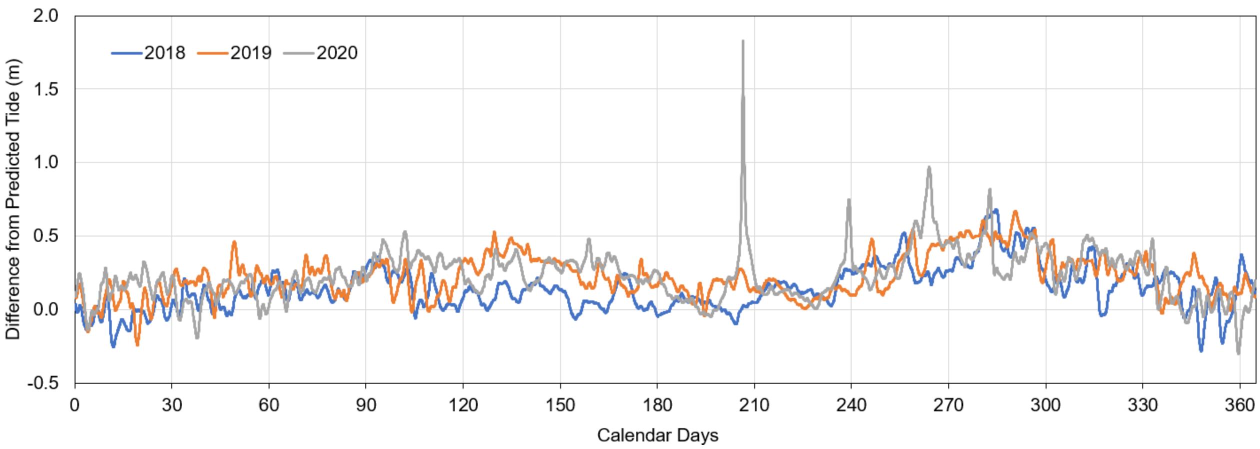


Figure 2.25: Seasonal variation of water level in the Gulf of Mexico calculated as the difference of water level measured at Bob Hall Pier and water level predicted by using tide constituents. The water level is referred to Mean Sea Level.

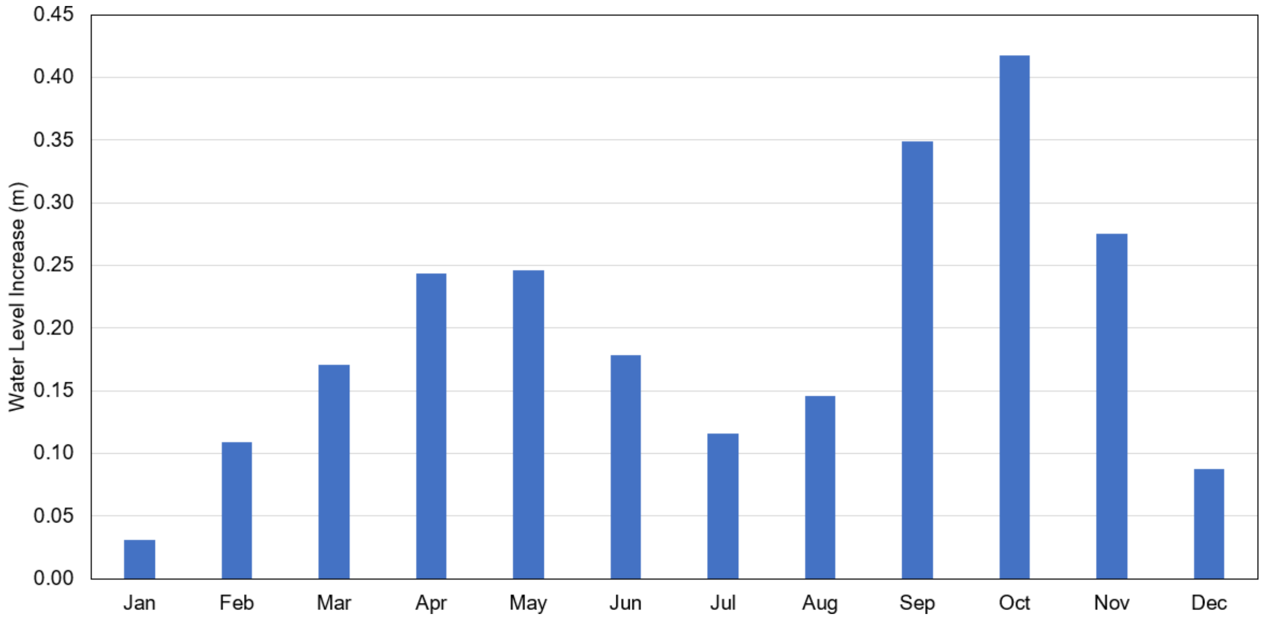


Figure 2.26: Monthly average variation of water levels at the offshore of project site resulting from seasonal wind variations

2.2.4 River Inflows

The Corpus Christi Bay receives freshwater from the Nueces River and Oso Creek through Nueces Bay and Oso Bay, respectively. Based on the measured discharge at Mathis in Nueces River, the average discharge in Nueces River is about 19 m^3/s, ranging from 1 m^3/s to 700 m^3/s. The monthly distribution of river discharge is shown in Figure 2.27 and indicates that the river has large high flow from May to November and low flow from December to April. Figure 2.28 provides annually averaged discharge in Nueces River, which shows significantly large variation of interannual river flow, ranging from 1 m^3/s in the dry years to 80 m^3/s in the wet years.

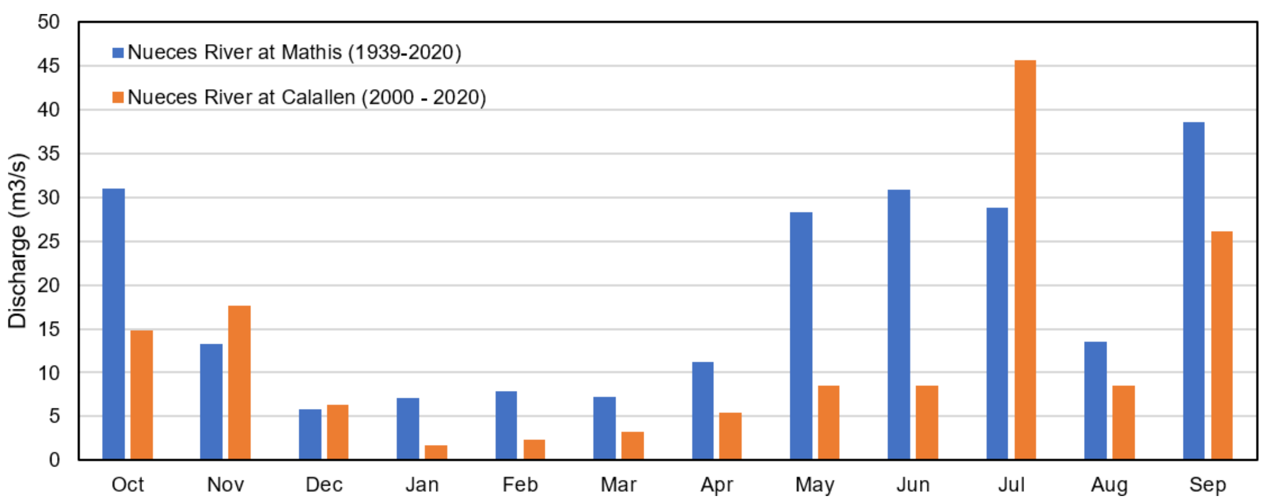


Figure 2.27: Seasonal Variation of River Discharge in Nueces River

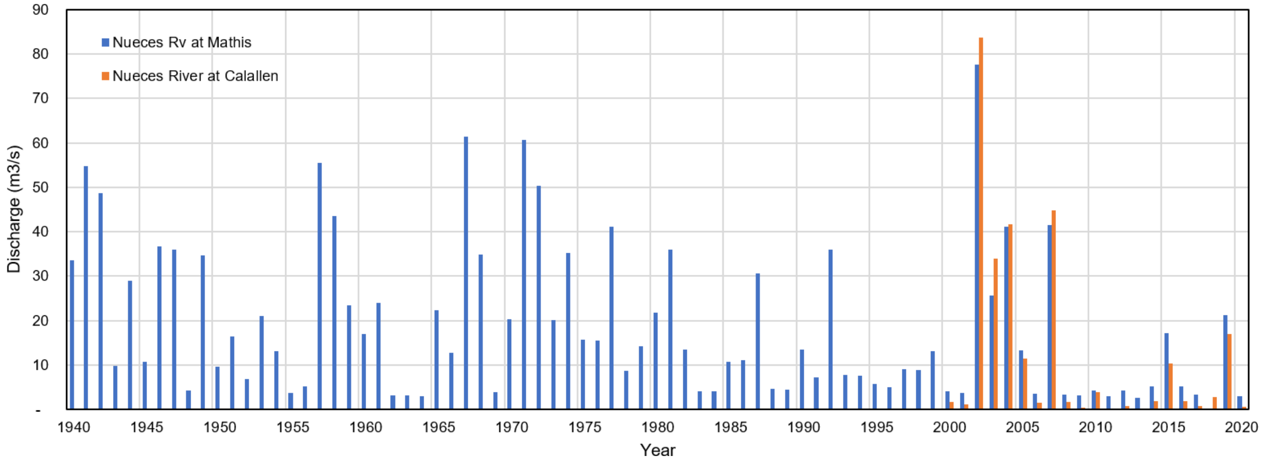


Figure 2.28: Annual average discharge in Nueces River

2.2.5 Salinity Sources

Understanding the salinity sources is essential for model calibration. There are many physical processes which drive salinity conditions in Corpus Christi Bay and Nueces Bay. The saltwater carried by tidal currents from the GOM is the origin of salinity in the bays. Figure 2.29 shows the measured salinity at the monitoring stations in the study area. The salinity in the intracoastal waterway (NPBSI and MANER4) and in Corpus Christi Bay (INPT) are the same level as the salinity in the GOM (TABS-D). Evaporation in dry season becomes important to drive salinity in shallow water areas to higher levels and sometimes even higher than in the GOM. The freshwater from the rivers and rainfalls results in significant decline of salinity in Nueces Bay (SALT01 and SALT03) due to dilution. When the river flow is large, the freshwater impact on salinity extends to Corpus Christi Bay through hydrodynamic advection. Stratification (i.e., higher salinity at the bottom than on the water surface) in the north part of Corpus Christi Bay was observed after a large river flow event in Nueces River (Islam et al, 2010). During extensive dry seasons, salinity in Nueces Bay and Baffin Bay becomes high and even exceeds the salinity level in Corpus Christi Bay and in the GOM (Ward & Armstrong, 1997). Carried by flood tide currents, this high saltwater can be transported to Nueces Delta resulting in the accumulation of salt in the delta marsh. The accumulation of salt in the marsh flat of Nueces River Delta was observed from satellite imagery (see Figure 2.30).

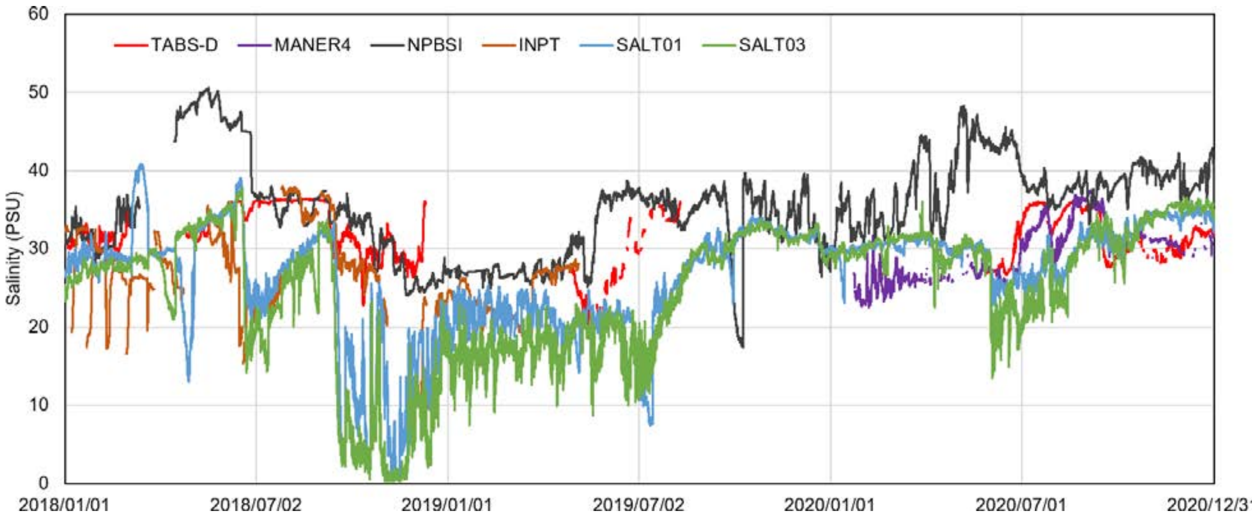


Figure 2.29: Measured salinity at the stations in the study area.

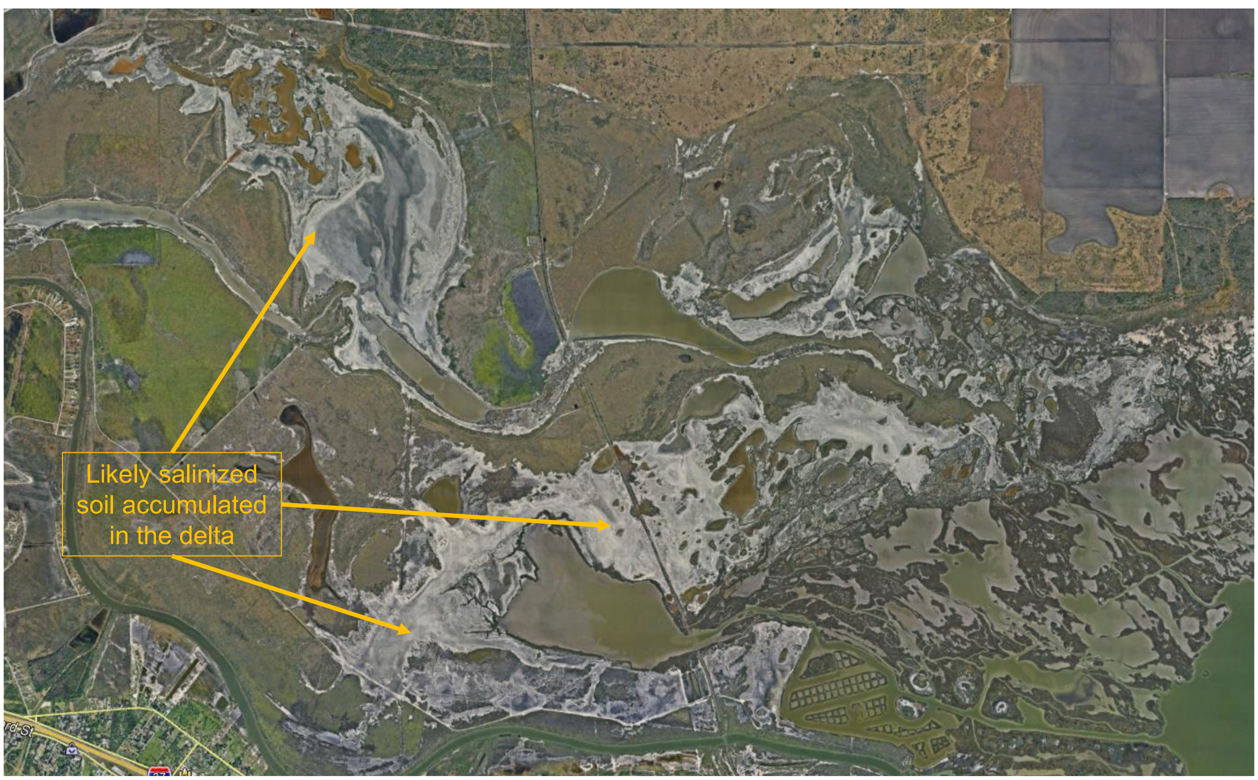


Figure 2.30: Salinized soil in Nueces Delta identified from satellite imagery

2.3 Data Gaps and Recommendations

Through the data collection and analysis, the following major data, which are required for model development, are missing:

- Bathymetry in Nueces Bay: There is no reliable bathymetry data in Nueces Bay. The Lidar Based bathymetry collected from the NOAA data source indicates a constant bed elevation of -0.1 m NAVD88, which is unlikely. The bathymetry in Nueces Bay is an important data set for the calculation of the tidal prism in Nueces Bay, and therefore, it could impact on the water exchange between Nueces Bay and Corpus Christi Bay significantly;
- Salinity data gap at Rockport: There is large temporal data gap of salinity at Rockport, which is used to develop the northeast open boundary condition for the open boundaries at the northeast of the intracoastal waterway;
- Storage of salt in Nueces River Delta: There is significant salt stored in the marsh flats of Nueces Bay. These salt deposits can be dissolved by rainfall and the flood flow of Nueces River and be carried to Nueces Bay by flood flows on the Nueces River.

3. Hydrodynamic and Salinity Model Development

3.1 Review of Previous Models

There are a few numerical models applied to Corpus Christi Bay areas to have been developed to simulate hydrodynamics and salinity in the Corpus Christi Bay area (Dawson & Phthina, 2001, Zhang, 2008 and 2010, Dawson *et al.*, 2011, Schoenbaechler *et al.*, 2011, Matsumoto *et al.*, 2001). Dawson and Pothina (2001) applied a three-dimensional (3D) model using finite element method, QUODDY4, to this study area to simulate hydrodynamics, temperature, and salinity. The report did not show the calibration result due to the model instability issues. In 2011, they applied another model, the University of Texas Bay and Estuary 3D (UTBEST3D), to the same areas to simulate hydrodynamics, temperature, and salinity. The model included tide, wind, and river inflow. Precipitation and evaporation were also considered. The model was able to reproduce water levels, though only by shifting the datum of measured data. Based on our data analysis, the model may not include (or may not reproduce) the net tidal currents from Aransas Bay to Corpus Christi Bay as described in Section 2.2.1. Our model tests indicate that including the net tidal currents significantly improves the water level calibration at USS Lexington.

Zhang (2008, 2010) applied OHSU's SELFE model to this area. The SELFE model is an open-source community-supported code using a semi-implicit finite-element/volume Eulerian-Lagrangian algorithm to solve the Navier-Stokes equations using a triangle mesh. The model simulated hydrodynamics, temperature and salinity and was calibrated against Year 2000 data.

Schoenbaechler *et al.* (2011) applied the TxBLEND model to Nueces Bay for support of freshwater resource management. The TxBLEND model is a two-dimensional (2D) depth-averaged model designed to simulate water circulation and salinity conditions in estuaries, which is an expanded version of the BLEND model specific to TWDB's needs (TWDB 1999). The model used a finite-element method with a triangular mesh. The model considered tide, wind, river inflow, precipitation, and evaporation and included the runoff from the ungagged catchments which directly drains to the Corpus Christi Bay. The model was extensively calibrated against measured data collected in 1994, 1995, 1999, through 2004. Similar to UTBEST3D model, the model underpredicted the mean water level at USS Lexington, which is likely associated with missing the net tidal currents from Aransas Bay to Corpus Christi Bay.

Matsumoto et al. (2001) applied the TxBLEND-3D model to assess the impacts of the Corpus Christi Ship Channel Improvement Project. The model was well calibrated against the measured current and salinity. The model may underestimate the stratification of salinity in Corpus Christi Bay. AECOM (2019) used the Delft3D model to assess the environmental impact of the FWP for the EIS study. Since the model was run in 2D mode, the model could not simulate the stratification in the bay.

All the above-mentioned models used the water level to control the offshore boundary conditions. These models may not appropriately simulate the long-shore currents in the GOM. The long-shore currents are necessary to estimate the cross-channel current speed in the outer channel, which is important information for navigation. The measured data at TABS-D shows that the long-shore current speed could be as high as 1 m/s.

3.2 Model Development

The model suite, MIKE21 and MIKE3, developed by Danish Hydraulic Institute (DHI), was selected to simulate hydrodynamics and salinity for this project. The main objective of this model study is to evaluate the impact of Corpus Christi Channel Deepening Project on the environment. The flexible mesh version of

DHI model was used to appropriately describe the complex shorelines and to refine the grid in the area of interest, e.g., along the navigation channel for this project. The model utilizes the finite volume method and can be used to simulate a range of hydraulic conditions, including tidal exchange, river flow and currents, wind driven current, density driven flow, and so on. The model is well known in the water resources and coastal community and has been extensively used by various government agencies, academia, and consultants to support surface water projects around the world. It is also a FEMA approved hydraulic and coastal model.

MIKE21 is a two-dimensional (2D) depth-averaged model, which has less computational demand. MIKE3 model is a three-dimensional (3D) model, which can be used to simulate the variation in water column, for example, stratification, but has much greater computational demand. To calibrate the model efficiently to meet with project schedule, MIKE21 was firstly used to perform the initial model calibration, and then MIKE3 was then used for the final model calibration and validation.

3.2.1 Model Domain

The model domain was selected to be centered on the project site (i.e., Aransas Pass) and includes the water bodies, which may be potentially impacted by the proposed project. It includes Corpus Christi Bay and its connected subtropical bays: Nueces Bay, Oso Bay, Redfish Bay, Aransas Bay, Copano Bay, and Baffin Bay. From Aransas Pass, the model domain extends to offshore about 50 km into the Gulf of Mexico to the -50 m NAVD88 contour, about 50 km north to Interstate Highway 37 including Nueces River Delta, and about 100 km along the GIWW. The two narrow connecting channels, Aransas Pass and Packery Channel, were included to make the connection between the bays and the GOM. Figure 3.1 shows the selected model domain.

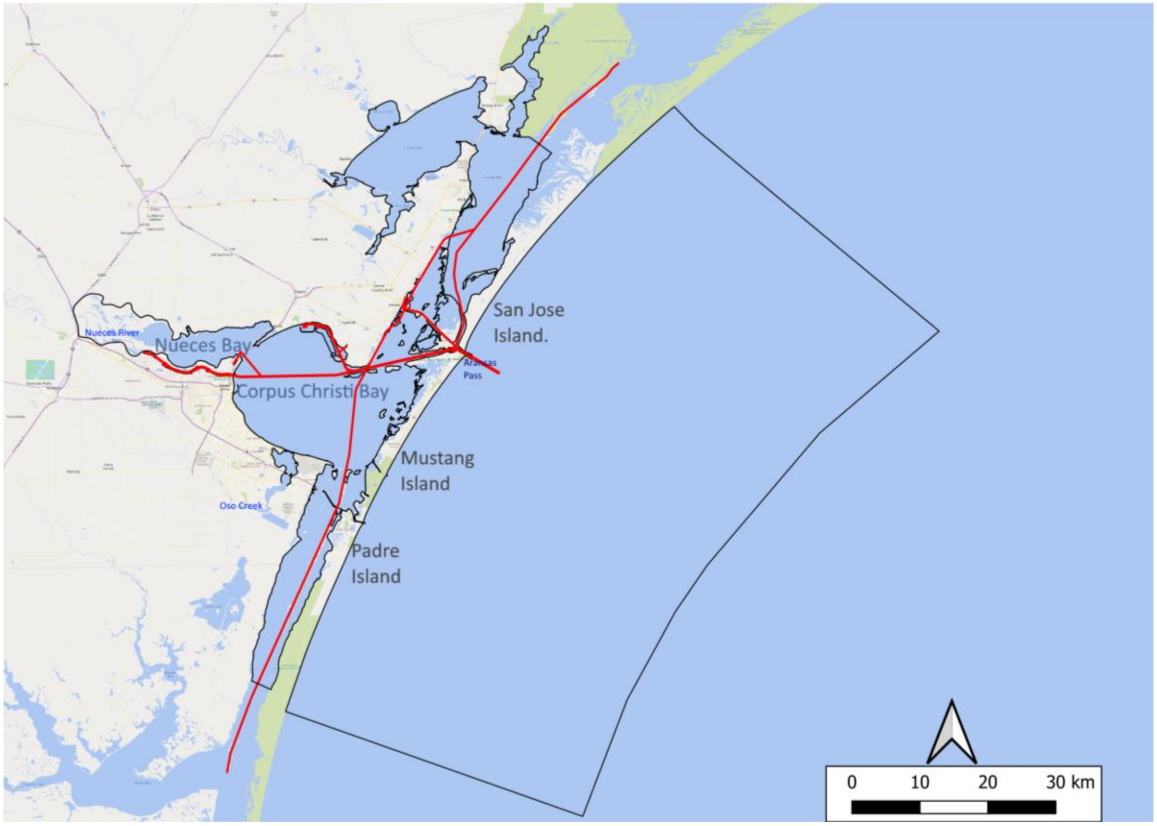


Figure 3.1: Model domain selected for this model assessment. The red lines show the existing navigation channels in the model domain.

3.2.2 Grid Generation

An unstructured mesh with the mixture of triangles and quadrilaterals was generated in the model domain. Mesh generation is one of the most important parts of the modeling strategy, since it defines the level of detail required while balancing computation time. The grid resolution varies depending on the hydrodynamic complexity and/or significance of an area. The mesh around the project site, along the navigation channels (both existing and proposed), the important narrow waterways, and the structures was significantly refined. Many test runs were performed to check whether there was sufficient grid resolution to simulate the complex flow patterns in the area of interest. The final model grid consists of 42,439 nodes and 80,015 elements (see Figure 3.2). The grid resolution in the navigation channel is about 30 m. The grid resolution in the bay and offshore was significantly reduced to reduce the computation time. The largest grid size is about 2,500 m. Figure 3.3 shows the variation in element resolution around Port Aransas.

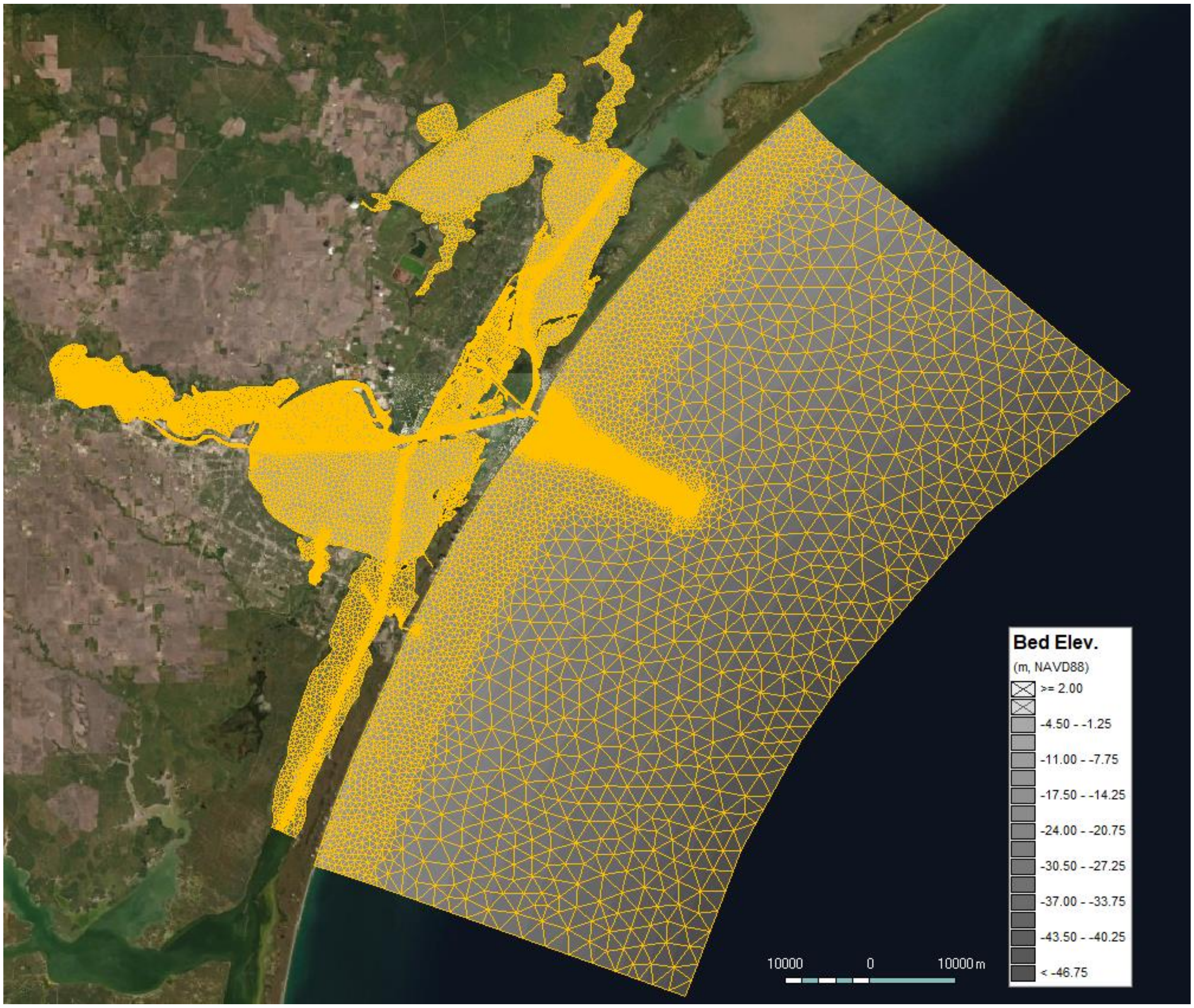


Figure 3.2: Final model mesh generated for this modeling study with mixture of triangles and quadrilaterals

Figure 3.3: Refinement of model mesh along the navigation channels

The bed elevations at the mesh nodes were interpolated from the assembled bathymetry data for the existing condition. Note that the bathymetry in Nueces Bay was modified during the calibration since there was no reliable bathymetry data available, which will be described in the next section. Figure 3.4 shows the interpolated bathymetry in the model domain, and Figure 3.5 shows the details of the bed elevation around Port Aransas.

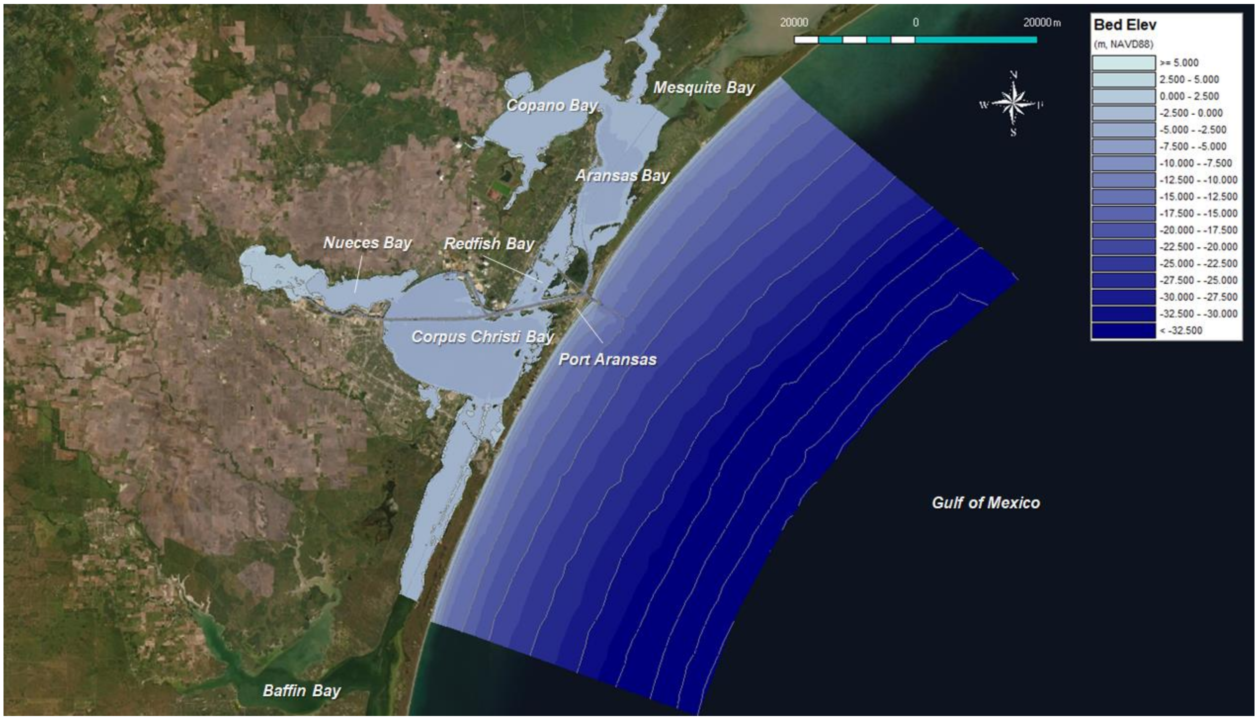


Figure 3.4: MIKE3 model domain and bathymetry in the existing condition

Figure 3.5: MIKE3 model bathymetry near Port Aransas in the existing conditions

3.2.3 Model Setup

The model requires the appropriate setup of initial conditions, open boundary conditions, driving forces, and physical parameters to correctly simulate the anticipated physical processes. Any errors from these inputs will result in inaccuracies in the simulation. Therefore, the measured data were used to develop the inputs to the model as much as possible.

3.2.3.1 Initial Conditions

The initial conditions for hydrodynamic simulation were set up as constant for water level and zero for flow velocity in the model domain. To avoid model instabilities, the start time of model simulation was carefully selected to coincide with slack tide time when the water level in at all open boundaries is at the same elevation to the extent as possible.

The initial conditions for salinity simulation were set up as a constant bay-wide for each individual bay, but varying bay-to-bay. Measured salinity at the simulation start time was used. No stratification in the water column was specified for the initial conditions.

3.2.3.2 Open Boundary Conditions

There are 10 open boundaries in the model domain which require specification of boundary conditions (BC) for model simulation. Table 3.1 lists the required details for the boundary conditions at these open boundaries, including:

- Open Boundary: Open boundary name;
- BC Type: the type of physical variable used to control the open boundary conditions;
- Variation: indicates whether the boundary conditions are varied (or constant) in time, horizontal space, and vertical column;
- Method: indicates the method to develop the boundary condition from the source data;
- Data Sources: indicates the data used to build the boundary condition.

Additional information on developing boundary conditions for certain open boundaries are described below.

Table 3.1: Open boundary conditions for hydrodynamic simulation

Open Boundary	BC Type	Variation	Method	Data Sources
Offshore	Water level	Time series and spatially varied	Extracted from HYCOM model and adjusted with measured water level	HYCOM model output
Offshore NE	Unit width flow flux	Time series and varied on boundary and water column	Extracted from HYCOM model	HYCOM model output
Offshore SW	Unit width flow flux	Time series and varied on boundary and water column	Extracted from HYCOM model	HYCOM model output

Open Boundary	BC Type	Variation	Method	Data Sources
Rockport	Water level	Time series and constant on boundary	Interpolated from measured water levels	Water levels measured at Rockport and Aransas Wildlife Refuge
Baffin Bay	Water level	Time series and constant on boundary	Measured water levels	Water levels measured at Baffin Bay
Oso Creek	Discharge	Time series	Measured discharge and adjusted for ungaged watershed	Discharge measured USGS gage and TrRR output
Nueces River	Discharge	Time series	Measured discharge and adjusted for ungaged watershed	Discharge measured USGS gage and TrRR output
Aransas River	Discharge	Time series	Measured discharge	Discharge measured USGS gage
Mission River	Discharge	Time series	Measured discharge	Discharge measured USGS gage
Copano Creek	Discharge	Time series	Measured discharge	Discharge measured USGS gage

The boundary condition for the offshore open boundary was controlled by water level and was extracted from HYCOM model output. However, the water levels from the HYCOM model are significantly different from the water level measured at Bob Hall Pier. By analyzing the water level difference, it was found that the HYCOM model likely did not include seasonal variation of water levels in the GOM fully as described in Section 2.2.3. Therefore, the following steps were performed to adjust the offshore water levels for boundary conditions:

- Calculate the difference of hourly water levels measured at Bob Hall Pier and predicted by HYCOM model;
- Perform the 25-hour moving average on the water level difference by removing tidal signals;
- Add the smoothed water level difference to the offshore water level predicted by HYCOM.

Discharges from Nueces River and Oso Creek were developed based on the daily discharge measured at the USGS gages. The runoff from the ungagged watershed for these inflows were added by using the predicted runoff from TxRR model. For Nueces River, the return flows from the water usage facilities were also added.

Salinity was defined at all 10 open boundaries for salinity simulation. Table 3.2 shows the setup of the salinity boundary conditions.

Table 3.2: Open boundary conditions for salinity simulation

Open Boundary	BC Type	Variation	Method	Data Sources
Offshore	Salinity	Time series and spatially constant	Gap filled salinity	Measured at TABS-D

Open Boundary	BC Type	Variation	Method	Data Sources
Offshore NE	Salinity	Time series and spatially constant	Gap filled salinity	Measured at TABS-D
Offshore SW	Salinity	Time series and spatially constant	Gap filled salinity	Measured at TABS-D
Rockport	Salinity	Time series and spatially constant	Gap filled salinity	Measured at MANER4
Baffin Bay	Salinity	Time series and spatially constant	Gap filled salinity	Measured at NPBSI
Oso Creek	Salinity	Constant	Fresh water	0 PSU
Nueces River	Salinity	Time series and spatially constant	Measured salinity with adjustment	Measured at SALT05, SALT01, SALT03
Aransas River	Salinity	Constant	Fresh water	0 PSU
Mission River	Salinity	Constant	Fresh water	0 PSU
Copano Creek	Salinity	Constant	Fresh water	0 PSU

There were outliers and large data gaps in the measured salinity data. All measured salinity data was first processed by filtering the outliers. The data gaps were filled by using neighboring gage data if available. The filled data gaps in salinity were revised during the model calibration.

The salinity for Nueces River inflow was developed based on the measured salinity at SALT05. However, the model tests indicated that the conveyance capacity of Nueces River downstream the USGS gage at Calallen is small. There are several small branches connected to the Nueces River, which diverts the freshwater to the ponds and shallow marshes in the delta, mixes with high salt water in the ponds and shallow marshes, and empties to Nueces Bay. Additionally, flooding over the Nueces Delta occurs during large river flow events. The flooding river freshwater associated with river floods could dissolve the salt soil accumulated in the delta marsh and eventually drain to Nueces Bay with high salinity. Many model tests were carried out during the model calibration. It was concluded that good model calibration could not be achieved if the measured salinity at SALT05 was used to control the salinity from Nueces River since MIKE3 model has no capability to account for above-mentioned physical processes. Therefore, the adjustment of salinity boundary conditions for Nueces River was made by using the information provided from the measured salinity at SALT01 and SALT03.

3.2.3.3 Driving Forces

Wind

Wind is one of the important forces driving the currents in the bays which is considered in this study. By analyzing the wind data measured at the meteorological stations in the model domain, wind direction is mostly constant in space under the normal weather conditions, except for the spatial variability during tropical storms. Since this model study mainly focuses on normal meteorological conditions, time-varying and spatially constant wind was implemented in the model. The hourly wind data measured at Bob Hall Pier was the most representative of average wind conditions in the open water of the study area and therefore was used for this modeling study.

Precipitation

Precipitation (or rainfall) was considered in the model setup, because it can be a freshwater source for the salinity simulation, although it may not have significant impact on hydrodynamics. Based on the comparison of daily precipitation data (which are available at many stations), the precipitation can be very localized and significantly varied in space. The precipitation increases from inland moving offshore, e.g., from Nueces River catchment to Port Aransas and Rockport, due to the lake affect. However, there was insufficient precipitation data available to develop a spatially varied precipitation dataset. Therefore, time-varying but spatially constant precipitation was used in the model, developed from the hourly precipitation data measured at Port Aransas. A scale factor was introduced to account for spatial variation, which was considered to be a calibration parameter.

Evaporation

Evaporation can cause increases in salinity, particularly in shallow waters. The impact may be greater during dry seasons. Therefore, the evaporation was considered in the model. Initially, a monthly average evaporation rate estimated by NOAA was used. With this data, the model did not produce the good calibration against the measured data. Therefore, the daily evaporation measured at the USGS gage at Mathis was used for the model. Since the gage is located inland, the evaporation over open waters could be greater than in the inland. Therefore, a scale factor was introduced as a calibration parameter.

Runoff

There are five catchments which directly drain to Corpus Christi Bay and Nueces Bay as shown in Figure 2.8. The daily runoffs from these catchments were provided from TxRR model output or estimated from the daily precipitation. For each catchment, the runoff was evenly divided into a few point sources that were implemented in the model. The locations of point sources were selected visually at the locations of small ditches using satellite imagery. The runoff is considered as freshwater (no salinity).

3.2.3.4 Physical and Numerical Parameters

There are several physical and numerical parameters which were determined through the model calibration. Table 3.3 lists the primary physical and numerical parameters and their final values determined through iterations of model runs during the model calibration.

Table 3.3: Primary physical and numerical parameters determined through the mode calibration

Physical Parameters	Variation	Value or Range	Notes
Roughness	Varied spatially	0.015 ~ 0.023	Determined from hydrodynamic model calibration
Wind Drag Coefficient	Constant in space and varied with wind speed	0.0013 (U_{10} <= 7 m/s) 0.0024 (U_{10} >= 25 m/s)	Determined from hydrodynamic model calibration
Horizontal eddy viscosity	Varied spatially	0.28 for Smagorinsky coefficient	Calculated by using Smagorinsky formulae
Vertical eddy viscosity	Varied spatially	Calculated from model	Using two-equation closure $\kappa - \varepsilon$ model
Horizontal diffusivity	Constant in space	10	Determined from salinity model calibration
Vertical diffusivity	Varied spatially	1 (scale factor)	Scale to vertical eddy viscosity

Bed roughness is one of the most important physical parameters for model calibration. Many sensitivity tests with roughness were performed to check response of surface elevation and current velocity to roughness variations. The final map of Manning's M values, ranging from 43 to 67, which corresponds to the Manning's n roughness from 0.023 to 0.015, as shown in Figure 3.6.

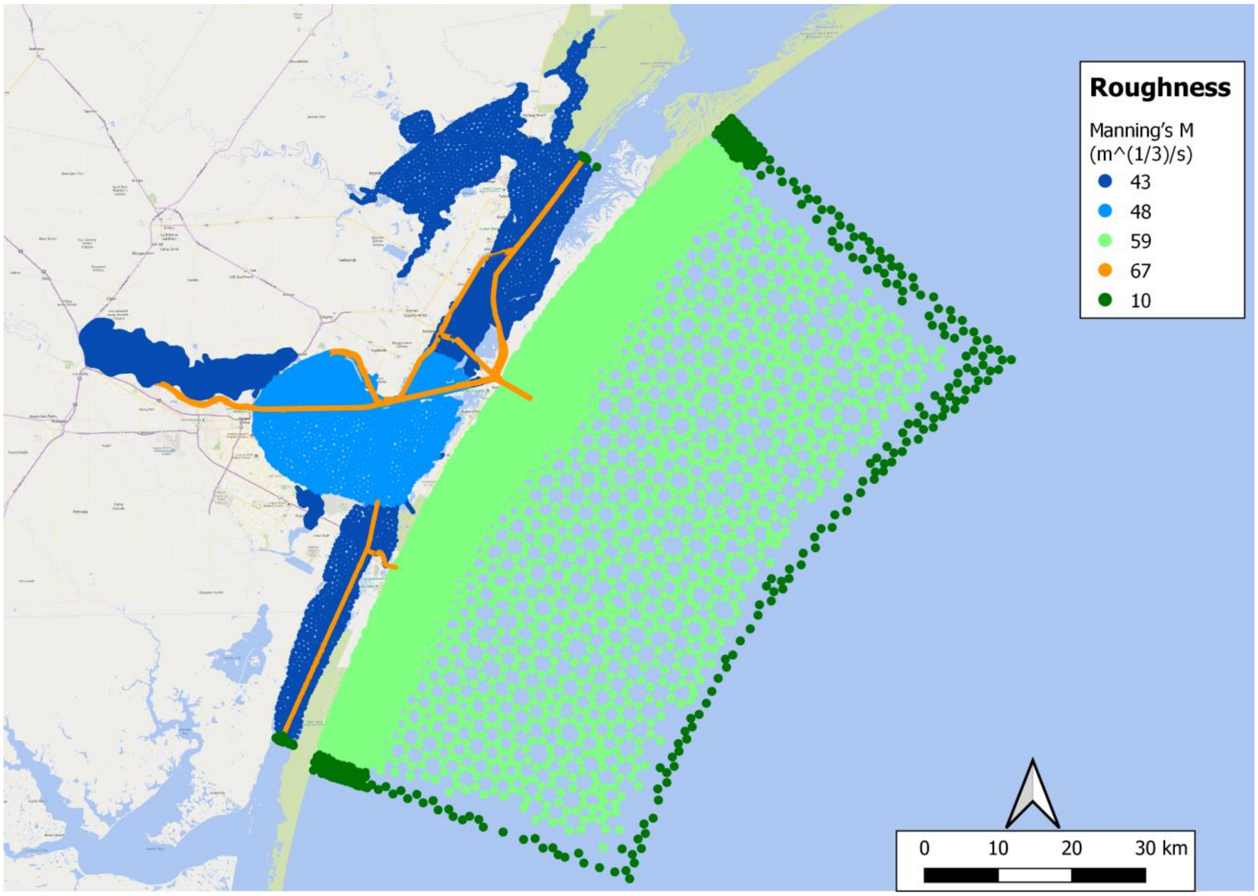


Figure 3.6: Bed roughness

3.3 Model Calibration and Validation

3.3.1 Simulation Periods

Three simulation periods with three-month duration each were selected for model calibration and validation based on the conditions of river inflows, wind, and salinity mixing in the Corpus Christi Bay. The three-month duration is sufficiently long to cover the full variation of tides. To understand the representative dynamics in the selected simulation periods, statistical analysis of the measured discharge and wind data was carried out. Figure 3.7 shows the monthly average discharge measured in Nueces River and their corresponding cumulative frequency, based on daily discharge measured at Nueces River, Calallen (USGS gage 08211500) in the period from October 1, 1997, to September 30, 2020. Figure 3.8 shows the monthly average wind speed and monthly maximum wind speed, based on the hourly wind data measured at Bob Hall Pier in the period from 2018 to 2020. Table 3.4 shows the three selected periods and the representative river flow, wind conditions, and physical processes.

Table 3.4: Selected simulation periods for model calibration and validation

Simulation Period	Start Date	Duration	Conditions
Period 1	June 1, 2018	90 days	• Normal river flow • Average wind • Salinity recovery from a rainfall event • Some salinity stratifications
Period 2	September 1, 2018	90 days	• Above-normal river flow (the 95th Percentile) • Average and below average wind • Salinity dilution with large river flow • Strong salinity stratification
Period 3	July 1, 2020	90 days	• Normal river flow • Above-normal wind with hurricanes • Well mixed salinity mixing in the bays

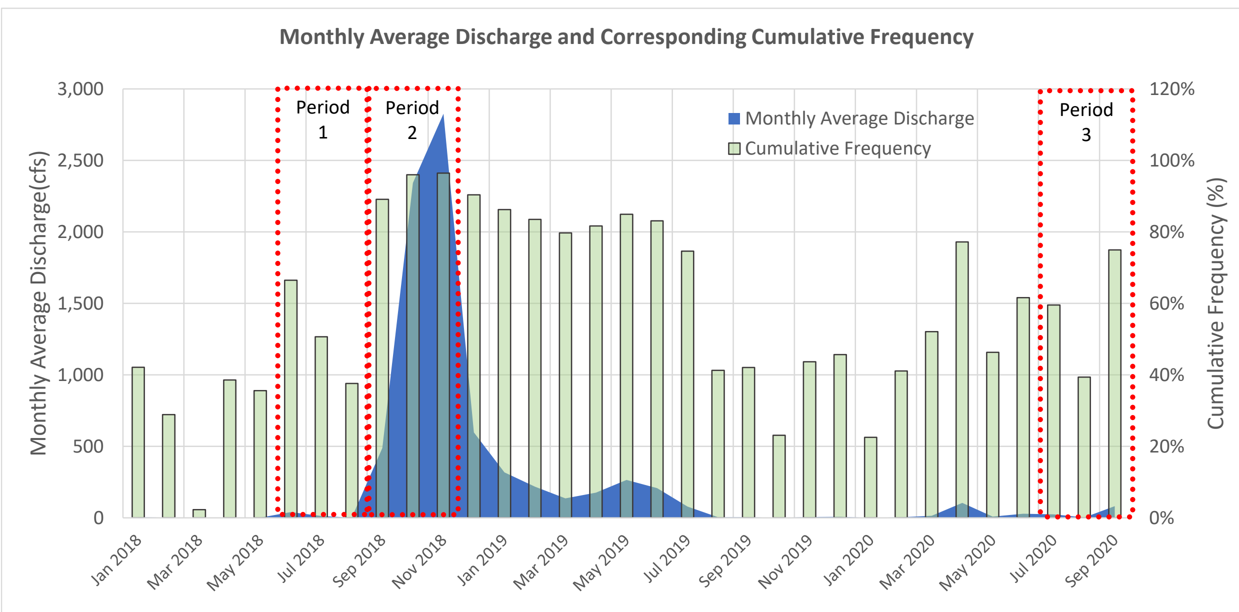


Figure 3.7: Monthly average discharge from Nueces River and the corresponding cumulative frequency of the discharge

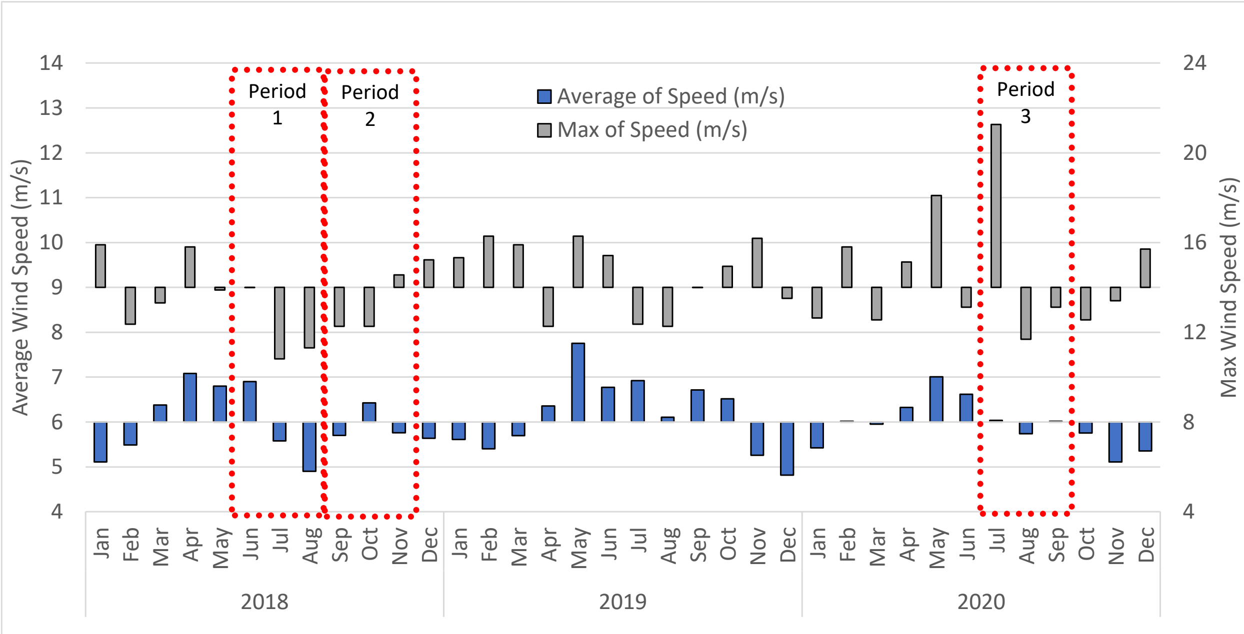


Figure 3.8: Monthly average wind speed and monthly max wind speed in Bob Hall Pier

3.3.2 Model Calibration

Period 2 was selected for model calibration since it covers the most complicated physical processes for hydrodynamics and salinity, including:

- The season features high water level in the bay, impacted by the seasonal variation of water level in the GOM as described in Section 2.2.3 (see Figure 2.25);
- Large freshwater inflow from Nueces River, resulting in significant dilution of salinity in Nueces Bay;
- Normal sustained wind from southeast;
- Strong stratification in Corpus Christi Bay, resulting from large river inflow and week mixing in the normal wind condition.

In the model calibration, the predicted water levels, current speed and direction, and salinity were compared with the measured data to evaluate the proficiency of model prediction. Periods 1 and 3 were used for model validation.

3.3.2.1 Water Levels

Figure 3.9 to Figure 3.11 show the comparisons of model predicted water level with the measured water level at Bob Hall Pier, Port Aransas, and USS Lexington, respectively. The plots showing the comparison of water level at other two other stations are attached in Appendix A. To evaluate the model prediction accuracy, three key performance indicators: bias, mean absolute error (MAE), and root mean square error (RMSE) were calculated as listed in Table 3.5. All three indicators shows that the model predicts water level well. The overall prediction error is less than 7 cm, based on the RMSE.

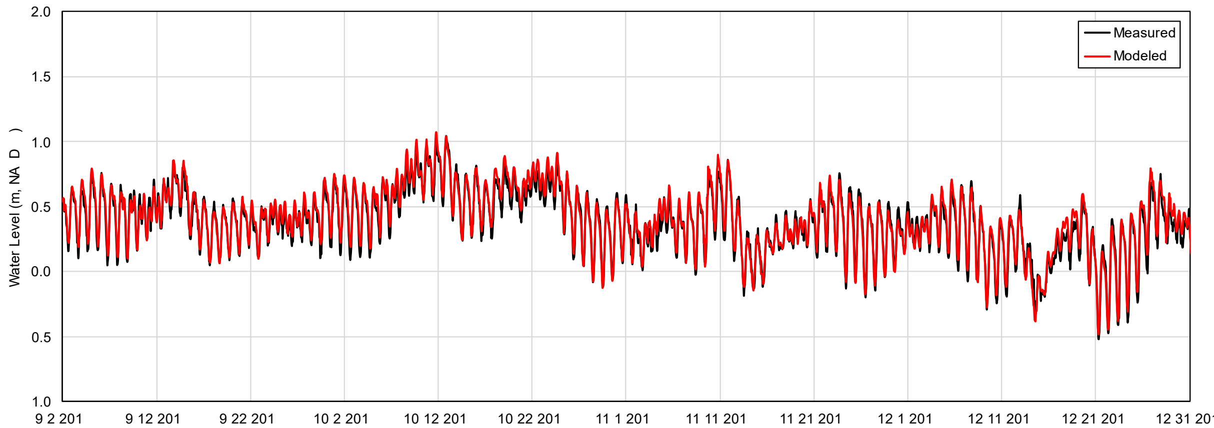


Figure 3.9: Comparison of the model predicted water level (red) to the measured water level (black) at Bob Hall Pier

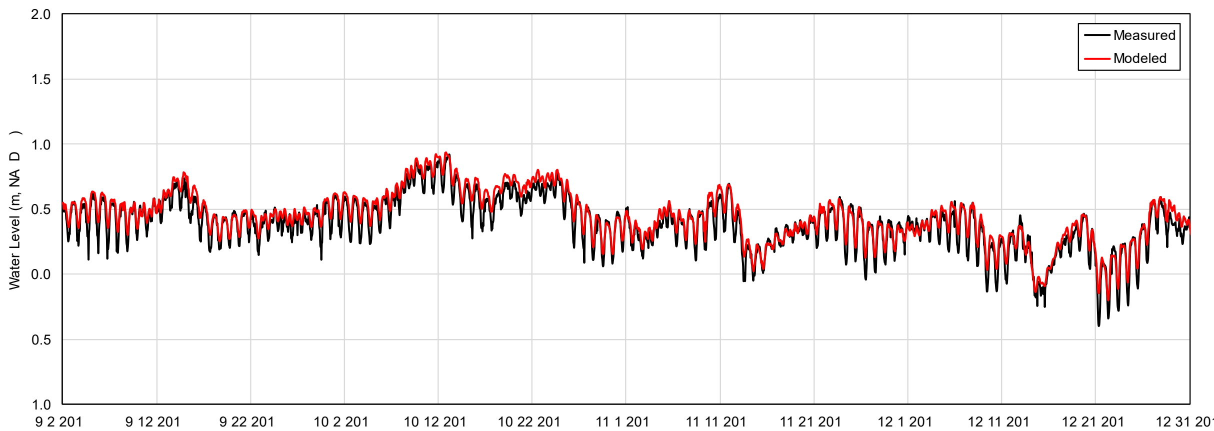


Figure 3.10: Comparison of the model predicted water level (red) to the measured water level (black) at Port Aransas

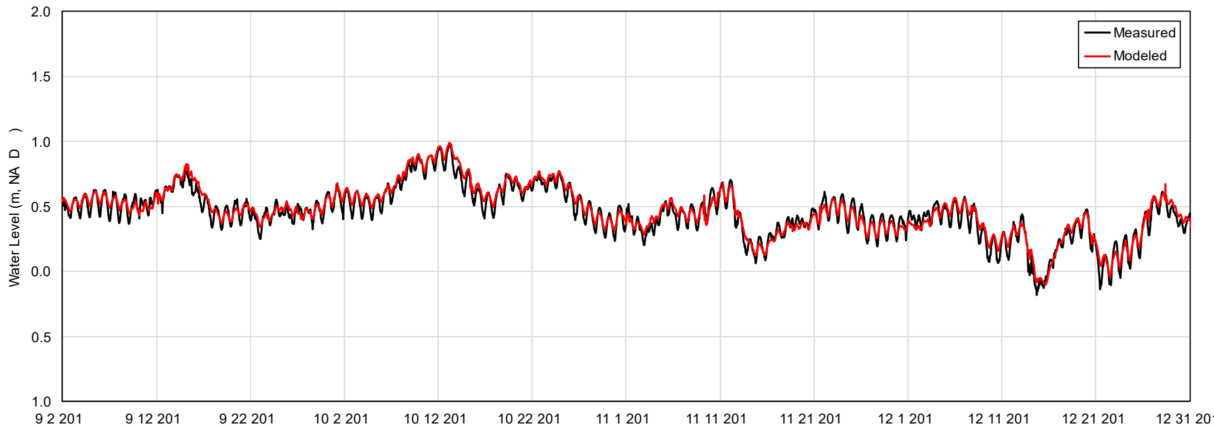


Figure 3.11: Comparison of the model predicted water level (red) to the measured water level (black) at USS Lexington

Table 3.5: Key performance indicators (KPI) of model prediction on water level in Period 2

KPI	Rockport	Port Aransas	USS Lexington	Packery Channel	Bob Hall Pier
BIAS (m)	-0.05	0.05	0.02	0.03	0.02
MAE (m)	0.05	0.06	0.04	0.04	0.05
RMSE (m)	0.05	0.07	0.05	0.06	0.06
R^2	0.98	0.92	0.94	0.92	0.96

Figure 3.12 shows the attenuation of tidal amplitude of tidal constituent O1 in percentage compared with its tidal amplitude at the head of the jetties in the outer channel. O1 is one of the major tidal constituents in the study area. The figure also shows the tidal phase lag in hours relative to its tidal phase at the jetty head, which is consistent with the understandings of tidal propagations as described in Section 2.2.1.

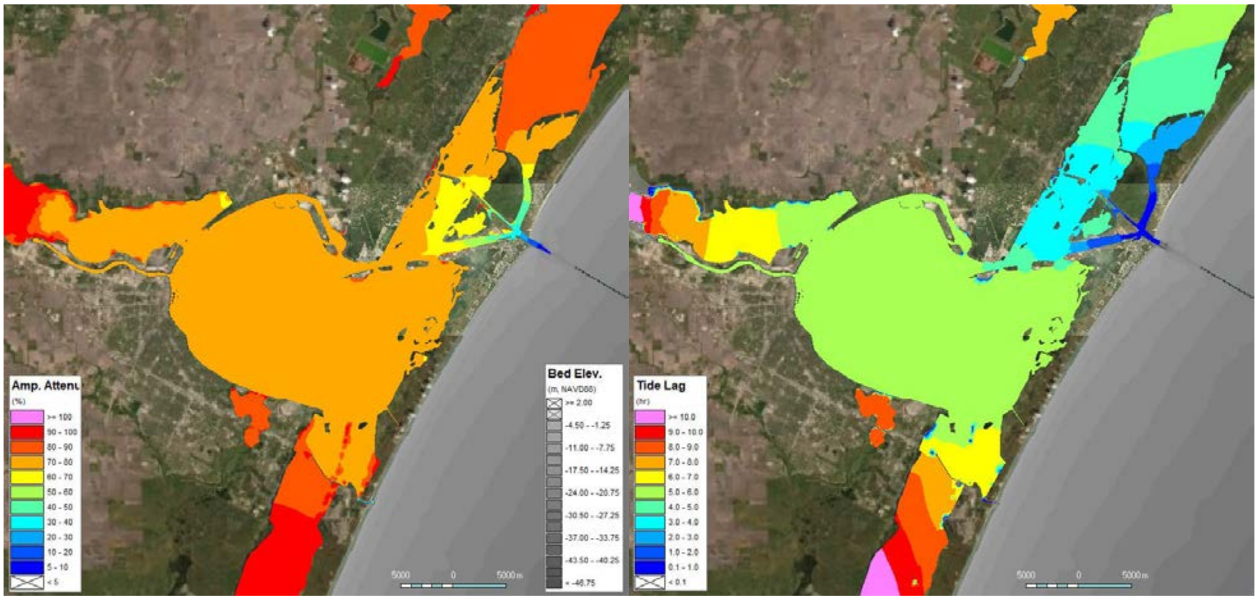
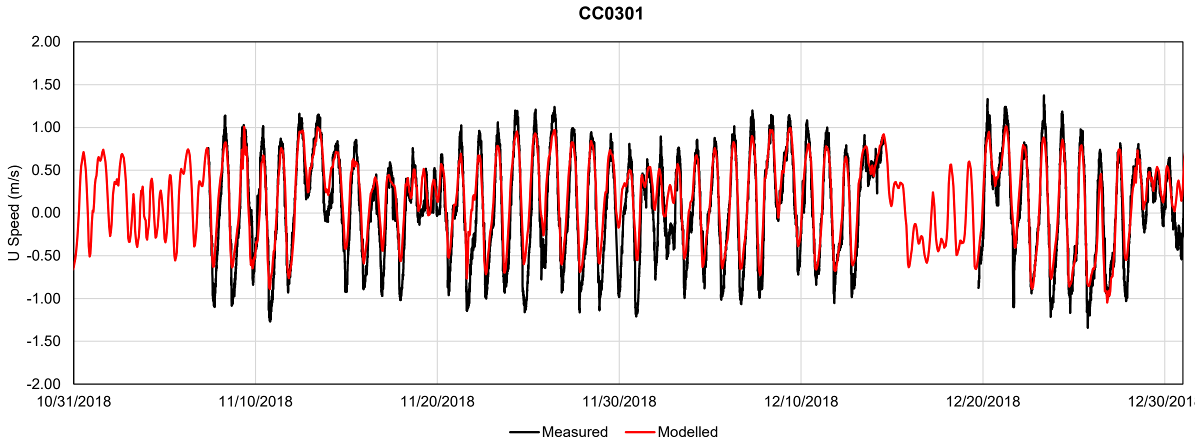


Figure 3.12: Tidal amplitude attenuation in percentage (left) and phase lag in hours (right) of O1 tidal constituent

3.3.2.2 Currents

Figure 3.13 and Figure 3.14 shows the comparison of model predicted flow velocity vectors with the measured data at Port View in Aransas Pass (CC0301) and at the navigation channel of MADS (CC0401). The flow vectors are broken down into U component with positive value pointing to east and V component with positive value pointing to north. Additional plots for velocity comparison are attached in Appendix A. The KPIs for the model prediction on flow velocity are listed in Table 3.6. The KPIs indicate that the model predicts flow vectors reasonably well. The model may underestimate the flow speed in Aransas Pass slightly, which may result from the underestimation of flow from the Redfish Bay due to the large grid resolution and/or due to the HYCOM model underprediction of long-shore currents in the GOM.



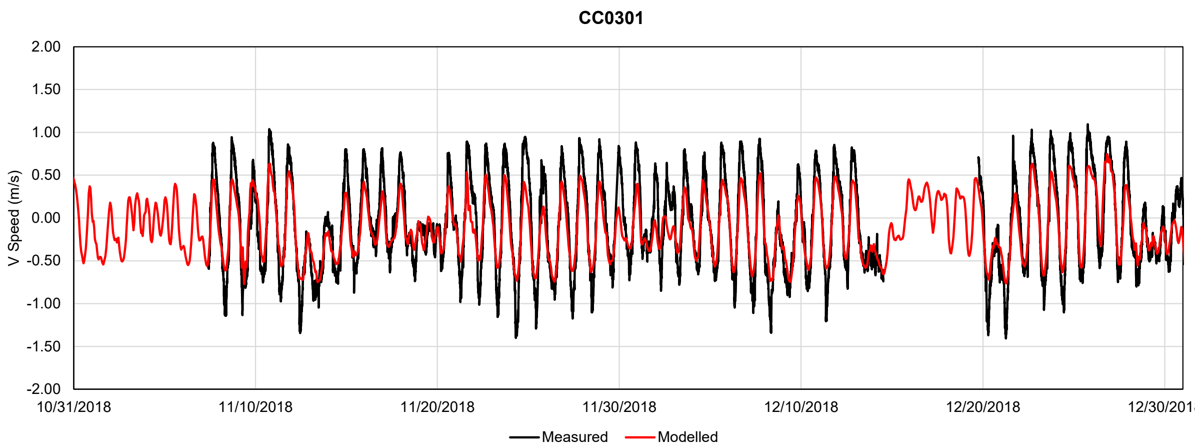


Figure 3.13: Comparison of model predicted flow velocity components, U (east) and V (north), with the measured data at Port View (CC0301)

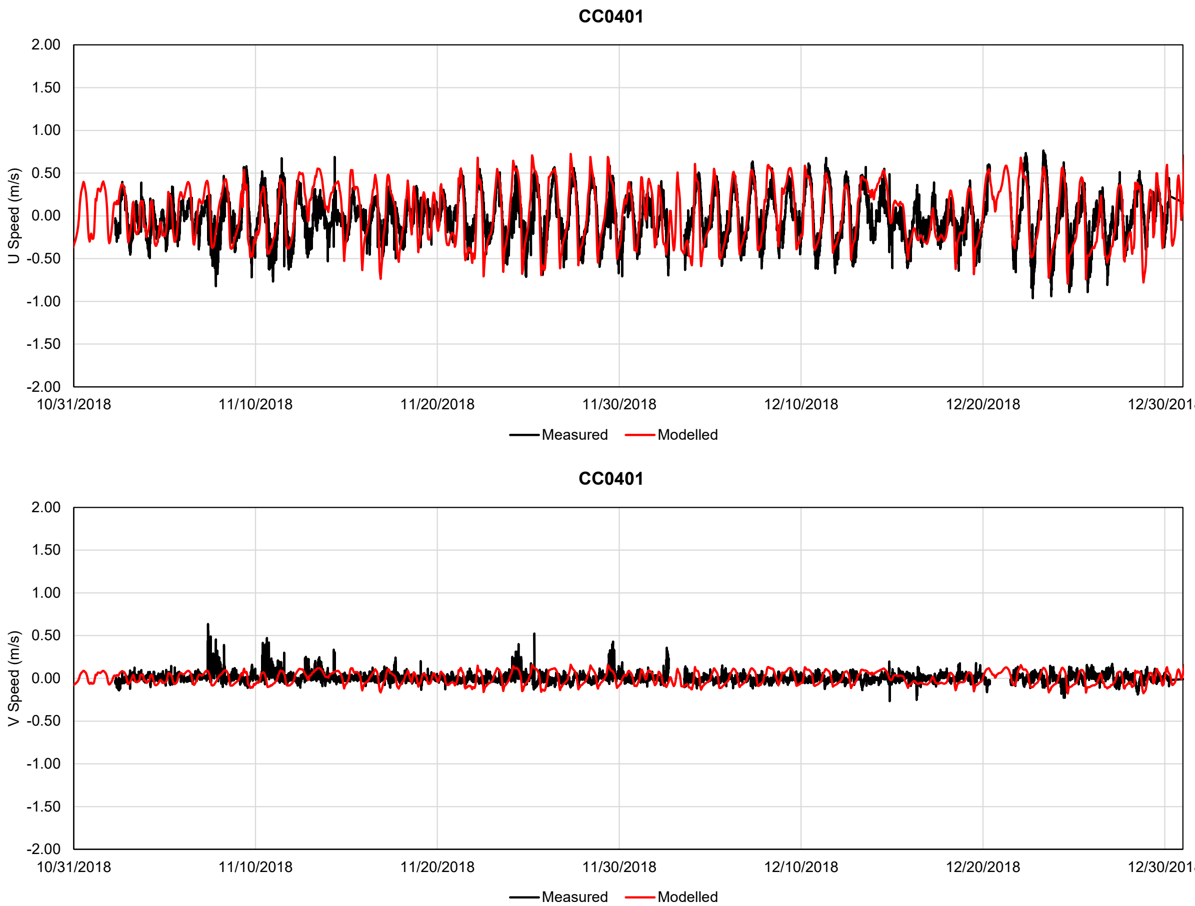


Figure 3.14: Comparison of model predicted flow velocity components, U (east) and V (north), with the measured data at MADS (CC0401)

Table 3.6: Key performance indicators of model prediction on current speed in Period 2

KPI	TABS-D	CC0101	CC0303	CC0401 (MADS)
BIAS (m/s)	0.04	0.08	0.02	0.01
MAE (m/s)	0.17	0.18	0.20	0.14
RMSE (m/s)	0.22	0.23	0.25	0.18
R^2	0.19	0.30	0.87	0.46

Figure 3.15 and Figure 3.16 show the flow vectors on water surface (black) around the inner basin with 3D flow vectors (red) in the selected locations during a flood tide and an ebb tide, respectively. During the flood tide, more water flows to Corpus Christi Bay, which likely results from the constant difference of water level between Rockport and Packery Channel (see Section 2.2.1). During ebb tide, the 3D flow structure is found beyond the jetties in the outer channel. The flow direction near the seabed is different from the flow direction on the water

surface, which likely results from the interaction of the strong flow from the Pass and the long-shore currents in the GOM.

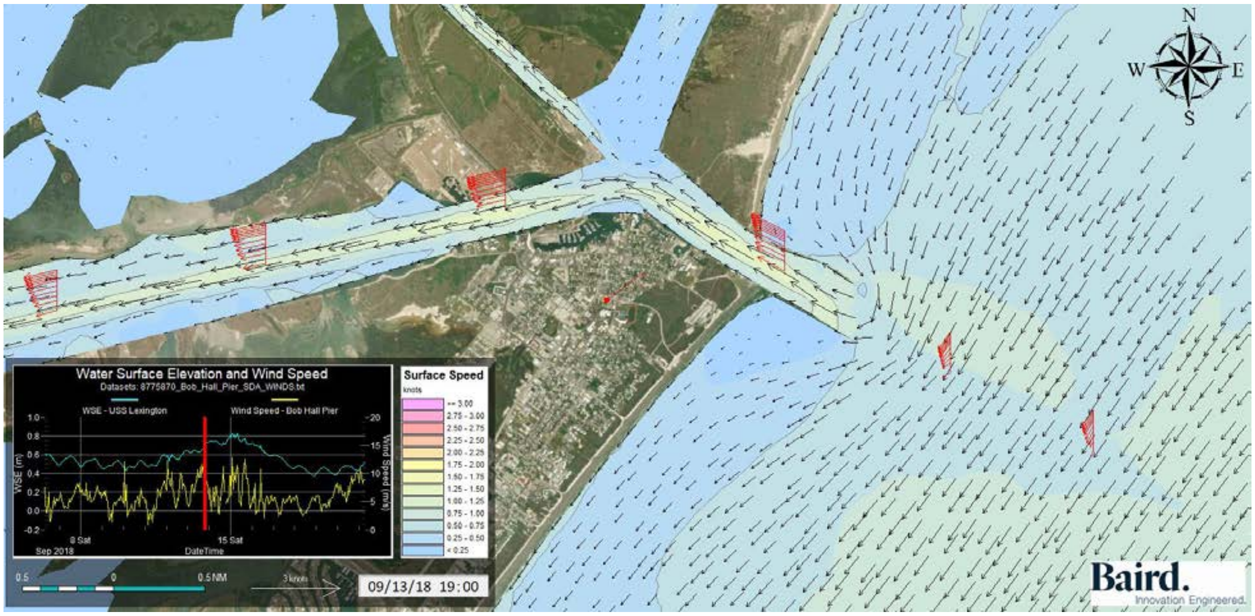


Figure 3.15: Flow patterns on water surface around the inner basin during a flood tide. The red stacked vectors are the flow vectors in water column predicted by the model. The red barb shows the wind speed and direction (from) measured at Bob Hall Pier

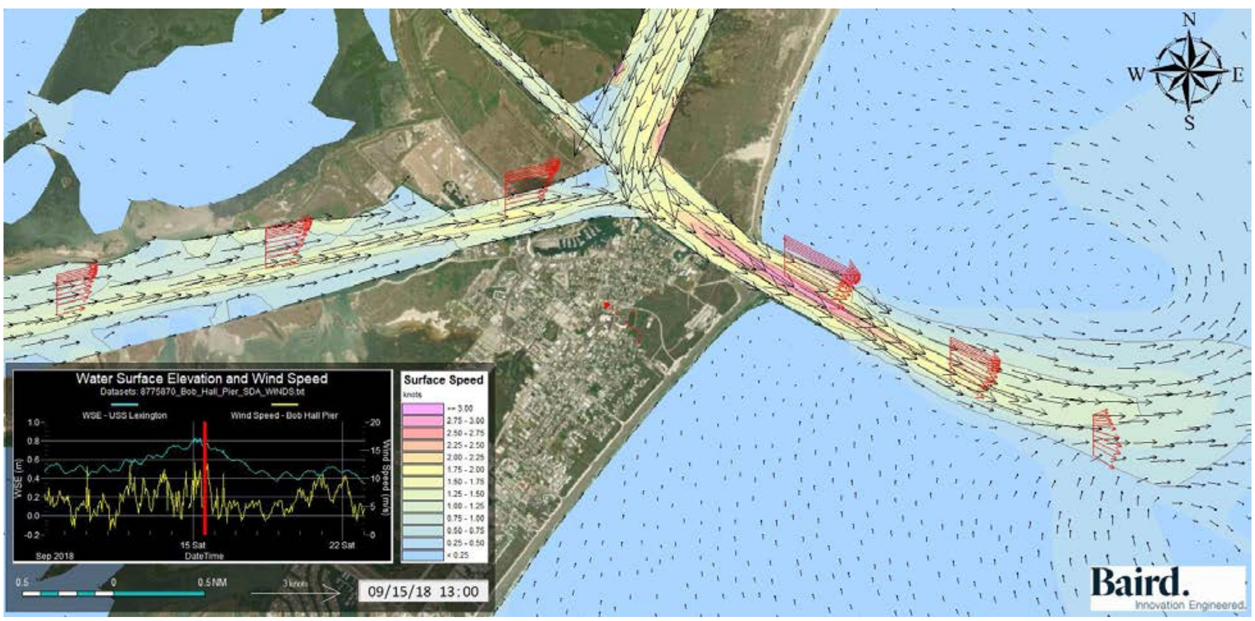


Figure 3.16: Flow patterns on water surface around the inner basin during an ebb tide. The red stacked vectors are the flow vectors in water column predicted by the model. The red barb shows the wind speed and direction (from) measured at Bob Hall Pier

To better understand the net tidal currents, which is an indicator of net salinity and sediment transport direction, the residual of tidal currents was calculated by averaging velocity components, U (easting) and V (northing), over the period from September 8, 2018 14:00 to November 30, 2018 22:00 (from neap tide to neap tide). The flow vectors of net tidal currents over the entire model domain are shown in Figure 3.17. The net current vectors zoomed to Corpus Christi Bay are shown in Figure 3.18. A log scale of flow speed was used for the vector plot to make small net current visible. The large net currents from Aransas Bay heading to Corpus Christi Bay (see Figure 3.19) likely results from the constant difference of water levels between Rockport and Packery Channel, which may be explained by the large inflows from the three rivers to Copano Bay. The net currents in Nueces Bay are always heading to Corpus Christ Bay due to the input of Nueces River. In Corpus Christi Bay, the net current speed is very small (< 4 cm/s). The net currents are heading to the GOM in the navigational channel from MODA to Port Aransas but heading to the Corpus Christi Port in the west section of navigation channel in Corpus Christi Bay.

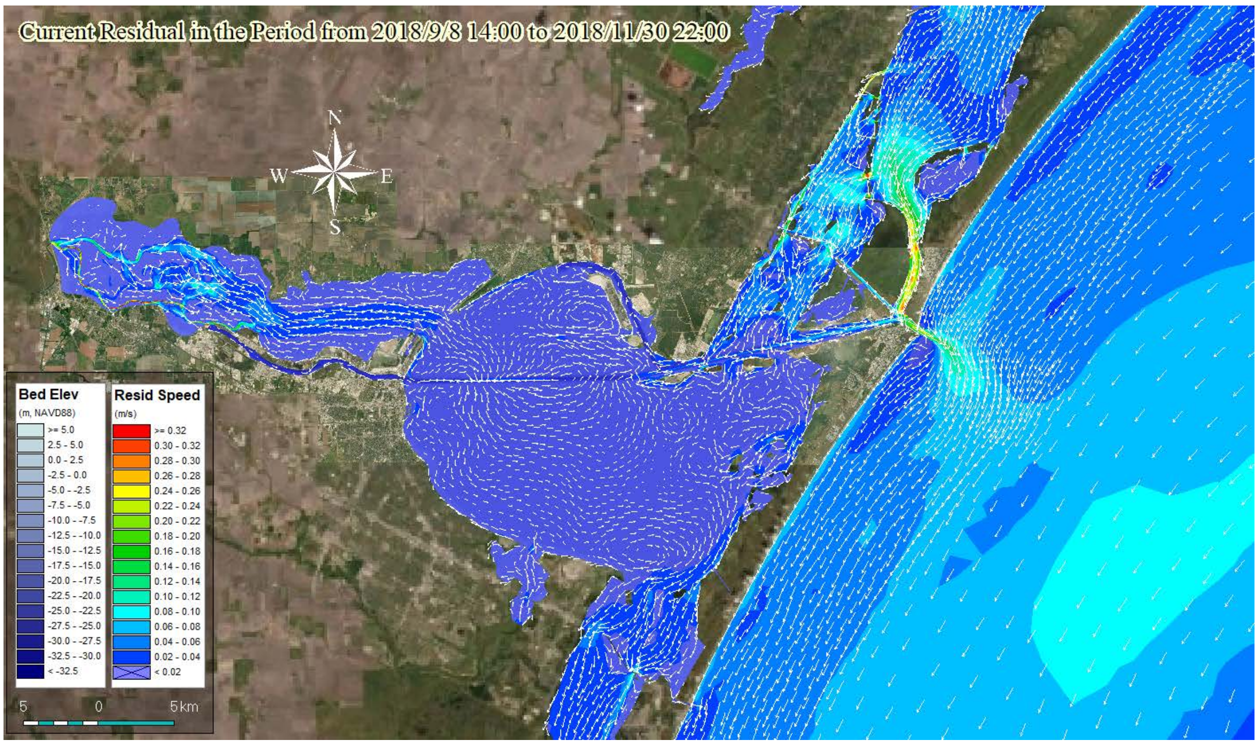


Figure 3.17: Residual currents in the model domain calculated from the depth-averaged velocity in the period from 2018/9/8 14:00 to 2018/11/30 22:00. Vector length is in the log scale of flow speed.

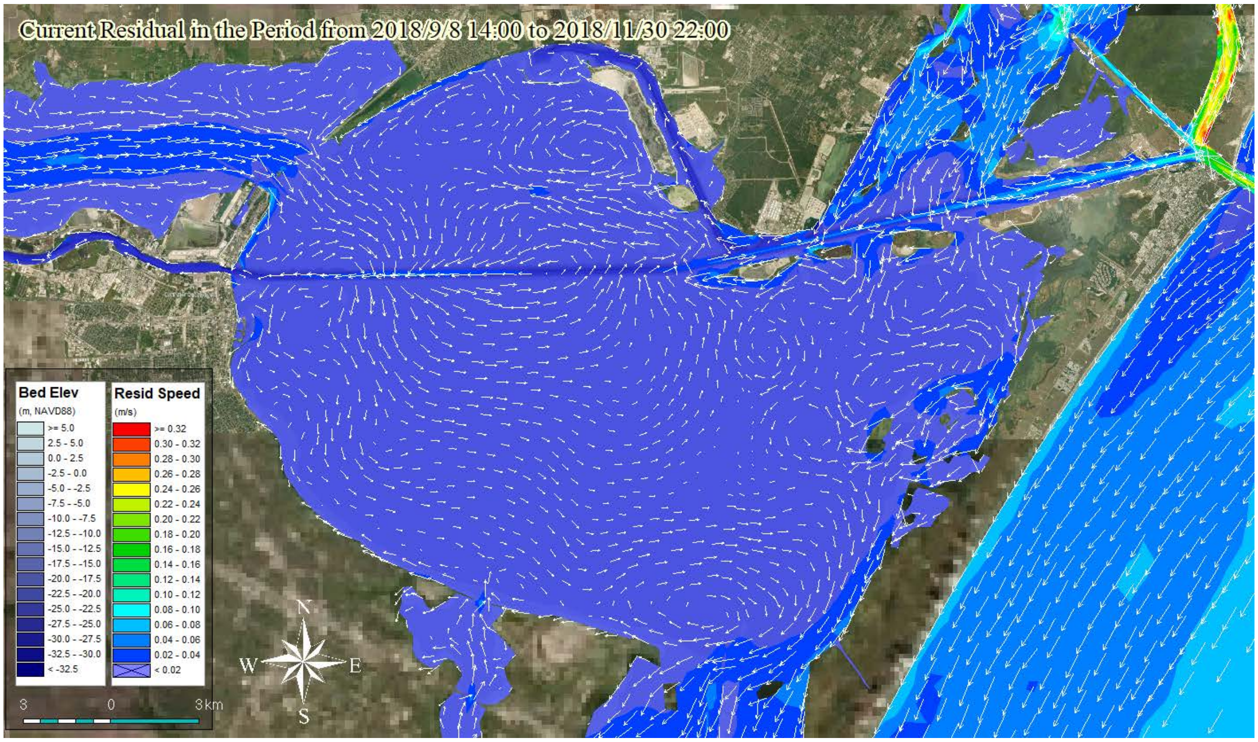


Figure 3.18: Residual currents in Corpus Christi Bay calculated from the depth-averaged velocity in the period from 2018/9/8 14:00 to 2018/11/30 22:00.

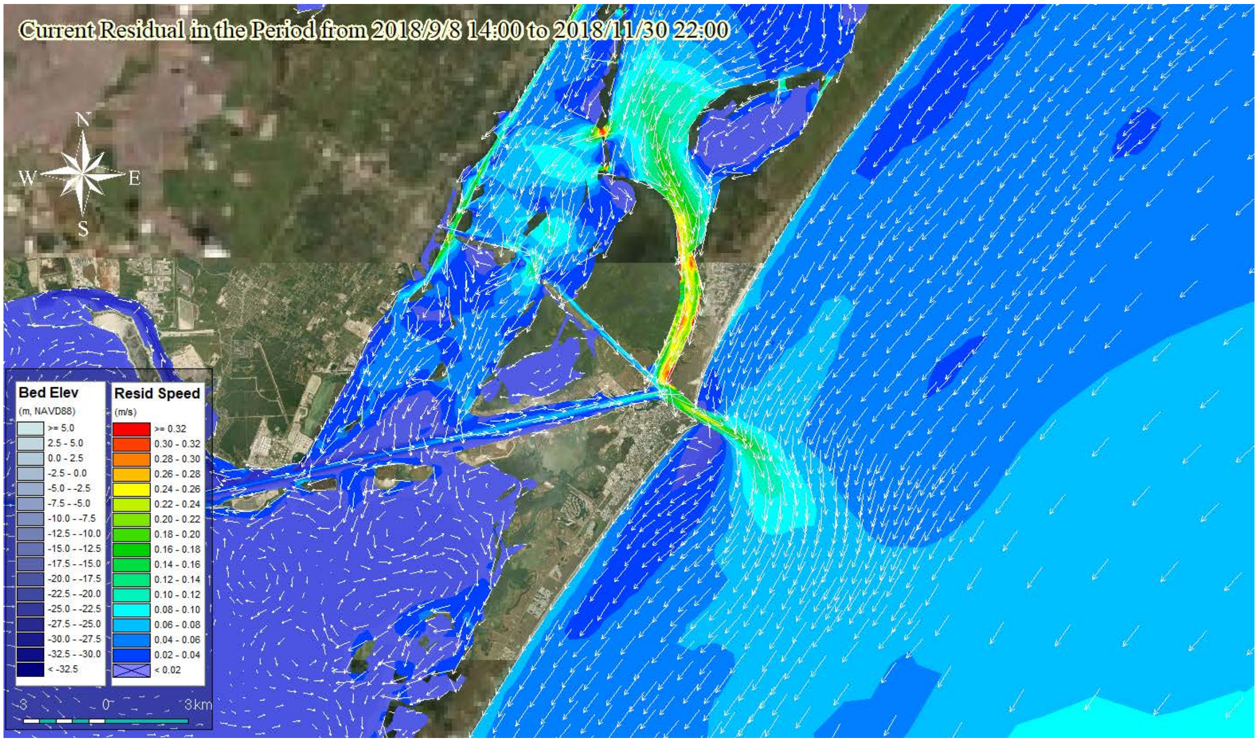


Figure 3.19: Residual currents in the GOM, Redfish Bay, Aransas Bay, and the inner basin calculated from the depth-averaged velocity in the period from 2018/9/8 14:00 to 2018/11/30 22:00.

3.3.2.3 Salinity

Figure 3.20 shows the comparison of model predicted salinity with the measured salinity at five stations (see locations in Figure 2.16). The KPIs for model prediction of salinity are listed in Table 3.7. The overall model prediction error on salinity is about 5 PSU (it is noted that there are several periods with gaps and noticeable calibration drift in measured salinities). The model predicts the salinity in Nueces Bay reasonably well and was able to reproduce the significant reduction of salinity due to the freshwater dilution during a large river flow event as well as salinity recovery during lower inflow periods.

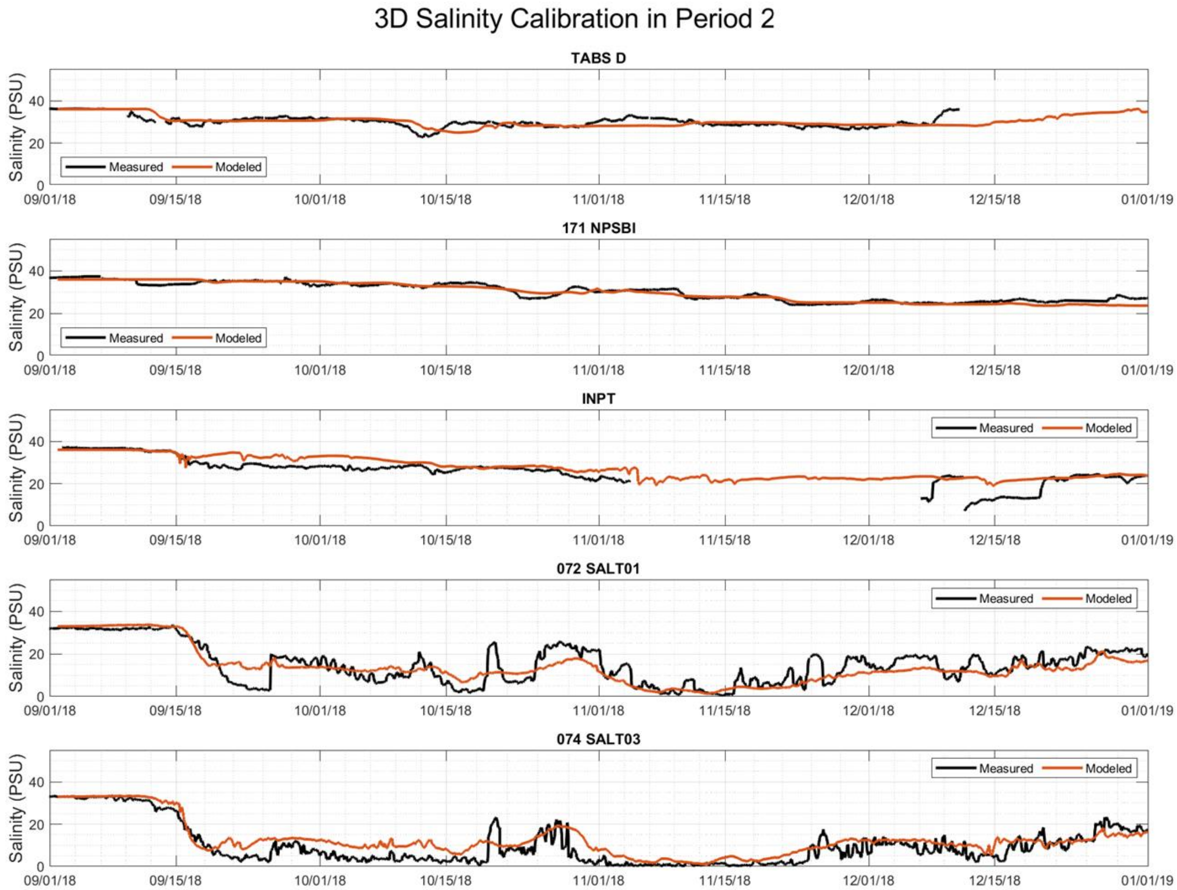


Figure 3.20: Comparison of model predicted salinity with measured data in Period 2

Table 3.7: Key performance indicators of model prediction on salinity in Period 2

KPI	074 SALT03	072 SALT01	INPT	171 NPSBI	TABS D
BIAS (psu)	-2.8	1.1	-2.8	0.3	0.3
MAE (psu)	3.8	3.8	3.2	1.2	1.7
RMSE (psu)	4.7	4.7	4.3	1.5	2.3
R2	0.84	0.73	0.75	0.90	0.33
Measured Mean (psu)	9.7	14.9	25.9	30.1	30.0
Predicted Mean (psu)	12.5	13.9	27.1	29.8	30.3

Figure 3.21 and Figure 3.22 show the snapshots of model predicted salinity at the time following a large river flow event on water surface and near the lakebed seabed (approximately at -4 m NAVD88), respectively. The comparison of the two figures indicates that there is strong salinity stratification (more than 10 PSU difference) in the northern part of Corpus Christi Bay. Figure 3.23 shows the salinity profile extracted at the navigation

channel which is indicated by the red star in Figure 3.22. In the navigation channel below -6 m NAVD88, the salinity is high and does not mix with the top layers well. The stratification predicted by the model is consistent with the measured data which was described in Islam *et al.* (2010).

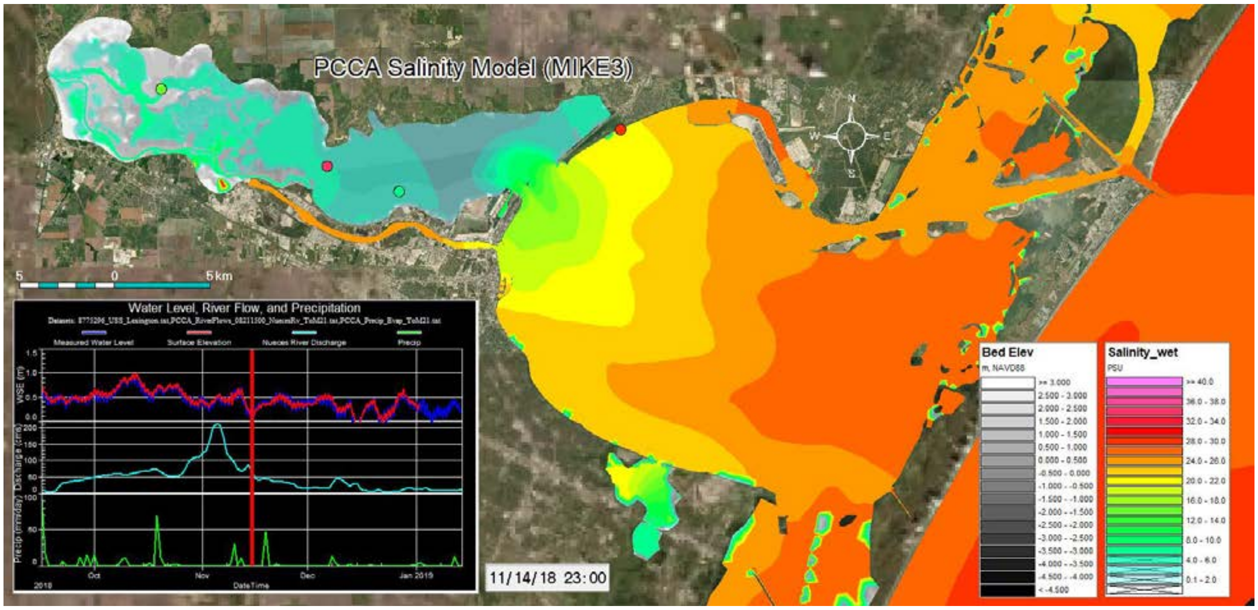


Figure 3.21: Snapshot of modeled salinity on water surface after a large river flow event

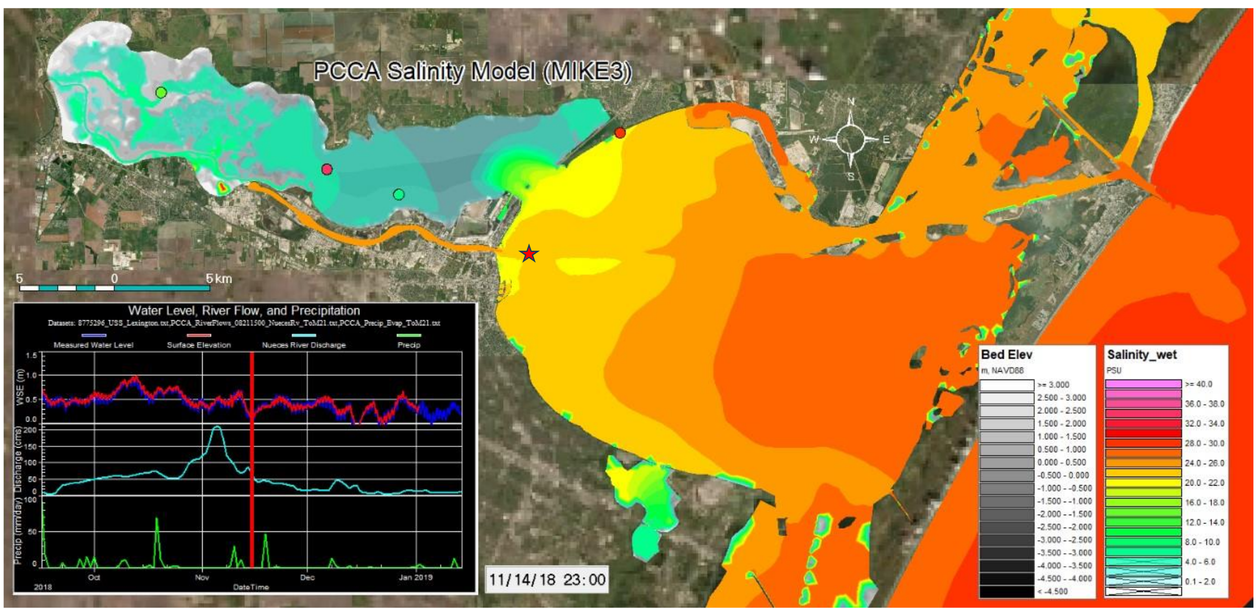


Figure 3.22: Snapshot of modeled salinity near the seabed (approximately -4 m, NAVD88) after a large river flow event

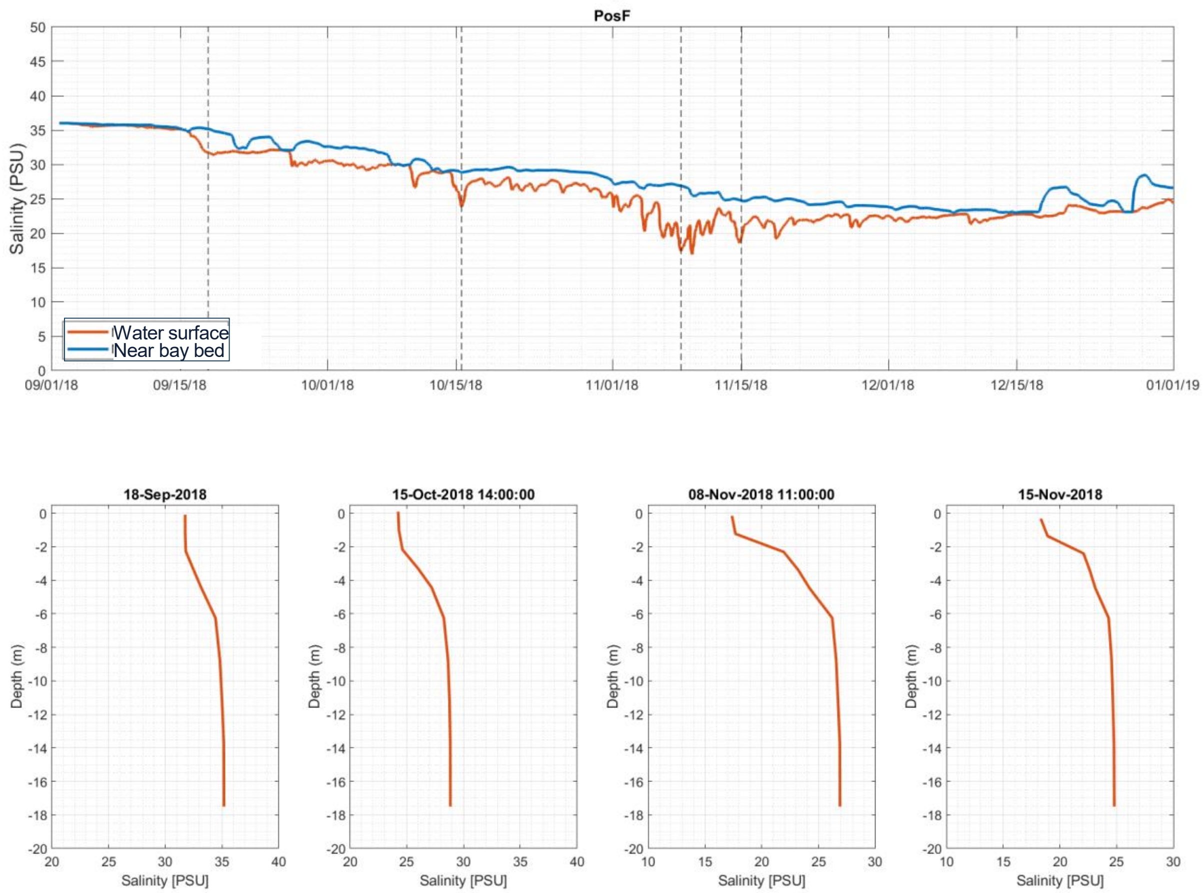


Figure 3.23: Salinity stratification predicted by the model. Top: model predicted salinity on water surface (orange) and near the bay bed (blue) extracted at the position of the red star shown in Figure 3.22. Bottom: snapshots of salinity profiles which times are indicated by vertical dash lines shown on the top plot.

3.3.3 Model Validation

The calibrated model was validated in Period 1 and Period 3. During the model validation, all parameters determined in the model calibration such as roughness, wind drag coefficient, eddy viscosity, diffusivity, scale factors for precipitation and evaporation were applied in the model validation. All open boundaries in the model validation periods were developed from the measured data using the same approaches as used for the model calibration. For some salinity boundaries, the approach to fill data gaps in the measured data was revised to achieve the better results during the model validation period.

3.3.3.1 Water Levels

Figure 3.24 and Figure 3.25 show the comparison of model predicted water level against the measured data at USS Lexington in Period 1 and Period 3, respectively. The plots of water level comparison at the other stations are provided in Appendix A. Table 3.8 and Table 3.9 list the key performance indicators of model prediction of water levels in Period 1 and Period 3, respectively. The model predicted the water levels well and the prediction errors are less 5 cm. The model may slightly underestimate the tide range at USS Lexington, which likely results from the uncertainty of bathymetry in Nueces Bay (see Section 2.3). Note the occurrence of Hurricane Hanna (Category 1 hurricane), which storm eye passed through Corpus Christi and made landfall on July 25, 2020, and the other two tropical storms on August and September, 2020 in Period 3. The model predicted the storm surges caused by the storms reasonably well.

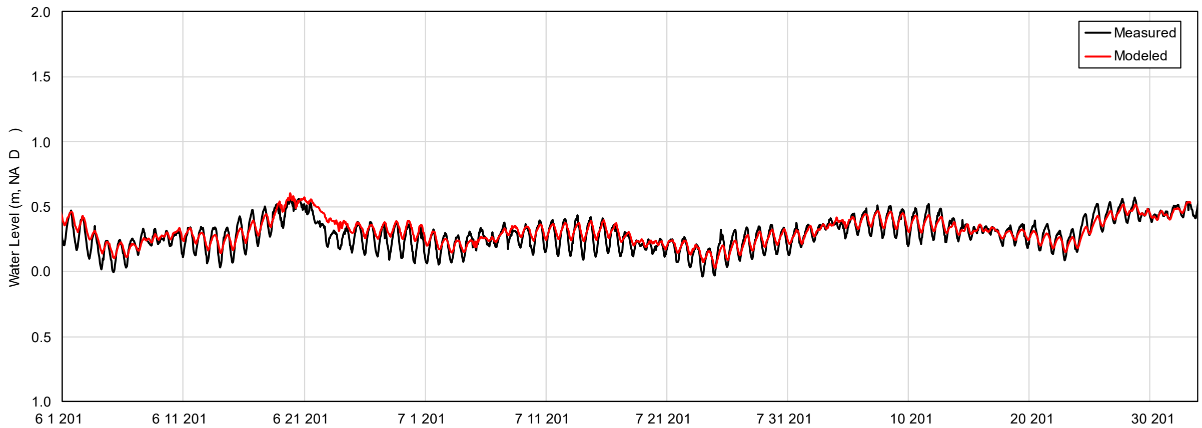


Figure 3.24: Comparison of model predicted water level with the measured data at USS Lexington in the model validation (Period 1)

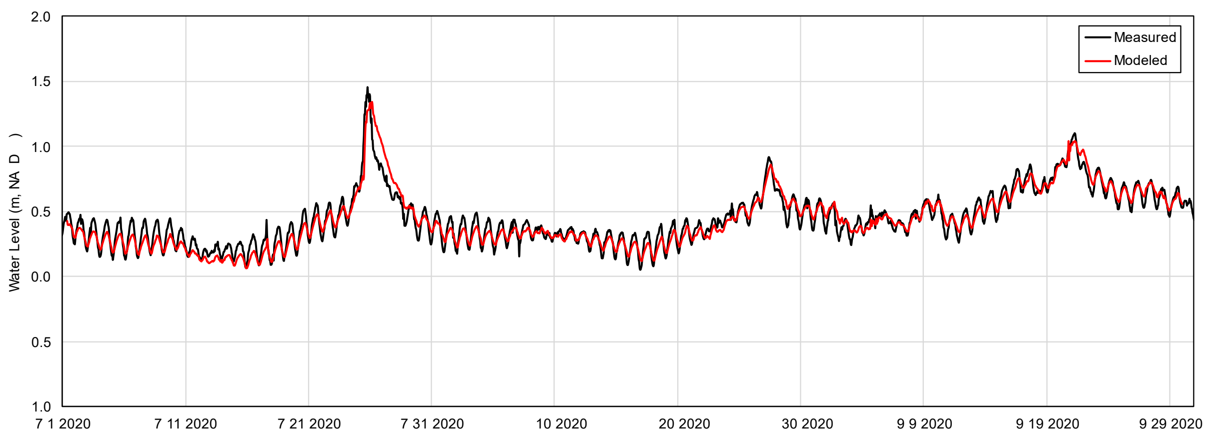


Figure 3.25: Comparison of model predicted water level with the measured data at USS Lexington in the model validation (Period 3)

Table 3.8: Key performance indicators of model validation of water levels in Period 1

KPI	Rockport	Port Aransas	USS Lexington	Packery Channel	Bob Hall Pier
BIAS (m)	-0.05	0.03	0.01	-0.03	0.05
MAE (m)	0.05	0.03	0.01	0.03	0.05
RMSE (m)	0.05	0.04	0.02	0.03	0.06
R^2	0.96	0.88	0.78	0.89	0.9

Table 3.9: Key performance indicators of model validation of water levels in Period 3

KPI	Rockport	Port Aransas	USS Lexington	Packery Channel	Bob Hall Pier
BIAS (m)	-0.05	0.04	-0.01	0.03	0.01
MAE (m)	0.05	0.05	0.05	0.04	0.06
RMSE (m)	0.05	0.07	0.06	0.06	0.08
R^2	0.99	0.94	0.93	0.94	0.93

3.3.3.2 Currents

Figure 3.26 and Figure 3.27 show the comparison of model predicted flow vectors, which break down into U (easting) component and V (northing) component, with the available measured data at current stations in Period 1 and Period 3, respectively. The two stations are located at the outer navigation channel (see Figure 2.15). The currents at Station CC0101 (AP Buoy) are mainly driven by the long-shore currents, while the currents at Station CC0201 (Aransas Pass LB6) results from the interaction of the strong channel currents from Aransas Pass and the long-shore currents with impact of the two parallel jetties.

Table 3.10 and Table 3.11 list the key performance indicators of model prediction of currents in Period 1 and Period 3, respectively. Station TABS-D (Offshore Buoy 42048), Station CC0301 (Port Aransas, Channel View), and CC0401 (MODA Currents) have been included where measured data is available. Plots for the additional stations are presented in Appendix A.

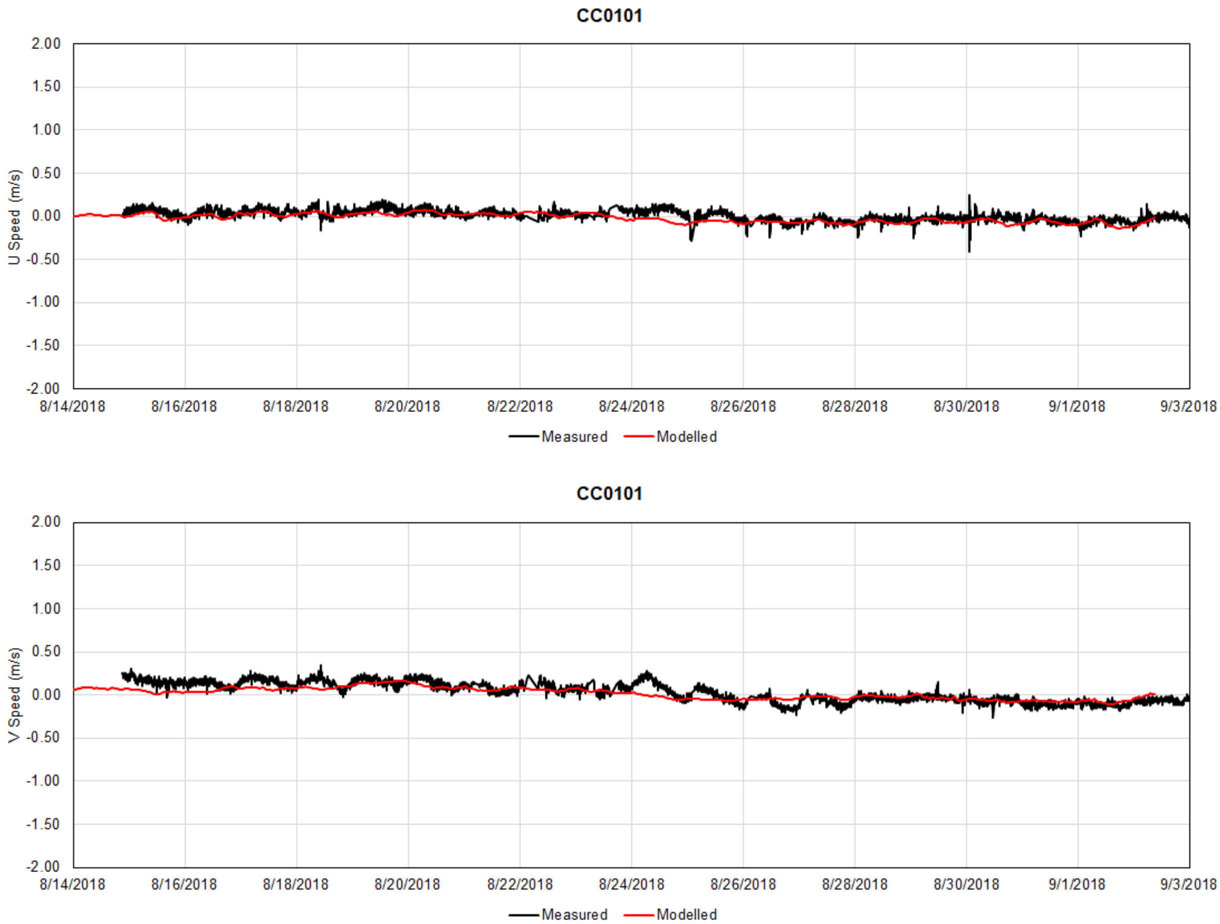


Figure 3.26: Comparison of model predicted flow velocity components with the measured data in the model validation (Period 1)

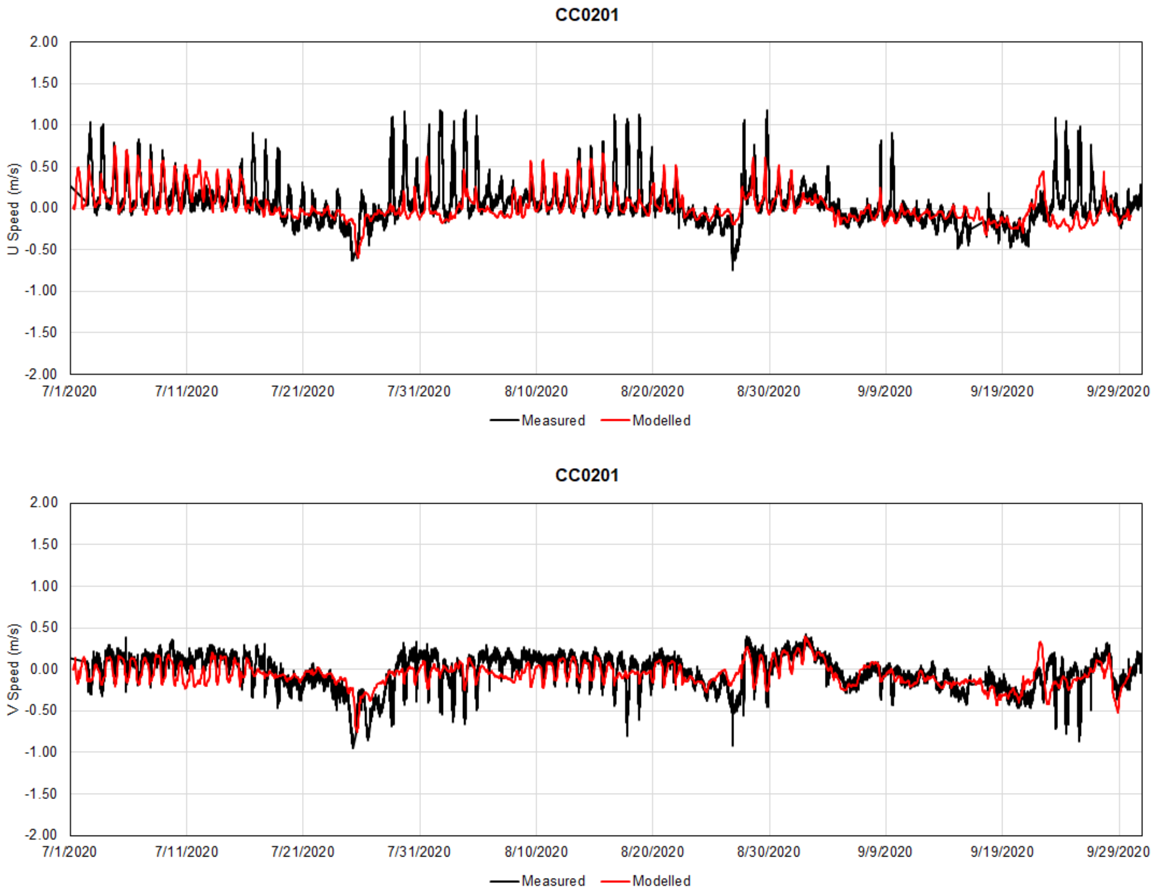


Figure 3.27: Comparison of model predicted flow velocity components with the measured data in the model validation (Period 3)

Table 3.10: Key performance indicators of model prediction of flow vectors in Period 1

KPI	TABS-D	CC0101	CC0401
BIAS (m/s)	-0.08	-0.03	-0.03
MAE (m/s)	0.10	0.06	0.14
RMSE (m/s)	0.13	0.07	0.18
R^2	0.32	0.5	0.44

Table 3.11: Key performance indicators of model prediction on flow vectors in Period 3

KPI	TABS-D	CC0201	CC0301	CC0401
BIAS (m/s)	0.04	-0.04	0.03	0.01
MAE (m/s)	0.16	0.13	0.18	0.10
RMSE (m/s)	0.22	0.19	0.23	0.13
R^2	0.08	0.35	0.86	0.65

3.3.3.3 Salinity

Figure 3.28 and Figure 3.29 show the comparison of model predicted salinity against the measured data at five stations in Period 1 and Period 3, respectively. The key performance indicators of model prediction are listed in Table 3.12 and Table 3.13, respectively. Note that R^2 may not be a good indicator for salinity, which does not significantly change with time, although the time series plots show the good agreement of predicted salinity with the measured salinity. Instead, the two additional indicators, mean measured salinity and mean predicted salinity, were added in the tables to indicate the degree of the model prediction errors. Overall, the model predicted the salinity reasonably well. The RMSE is less than 7 PSU and 4 PSU for Period 1 and Period 3, respectively. Note that there are large data gaps and data noise in the measured salinity data, including some indications of calibration drift, which may affect the evaluation of model prediction errors.

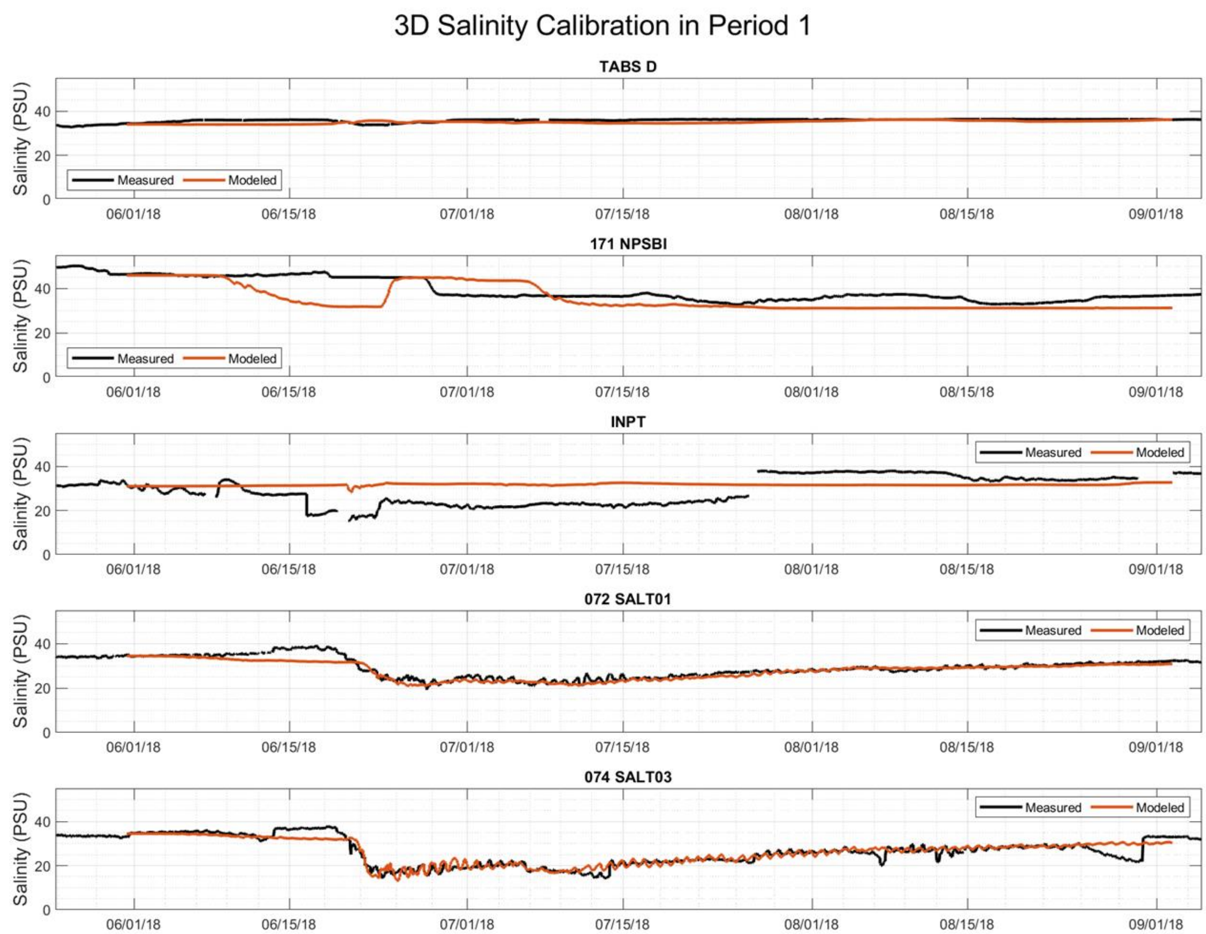


Figure 3.28: Comparison of model predicted salinity with the measured data in the model validation (Period 1)

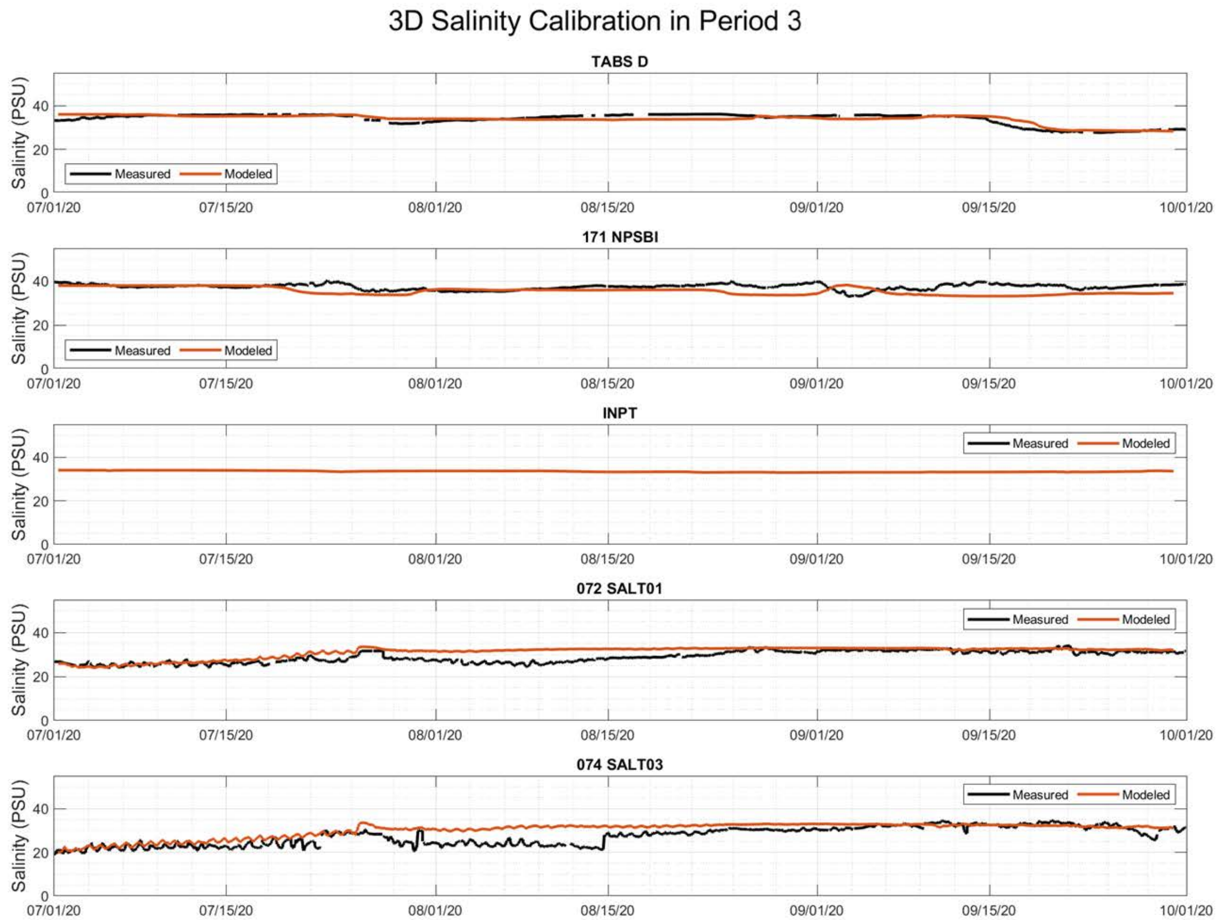


Figure 3.29: Comparison of model predicted salinity with the measured data in the model validation (Period 3)

Table 3.12: Key performance indicators of model prediction of salinity in Period 1

KPI	074 SALT03	072 SALT01	INPT	171 NPSBI	TABS D
BIAS (psu)	-0.1	1.0	-2.7	0.3	0.9
MAE (psu)	1.7	1.3	5.9	4.9	1.0
RMSE (psu)	2.4	2.0	6.9	5.5	1.2
R^{2*}	0.85	0.86	0.16	0.06	0.04
Measured Mean (psu)	26.0	29.0	28.8	35.8	35.9
Predicted Mean (psu)	26.1	28.0	31.6	35.4	35.0

*R^2 should not be used as a performance indicator when the variation of salinity with time is small.

Table 3.13: Key performance indicators of model prediction of salinity in Period 3

KPI	074 SALT03	072 SALT01	INPT	171 NPSBI	TABS D
BIAS (psu)	-2.7	-2.1	ND*	1.9	0.1
MAE (psu)	3.0	2.3	ND	2.3	1.1
RMSE (psu)	4.0	2.9	ND	2.9	1.4
R^2	0.52	0.51	ND	0.03	0.69
Measured Mean (psu)	27.5	29.0	ND	37.4	33.9
Predicted Mean (psu)	30.2	31.1	33.4	35.5	33.8

*ND – no measured data

3.4 Sensitivity Tests

Many sensitivity tests were carried out during the model development and calibration to understand the performance of the variation of model results with input parameters. Only the tests that significantly impacted the model performance results are described in this section.

3.4.1 Grid Resolution

Grid resolution was first tested during grid generation. The grid resolution depends on the complexity of bathymetry, shorelines, and structures. The model stability and computational time were also considered during grid generation. A high-resolution grid was used in the areas of complex shorelines and along the navigation channels where the study was focused. The sensitivity tests indicate that the grid resolution has some impact on the model results if there are insufficient grids distributed along the narrow openings.

3.4.2 Offshore Open Boundary Conditions

Many sensitivity tests were carried out by applying different approaches to construct the offshore boundary conditions; observations are described below:

- Using the predicted tide from the major tide constituents with the DHI MIKE utility cannot reproduce the seasonal water level variation in both the GOM and in the subtropical bays. The model significantly underpredicts long-shore currents (driven by oceanographic currents, not wave momentum) in the GOM;
- Using the measured water level at Bob Hall Pier can reproduce the offshore water level at the offshore reasonably well but significantly underpredicts the mean water level in Corpus Christi Bay, e.g., at USS Lexington. The long-shore current in the GOM is also underpredicted;
- Using the HYCOM model results without water level adjustment can produce reasonably large, long-shore currents but cannot reproduce the water levels in the bays well.

Finally, the offshore boundary conditions were developed by using the HYCOM modeled currents to control the northeast and southwest open boundaries and using adjusted water level from the HYCOM predicted water level and measured data at Bob Hall Pier (see details in Section 3.2.3.2). A good calibration result was achieved with this approach.

3.4.3 3D Impacts

Sensitivity tests on the 3D model impact were carried out by performing the model runs using the same grid and the same model setting using both MIKE21 model (2D) and MIKE3 model (3D). The predicted water levels and depth-averaged flow velocity were compared. The results show that there is no significant difference in water level and depth-averaged flow velocity predicted by using these two models.

However, a 3D model is required to correctly simulate both hydrodynamics and salinity for this study. Wind generally produces reversed current in the deep water, e.g., the navigation channel of Corpus Christi Bay, to the current on water surface as shown in Figure 3.18. Strong alongshore currents in the gulf result in significant difference of current direction in water columns of the outer channel (see Figure 3.16). The cross-channel currents in the outer channel are important information for navigation simulation. When there is a large river inflow from Nueces River, there is the significant stratification of salinity in the Corpus Christi Bay (see Figure 3.22 and Figure 3.23). All above-mentioned 3D profiles of currents and salinity cannot be produced by the 2D model and therefore a 3D model is required.

3.4.4 Diffusivity Coefficient

Sensitivity tests on diffusivity coefficient for salinity simulation were performed. There are two approaches to set up the diffusivity coefficient for salinity: a) scale to the eddy viscosity which was calculated by the hydrodynamic model; and b) user specified values. The sensitivity tests show that the salinity is sensitive to diffusivity and therefore this parameter is regarded as a calibration parameter.

3.4.5 Evaporation and Precipitation

Many sensitivity tests on evaporation and precipitation were performed during the model development. The results show that the hydrodynamics are not sensitive to evaporation and precipitation but the salinity in shallow water is sensitive to evaporation and precipitation. Therefore, these two parameters are regarded as the calibration parameters for salinity model.

3.5 Model Uncertainties

3.5.1 Bathymetry in Nueces Bay

The bathymetry in Nueces Bay is identified as a significant data gap during the model development. The bathymetry downloaded from NOAA data source indicates a constant bed elevation of -0.1 m NAVD88, which is incorrect as historical satellite images (see Figure 3.30) show that there are many small channels in and between Nueces Bay and connected to Corpus Christi Bay. The bathymetry in Nueces Bay is important to calculate tide prism in of Nueces Bay, and therefore, it significantly impacts on the tidal exchange between Nueces Bay and Corpus Christi Bay.

Figure 3.30: The connecting channels between Nueces Bay and Corpus Christi Bay in the historical satellite images

In the current present model, a representative bathymetry dataset of Nueces Bay was constructed based on information available in previous model reports (Li & Hodges, 2015), discussions with hydrographic surveyors familiar with the area, and satellite imagery and was adjusted to achieve an acceptable model calibration and validation. The final model bathymetry for Nueces Bay is shown in Figure 3.31.

Figure 3.31: The finally constructed bathymetry in Nueces Bay

3.5.2 Salt in Nueces Delta

There is large volume of salt stored in Nueces Delta, which has been observed in satellite imagery (see Figure 2.30). This salt storage has impacts on the salinity in Nueces Bay. During a large rainfall event, these salts are dissolved by rain and runoff and carried to the bay. Additionally, during a large river flow event, flooding may occur in the delta and dissolve the stored salt, resulting in high salinity in Nueces Bay. During the model calibration, it was recognized that the salt storage in the delta cannot be ignored, otherwise, a reasonable salinity calibration cannot be achieved in Nueces Bay. Unfortunately, there is very limited information on salt storage in the delta. In this model, the boundary conditions for salinity at the open boundary of Nueces River and the salinity with the runoff to the delta was developed to account for the dissolution of salt in the delta and adjusted during the calibration (see Section 3.3.2.3 for more details).

3.5.3 Salinity Data Gap in Aransas Bay

There are large temporal data gaps in the measured salinity, which is required to construct the boundary conditions for salinity along the open boundary of Aransas Bay. The salinity in Aransas Bay has been identified to be an important source to Corpus Christi Bay since there is a net flow along the intercoastal waterway from Aransas Bay to Corpus Christi Bay. Unlike water level, it is more difficult to fill data gaps for salinity using the other stations. In this model, the boundary condition for salinity in Aransas Bay was developed by using the measured data from stations further to the northeast along the GIWW (e.g., CHKN in San Antonio Bay).

3.5.4 HYCOM Model Prediction

To better understand the accuracy of HYCOM model, the flow velocity was extracted from the HYCOM model at the NOAA monitoring station, TABS-D, at a depth of -2 m NAVD88. Figure 3.32 shows the comparison of the HYCOM modeled velocity with the measured data at TABS-D in time series. Figure 3.33 shows the correlation of velocity components (U (easting) and V (northing)) between the HYCOM model prediction and the measured data. These plots show that the HYCOM model underpredicted the currents at TABS-D significantly (about 65% less). This means that the HYCOM model underpredicted the alongshore currents in the GOM. Since the HYCOM model results were used to develop the offshore boundary condition, it may bring uncertainty to the developed model.

Figure 3.34 shows the comparison of water level predicted by the HYCOM model with the water level measured at Bob Hall Pier. The HYCOM model predicted tide signals well. However, the model underpredicts surges produced by wind, which have a seasonal variation as described in Section 2.2.3. Nevertheless, in this model calibration, the offshore boundary condition of water level was constructed by using HYCOM predicted water levels and adjusted with the seasonal variation of water level based on the measured water level at Bob Hall Pier as shown in Figure 3.34. With this adjustment, a good water level calibration was achieved.

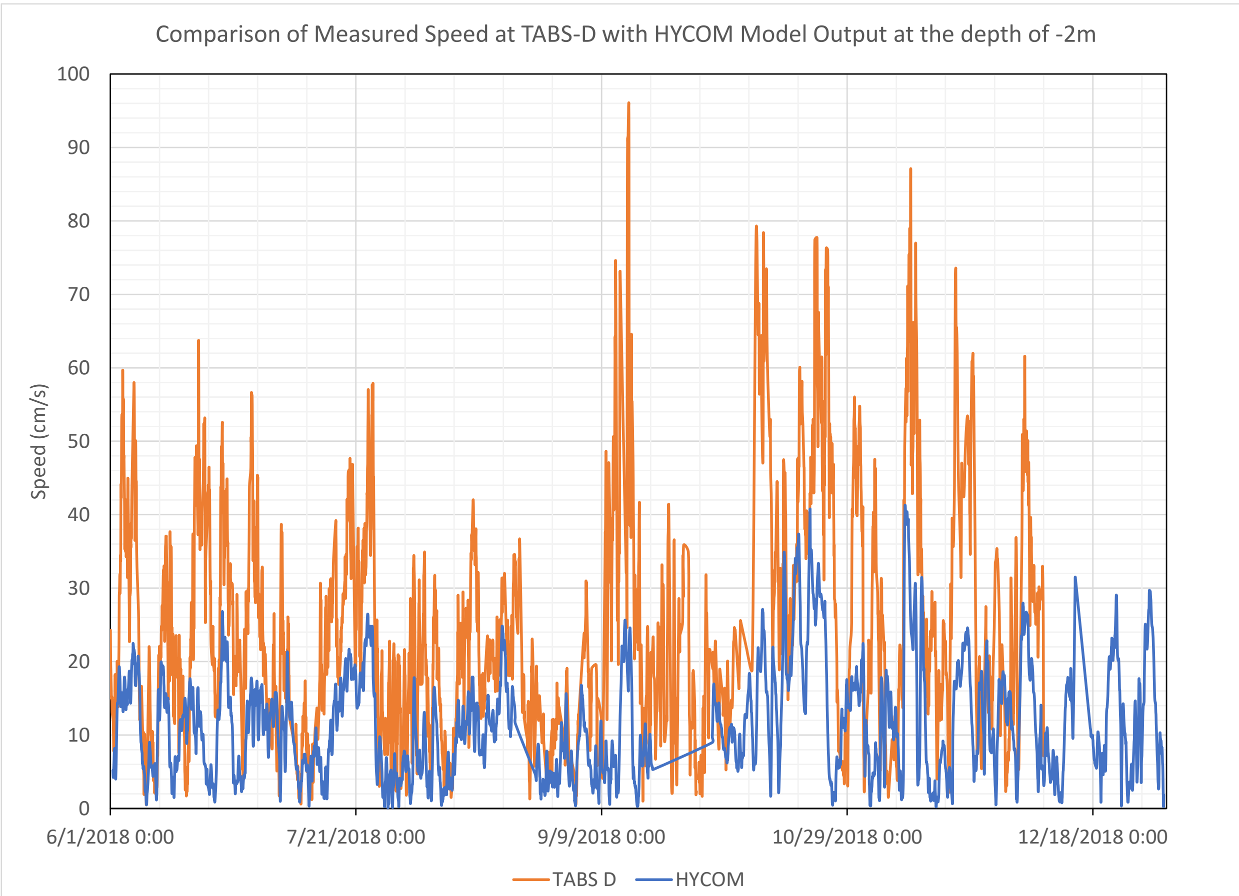


Figure 3.32: Comparison of HYCOM predicted current speed with the measured data at TABS-D

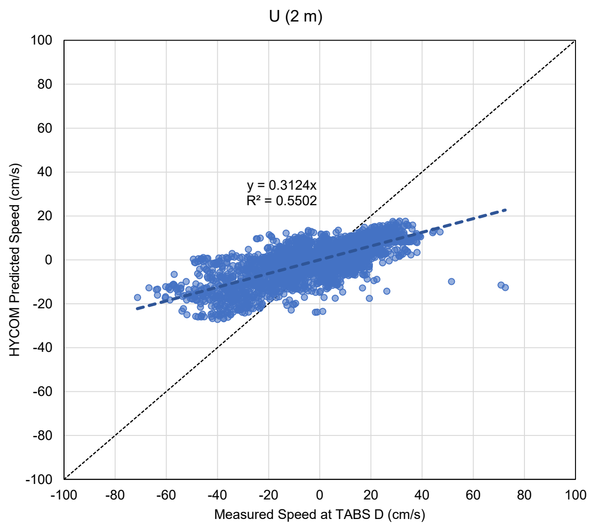


Figure 3.33: Correlation of HYCOM Predicted Velocity Components with the measured data at TABS-D.

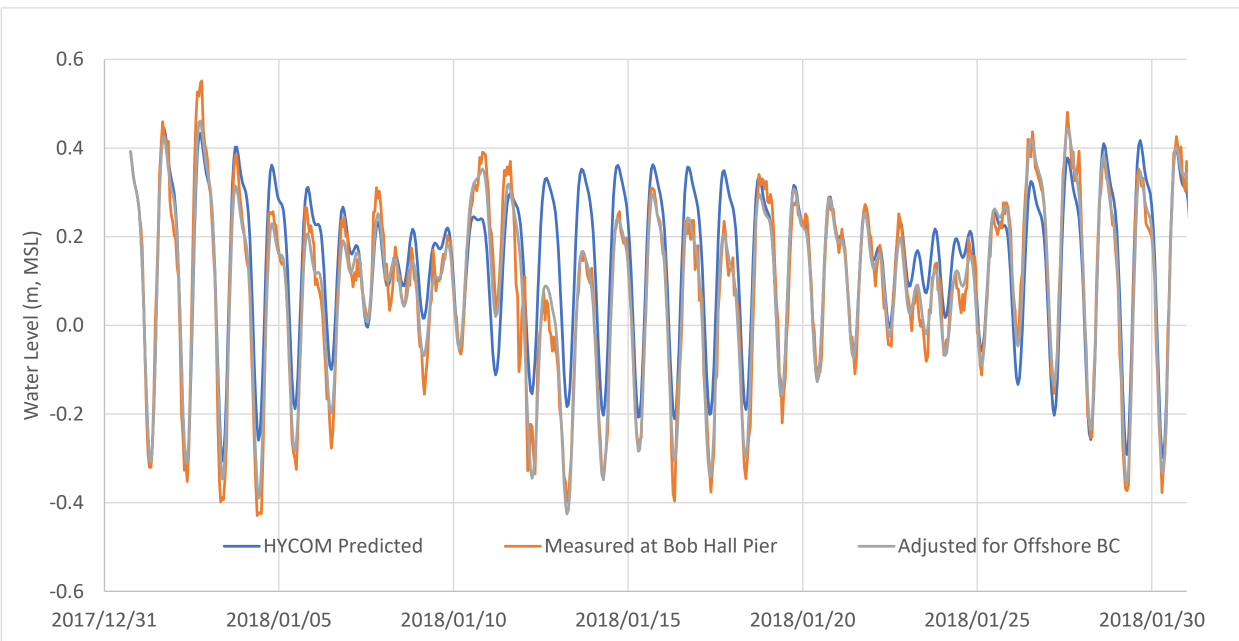


Figure 3.34: Comparison of HYCOM predicted water level with the measured water level at Bob Hall Pier

4. Impact Assessment for Future With Project

4.1 Production Model Runs

The main objective of this modeling study is to evaluate the impact of Future With Project (FWP) compared to Future Without Project (FWOP). The Future Without Project is the 54 ft channel deepening project that has been approved and is now in construction. The navigation channel in the FWOP is being dredged from the Port of Corpus Christi to the GOM to -54 ft MLLW (-16.6 m NAVD88), including Humble Basin and the Turning Basin (see Figure 4.1). The FWP is the proposed project to dredge the Corpus Christi navigation channel to -75 ft MLLW (-23.65 m NAVD88) from approximately Light #1 near Port Aransas to the GOM (see Figure 4.2). Both two project scenarios were simulated by using the developed 3D model, which was calibrated and validated against the field data (see Section 3.3).

Figure 4.1: Bathymetry used for FWOP production model runs

Figure 4.2: Bathymetry used for the FWP production model runs

The model production runs for both two project scenarios were carried out for the three periods that were selected for model calibrations and validations. The duration for each model run is three months. The representation of driving forces for these three periods are described in Section 3.3.1. To evaluate the impact of the FWP with strong wind conditions, the river inflow from Nueces River is forced to zero in Period 3. A total of six runs were carried out with the model.

To minimize the impacts from the other numerical factors (e.g., grid), all model runs were carried out using the same grid. The grid along the section of navigation channel that was deepened to 54 ft for the FWOP conditions and will be deepened to 75 ft for the FWP conditions was refined to appropriately represent the post-project bathymetry as shown in Figure 4.3. The same boundary conditions and physical and numerical parameters, except the bathymetry in the dredge areas, are used for all production model runs.

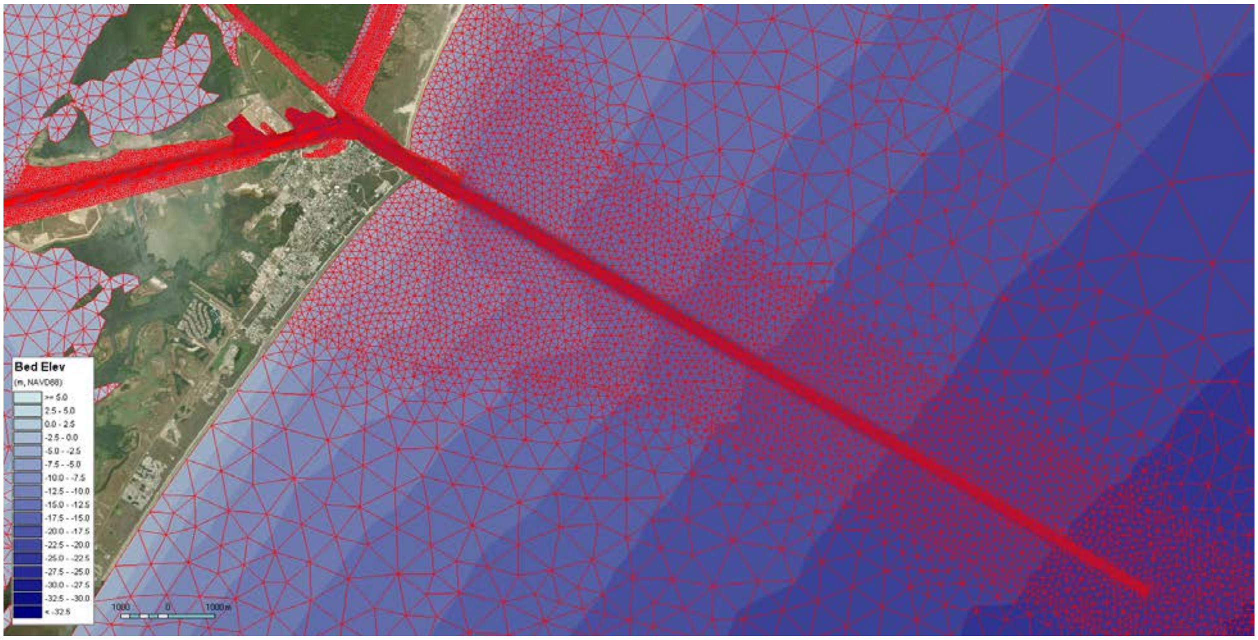


Figure 4.3: Refinement of model grid in the vicinity of the FWP construction areas

All production model runs output the results in one-hour intervals, including water level, velocity vectors (speed and direction), and salinity. The impacts of the FWP were assessed by comparing water level, current speed, and salinity between the FWP and FWOP scenarios in time and in 3D space. To better understand the impact, statistical analysis was carried out through entire simulation period (excluding the warmup period) and the outputs include mean, range, and standard deviation of the changes between FWP and FWOP. The post-processing of model results was mainly carried out by using Baird in-house software, Spatial Data Analyzer (SDA), which is a powerful tool to visualize and analyze the dynamic data in time and 3D space that are typically generated by models with GIS capability. The results were also extracted at the selected locations (see Figure 4.4) to represent the bays of interest in this analysis.

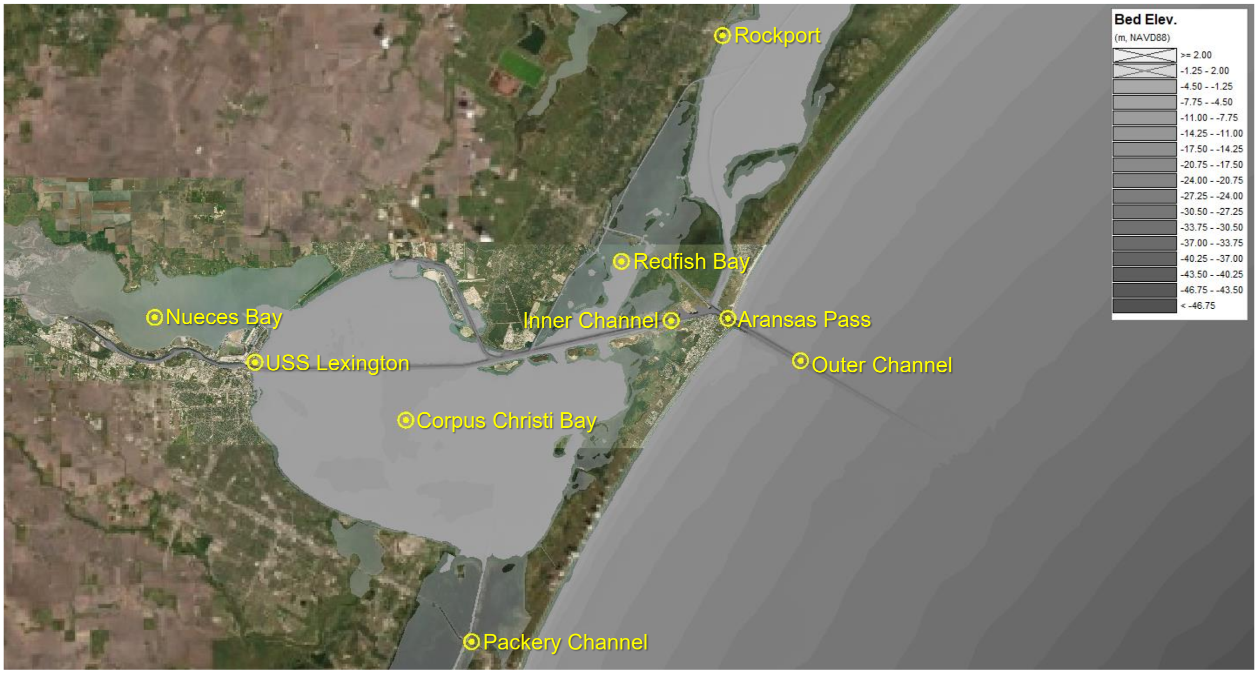


Figure 4.4: Selected stations to represent the bays of interest in the impact assessment

4.2 Impact to Water Levels

4.2.1 Mean Water Level

The changes in water level caused by the FWP were first analyzed by subtracting the hourly water levels predicted in the FWOP scenario from these predicted in the FWP scenario. A statistical analysis of the difference of hourly water levels was then carried out. Figure 4.5 shows the change of mean water level caused by the FWP in Period 2, which shows a decrease of mean water level less than 1 cm. The plots for the change of mean water levels in Period 1 and Period 3 are attached in Appendix B.1.1, which show similar results. This indicates that the FWP is unlikely to change mean water levels in the bays.

Figure 4.5: Impact of FWP to mean water levels as compared to FWOP during Period 2

4.2.2 High Tide and Low Tide

To understand the details of water level change caused by the FWP in the tide environment, the predicted water levels in the inner channel (see Figure 4.4 for location), where there is the largest water level change observed from the model result, are compared between FWP and FWOP, as shown in Figure 4.6. In the FWP, the water levels at high tide increase, and the water levels at low tide decrease.

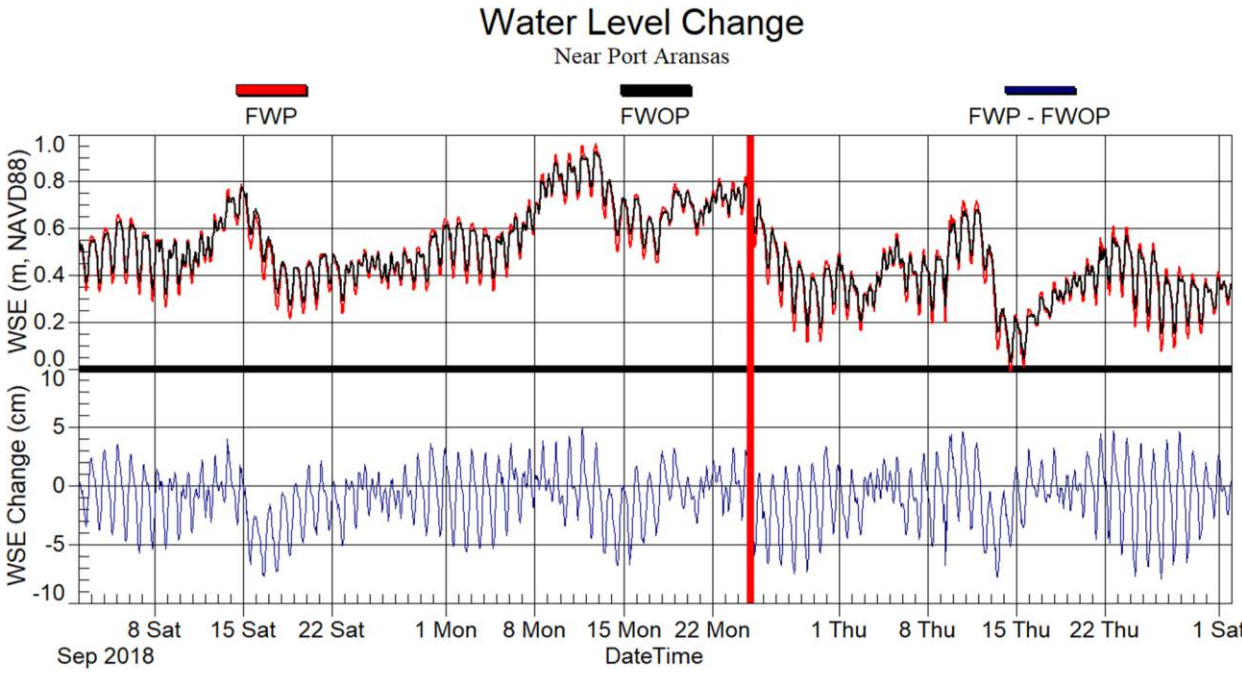


Figure 4.6: Comparison of predicted water levels for FWP and FWOP

To quantitively estimate the change, the high tides (i.e., the highest water level in a tide cycle) were analyzed from the model hourly output with the following steps:

- Calculate high tide predicted for both FWP and FWOP in all tidal cycles;
- Calculate the difference of high tide between FWP and FWOP for all tidal cycles;
- Perform the statistical analysis of high tide difference which outputs the mean, minimum, maximum, and standard deviation.

Figure 4.7 shows the average increase of high tide caused by the FWP in Period 2 and the similar plots for Period 1 and Period 3 are attached in Appendix B.1.2. Table 4.1 shows the increase of high tides caused by the FWP at the selected stations, which was combined from the results of all three modeling periods. The model predicted that the increase of high tide is less than 2 cm in Corpus Christi Bay and Redfish Bay. The maximum increase of high tide occurs at Humble Basin which is about 4 cm. It is unlikely that the FWP would cause any flooding issues in the vicinity of the proposed dredge area.

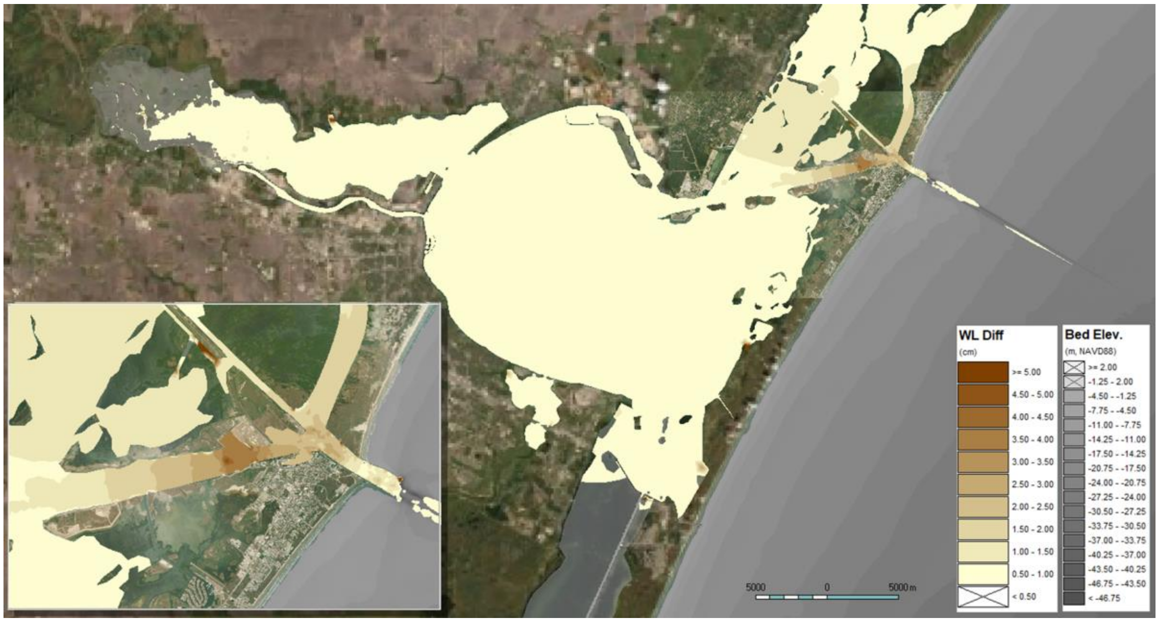


Figure 4.7: The average increase of high tide caused by FWP in comparing with FWOP in Period 2

Table 4.1: Increase of high tide caused by the FWP

Station	High Tide Change (cm)			Percentage
	Mean	Minimum	Maximum	
Outer Channel	0.0	-0.2	0.1	0%
Aransas Pass	0.4	-0.2	1.8	1%
Inner Channel	1.0	-1.5	3.8	2%
Redfish Bay	0.3	-1.1	1.6	1%
Corpus Christi Bay	0.2	-1.1	1.5	1%
USS Lexington	0.2	-1.2	1.5	1%
Nueces Bay	0.1	-1.4	1.2	0%
Packery Channel	0.1	-0.8	1.3	0%
Rockport	0.1	-0.3	0.6	0%

Using a similar approach, the lowering of low tides was calculated, and the results are shown in Figure 4.8. Similar plots for Period 1 and Period 3 are attached in Appendix B.1.2. Table 4.2 shows the lowering of low tide caused by the FWP, which was integrated from model results for all three modeling periods. The model predicted that the FWP would cause less than 4 cm drop of low tide in Corpus Christi Bay and Redfish Bay. The maximum drop of low tide occurs in the inner channel near Humble Basin which is about 10 cm. This small drop of low tide unlikely causes a navigation risk.

Figure 4.8: The average drop in low tide caused by the FWP in comparing with the FWOP in Period 2

Table 4.2: Drop in low tide caused by the FWP

Station	Low Tide Change (cm)			Percentage
	Mean	Minimum	Maximum	
Outer Channel	0.0	-0.1	0.0	0%
Aransas Pass	0.3	-0.1	0.0	0%
Inner Channel	-2.8	-9.4	-4.8	-7%
Redfish Bay	-1.0	-3.7	-1.7	-3%
Corpus Christi Bay	-0.9	-2.9	-1.3	-2%
USS Lexington	-0.9	-2.7	-1.4	-2%
Nueces Bay	-0.6	-2.0	-1.2	-2%
Packery Channel	-0.3	-1.0	-0.5	-1%
Rockport	-0.2	-0.5	-0.4	0%

4.2.3 Tidal Range

The pattern of water level change mentioned above (i.e., the increase in high tide and lowering of low tide) implies that the FWP will increase the tidal range in the vicinity of the project site. To quantitively evaluate the increase of tidal range caused by the FWP, two approaches were applied to calculate the tide range change:

- Using tidal harmonic analysis from the hourly water levels to estimate the relative change of tidal amplitude in percentage;

- Performing the statistical analysis on the tidal ranges which are directly calculated from the hourly water levels for all tidal cycles to estimate the absolute tidal range change.

A tide harmonic analysis with 26 major tidal constituents was carried out by using the three-month hourly water levels predicted by the model in Period 2. Figure 4.9 and Figure 4.10 show the comparison of the tidal amplitudes of these major tide constituents between FWP and FWOP at the selected locations (see locations in Figure 4.4) for Period 2. Similar plots are attached in Appendix B.1.3 for Periods 1 and 3. The slopes of the linear fitting lines (without intercept) as shown in the plots indicates the degree of relative increase in tidal amplitude. The percentage of tidal amplitude increase can be calculated by subtracting one from the slope of the fitting lines, which are listed in Table 4.3. The model predicted tidal amplitude increases about 11% in Redfish Bay, 8% in Corpus Christi Bay, 7% in Nueces Bay, and 3% at Rockport. The tidal amplitude at the inner channel near Port Aransas has the largest increase which is about 17%. There is no significant change in tidal amplitudes in Aransas Pass and the outer channel. Note that the tidal ranges in these locations are small and therefore the actual increase in tidal ranges may not be significant despite the fact the percentage of increase is significant.

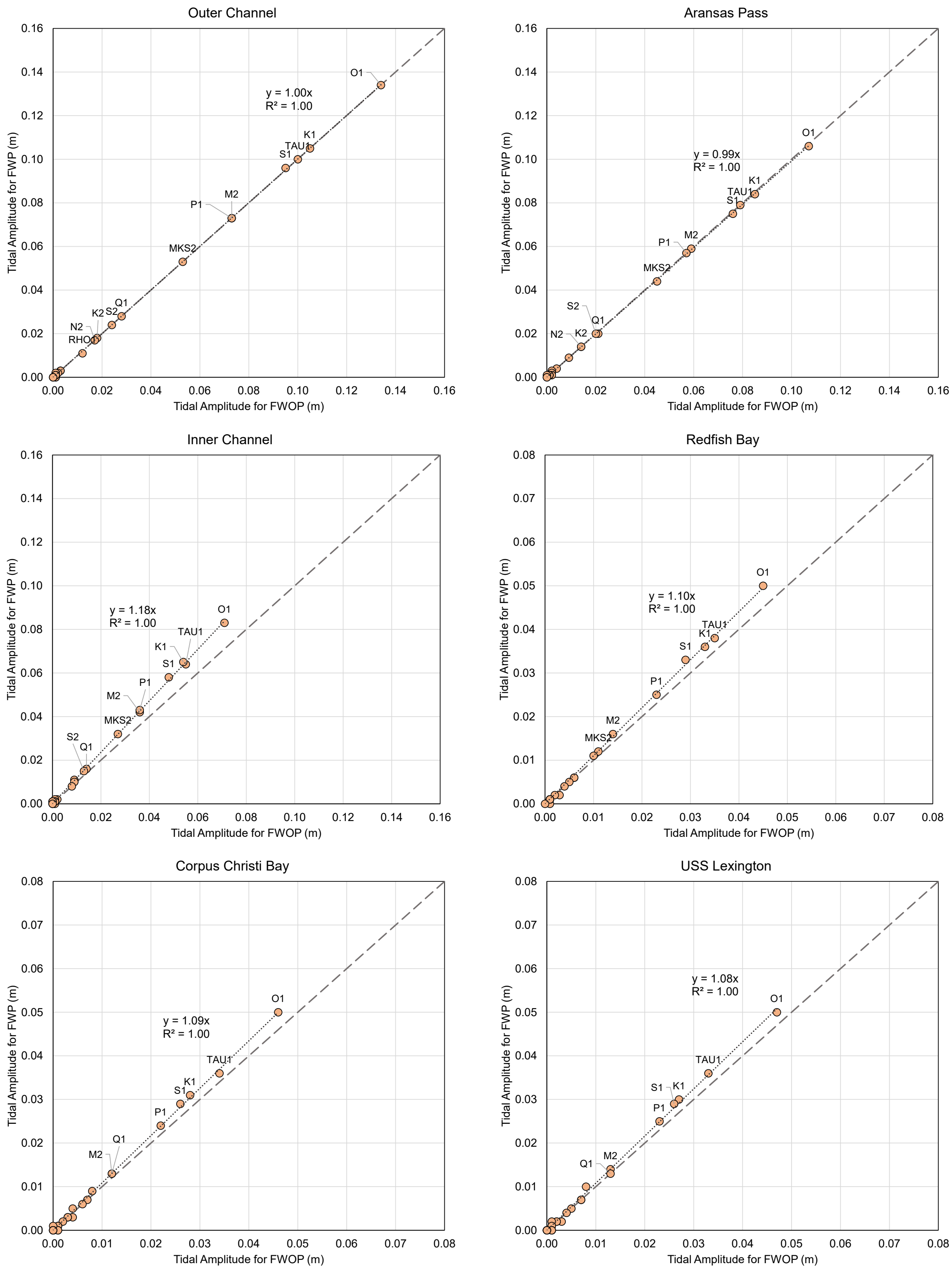


Figure 4.9: Comparison of tide amplitudes between FWP and FWOP in for Period 2

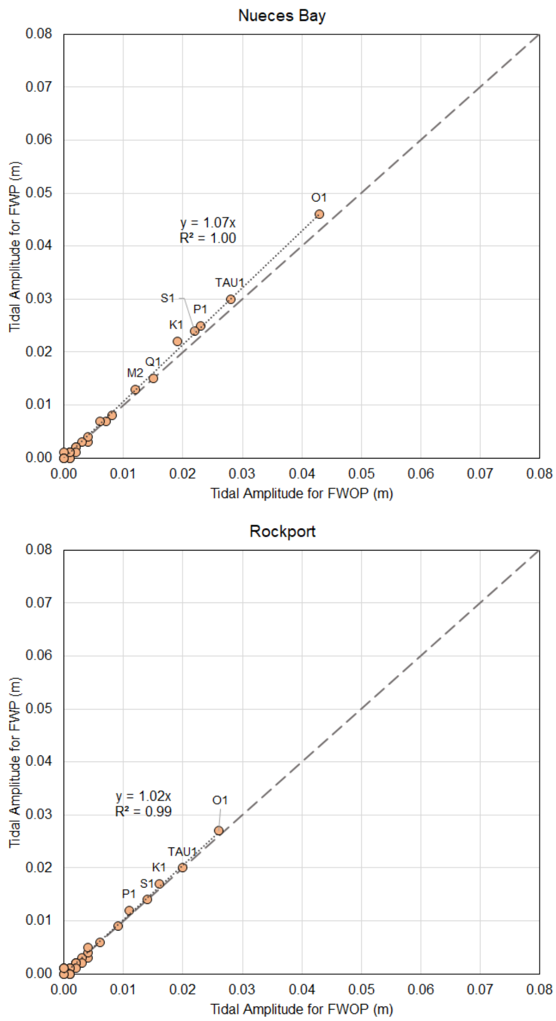


Figure 4.10: Comparison of tide amplitudes between FWP and FWOP in Period 2 (continued)

Table 4.3: Relative increase of tide amplitudes caused by the FWP

Locations	Tide Amplitude Increase (%)			
	Period 1	Period 2	Period 3	Average
Outer Channel	0%	0%	0%	0%
Aransas Pass	0%	-1%	0%	0%
Inner Channel	16%	18%	16%	17%
Redfish Bay	11%	10%	11%	11%
Corpus Christi Bay	7%	9%	9%	8%
USS Lexington	8%	8%	9%	8%
Nueces Bay	6%	7%	7%	7%

Locations	Tide Amplitude Increase (%)			
	Period 1	Period 2	Period 3	Average
Packery Channel	5%	4%	7%	5%
Rockport	4%	2%	4%	3%

To quantitively estimate the absolute increase of tidal range, the spatially varied tidal ranges over three-month periods were calculated (totally about 80 tide cycles). Figure 4.11 shows the average tidal range change in centimeters for Period 2. Similar plots for Period 1 and Period 3 are attached in Appendix B.1.3. Table 4.4 lists the average tidal range increase with the minimum and maximum values found in the three simulation periods. The model predicted that the average tidal range increase is about 4 cm at the inner channel near Port Aransas, ranging from 0.3 cm to 9 cm. The average tidal range increase at Corpus Christi Bay and Redfish Bay is less than 2 cm, ranging from -0.1 cm to 4 cm.

The percentage of tidal range increase in the model domain for Period 2 is shown in Figure 4.12. The percentage of tidal range increase listed in Table 4.4 is consistent to the percentage of tide amplitude increase listed in Table 4.3. Although the percentage is significant, the absolute tidal range changes are actually small (e.g., in the order of 1 cm or less), which may not result in significant impacts on the environment in Corpus Christi Bay and Redfish Bay, in Baird's opinion. A noticeable impact on the tidal range is limited to the Navigation Channel from Point Mustang to the inner basin.

Table 4.4: Change of tide range caused by the FWP

Station	Tide Range Change (cm)			Percentage of Average Change
	Mean	Minimum	Maximum	
Outer Channel	-0.1	-0.3	0.2	0%
Aransas Pass	0.1	-0.8	2.0	0%
Inner Channel	3.8	0.3	9.0	16%
Redfish Bay	1.2	-0.1	3.0	8%
Corpus Christi Bay	1.1	0.0	4.0	7%
USS Lexington	1.1	0.0	4.0	7%
Nueces Bay	0.8	-0.6	3.0	4%
Packery Channel	0.4	-0.3	1.0	4%
Rockport	0.3	-0.1	2.0	3%

Figure 4.11: Average tide range increase caused by the FWP for Period 2

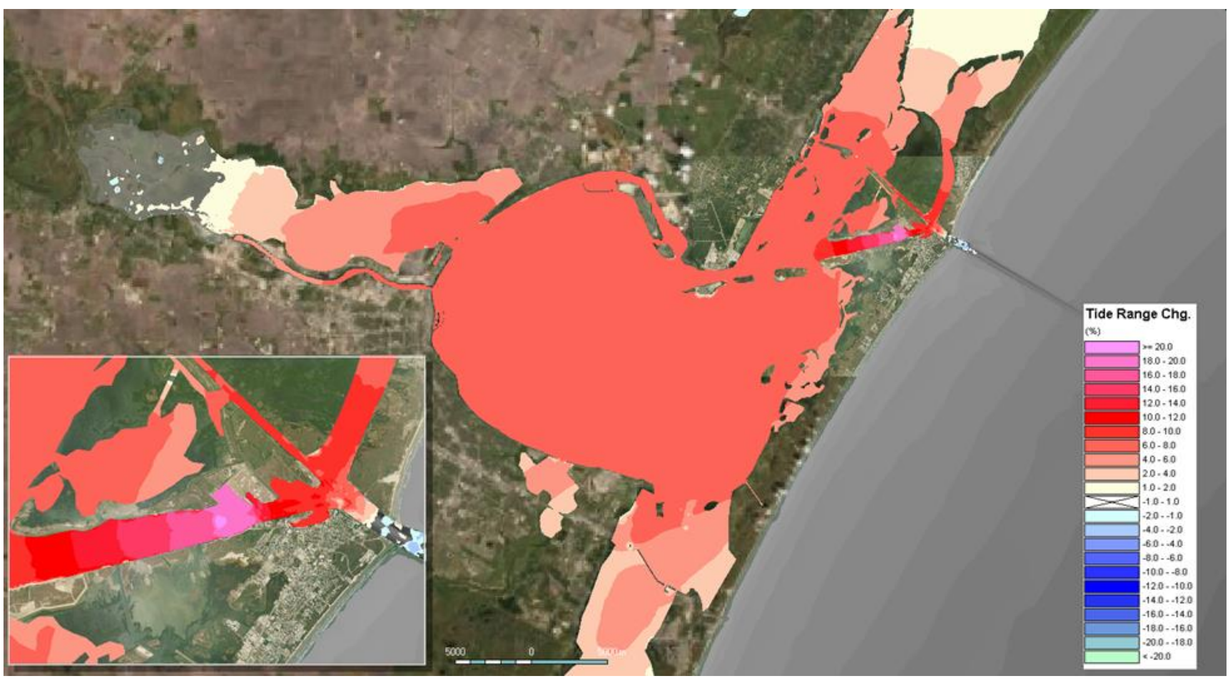


Figure 4.12: Percentage of tide range increase caused by FWP for Period 2

The predicted increase in tidal range due to the FWP is consistent with the hydrodynamic analysis from the 2007 Moffatt & Nichol report "*Matagorda Ship Channel Improvement Project, Point Comfort, Texas*". Located approximately 100 km northeast of Corpus Christi, the project features deepening the Matagorda Ship Channel from 38 ft Mean Low Tide (MLT) to 44-46 ft MLT and double widening the channel width. MIKE3 modeling predicted that the tidal range in Matagorda Bay would be increased by about 20% as a result of the channel deepening and widening.

4.3 Impact to Current Speed

Figure 4.13 presents the impact of the FWP on depth-averaged current speed as compared to the FWOP in Period 2. Similar plots of the depth-averaged speed change in Period 1 and Period 3 are provided in Appendix B.2. The change of current speeds on the water surface and at the depths of -5 m and -10 m NAVD88 are also plotted, which shows the similar patterns in the current speed change as observed in the depth-averaged current speed change. These plots are also attached in Appendix B.2. Table 4.5 lists the summary of depth-averaged speed change caused by the FWP at the selected stations in all three periods.

Overall, the impact of FWP on the current speed is limited to the proposed dredge areas and the navigation channel extending about 15 km to Port Ingleside from the proposed dredge area near Port Aransas. There is no significant impact on currents in Corpus Christi Bay, Redfish Bay, and Nueces Bay. The model predicted that the FWP would reduce current speeds through the proposed dredge area, which results from deepening the navigation channel. The mean current speed at Aransas Pass is reduced by about 7 cm/s on average and up to 19 cm/s as a maximum. The current speed increases in the Corpus Christi Channel from Port Aransas to Port Ingleside where the water depth remains unchanged. The current speed at the inner channel near Port Aransas increases about 3 to 4 cm/s, up to 11 cm/s. Increases in current speed may raise navigation concerns and the current speed change may result in local morphological change.

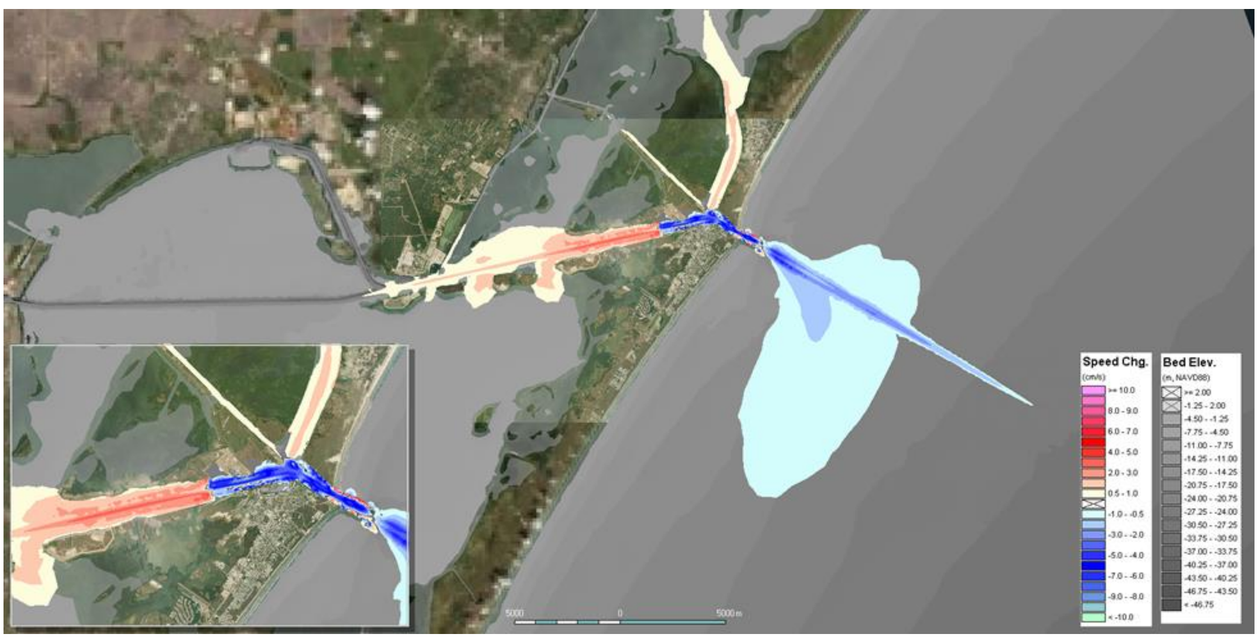


Figure 4.13: The change of depth-averaged speed caused by the FWP in for Period 2

Table 4.5: Change of depth averaged speed caused by the FWP at the selected locations

Station	Flow Speed Change (cm/s)			Percentage
	Mean	Minimum	Maximum	
Outer Channel	-1.6	-18.5	12.6	-17%
Aransas Pass	-6.5	-18.7	8.8	-14%
Inner Channel	2.9	-5.8	10.5	8%
Redfish Bay	0.0	-0.6	0.6	1%
Corpus Christi Bay	0.1	-0.3	0.4	3%
USS Lexington	0.0	-0.4	0.5	0%
Nueces Bay	0.1	-0.9	0.9	2%
Packery Channel	0.1	0.0	0.2	0%
Rockport	0.0	-0.2	0.2	0%

To better illustrate the impact of FWP on tidal range and current speed, four cross-sections in the navigation channels around the inner basin are selected as shown in Figure 4.14. Using the hourly model outputs, the wet cross-section area, total discharge, and cross-section averaged speed are calculated. Figure 4.15 demonstrates how the percentage of discharge change from the hourly discharge results is determined. The plot shows the comparison of calculated discharge passing through Aransas Pass (cross-section A) between FWOP (referred to x-axis) and FWP (referred to y-axis) in Period 2. The percentage change of discharge caused by the FWP is then determined by the slope of the fitting line minus one. The plot shows the increase of discharge through Aransas Pass during both flood tides (negative discharge) and ebb tides (positive discharge) constantly.

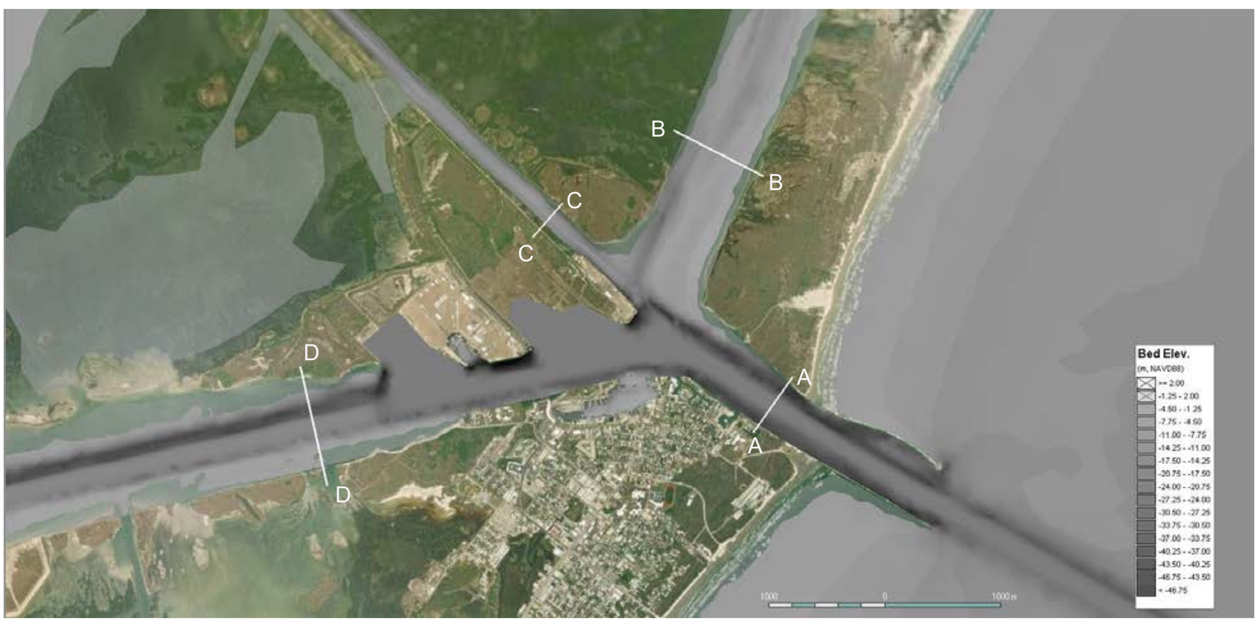


Figure 4.14: Locations of cross-sections to calculate discharge

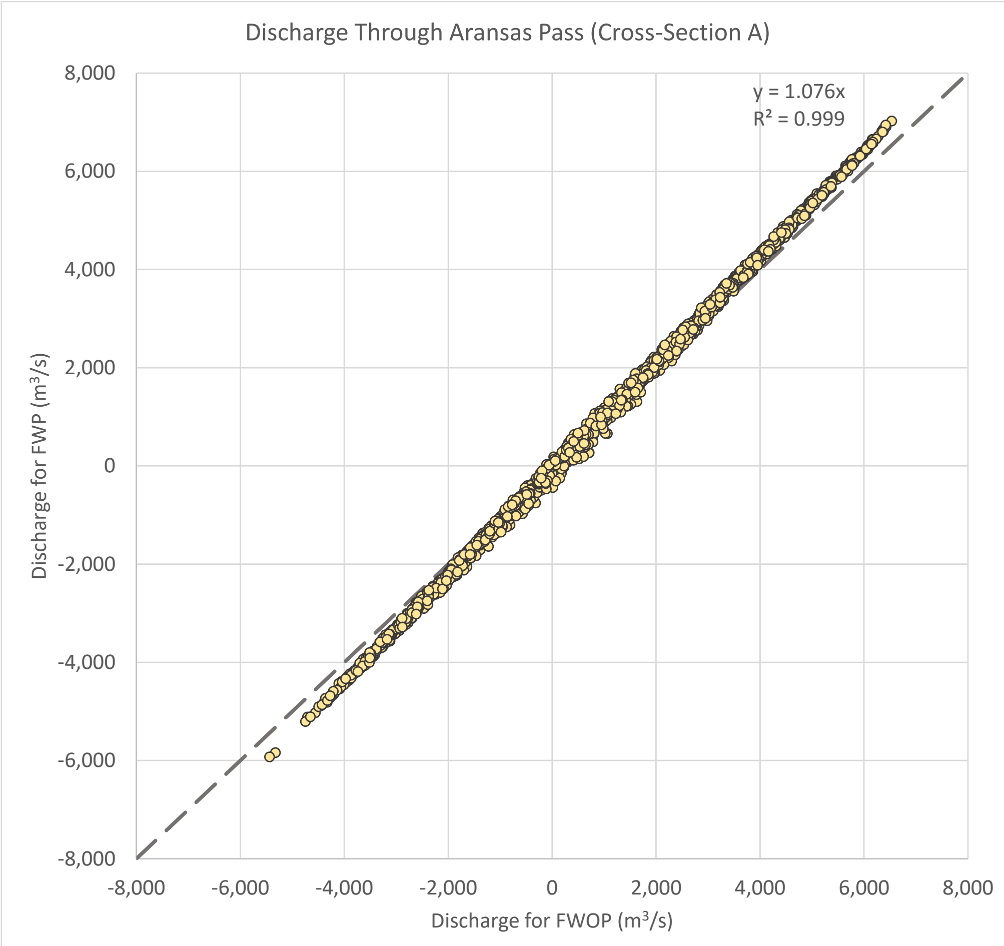


Figure 4.15: Comparison of discharge between FWOP and FWP along Cross-Section A-A in for Period 2

Table 4.6 lists the percentage of changes in cross-section area, cross-section averaged current speed, discharge, and net flow caused by the FWP, which are averaged from all three model runs for all three periods. Aransas Pass is the primary outlet of the bays to the GOM. Figure 4.16 shows the discharge variations through these four cross-sections in both FWOP and FWP scenarios and provides the flow distribution in these three branches connected to Aransas Pass. The peak flow discharge in the pass is about 6,000 m^3/s in normal conditions and could reach more than 9,000 m^3/s during storms.

Deepening the navigation channel in Aransas Pass significantly increases the cross-sectional wet area, which is about 20%. This results in the increase of conveyance capacity in the pass. As a result, tidal exchange between the bays and the GOM significantly increases. The model predicts that the discharge through the pass increases by about 8% although the cross-section averaged speed reduces about 10% due to water depth increase.

In response to the discharge increase in Aransas Pass, the discharges increase about 3% to Aransas Bay and Redfish Bay and about 8% to Corpus Christi Bay after the construction of the FWP. As the result, the tidal range and current speeds in the navigation channels to these bays increases accordingly because the cross-sections to Aransas Bay (B-B), Redfish Bay (C-C), and Corpus Christ Bay (D-D) remain unchanged after the FWP.

The net flow, which is the net water volume through the cross-sections in the simulation periods, decreases at the cross-section to Redfish Bay but increase at the cross-section to Corpus Christi Bay. This indicates that there is an increase in net flow from Redfish Bay to Corpus Christi Bay after the FWP construction.

Table 4.6: Percentage changes of area, discharge, and net flow caused by FWP in four cross-sections around the inner basin

Cross-Section	A-A	B-B	C-C	D-D
Connected Bay	Aransas Pass	To Aransas Bay	To Redfish Bay	To Corpus Christi Bay
Area	20%	0%	0%	0%
Speed	-10%	3%	3%	9%
Discharge	8%	3%	3%	8%
Net Flow	2%	0%	-3%	5%

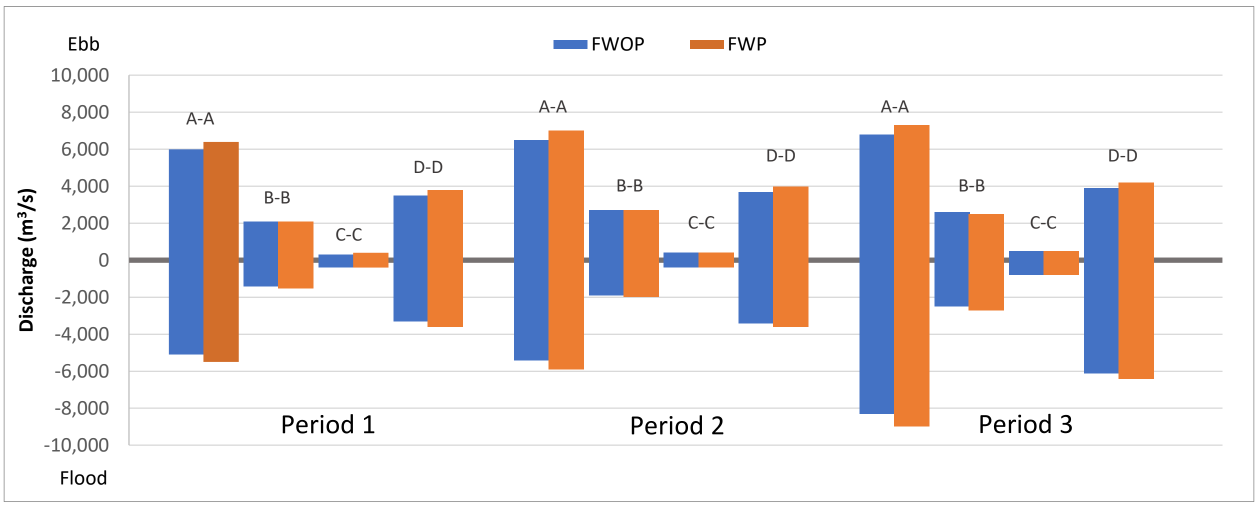


Figure 4.16: Comparison of discharge variation through four cross-sections between FWOP and FWP in three modeling periods

4.4 Impact to Salinity

The impact of FWP on salinity was assessed by comparing the salinity predicted in the FWP scenario with the salinity predicted in the FWOP scenario in time and 3D space. The salinity change caused by the FWP was calculated as the difference of salinity predicted by the FWP and FWOP. The model results show that the salinity change are similar in the vertical column. To better understand the impact, a statistical analysis on the salinity change was performed for all time steps and all layers in the 3D model mesh. Figure 4.17 shows the salinity change averaged over time and water column during Period 2. The average change in salinity caused by FWP is very small. Figure 4.18 shows the range of salinity change, which was calculated as the maximum salinity change minus the minimum salinity change. It indicates that the FWP may cause some disturbing change in salinity of less than ±3 PSU in the proposed dredge area and the connected navigation channels. Note that the large range of salinity change in the very shallow water (generally at a few inches water depth) likely results from the wetting and drying process in the model (i.e., the cell may be dry in one model run but the cell is wet in the other model run). Table 4.7 lists the average salinity change, minimum and maximum, and percentage at the selected stations. It is concluded that the FWP is unlikely to cause significant impact on salinity in these bays.

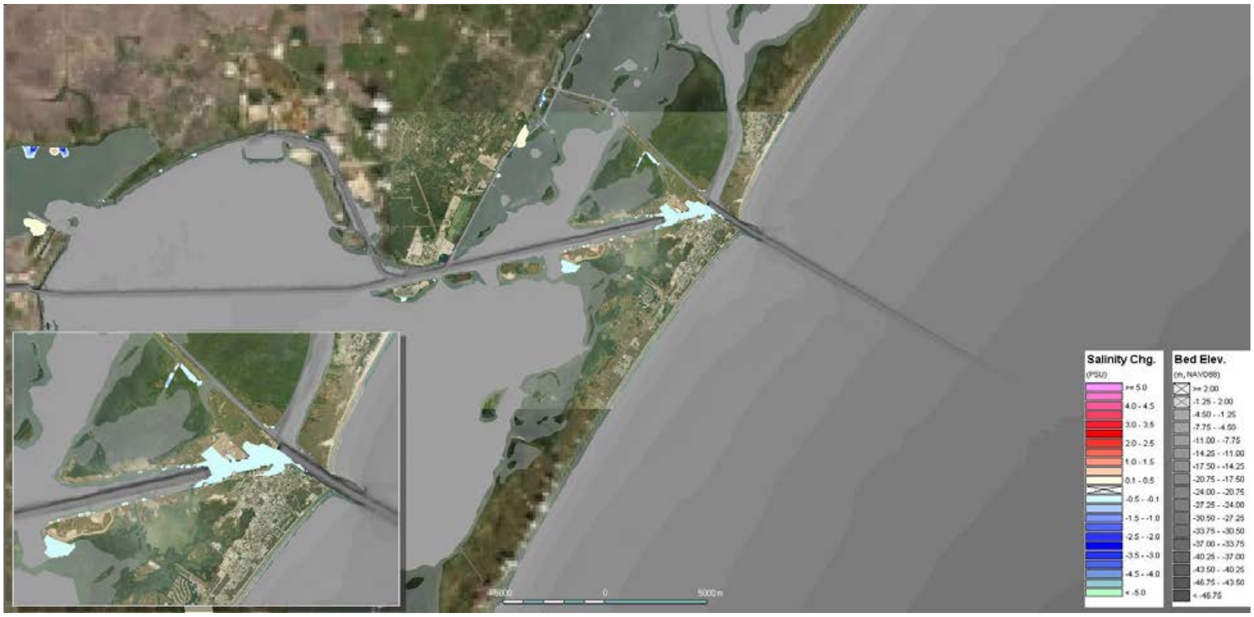


Figure 4.17: Average salinity change caused by FWP in Period 2

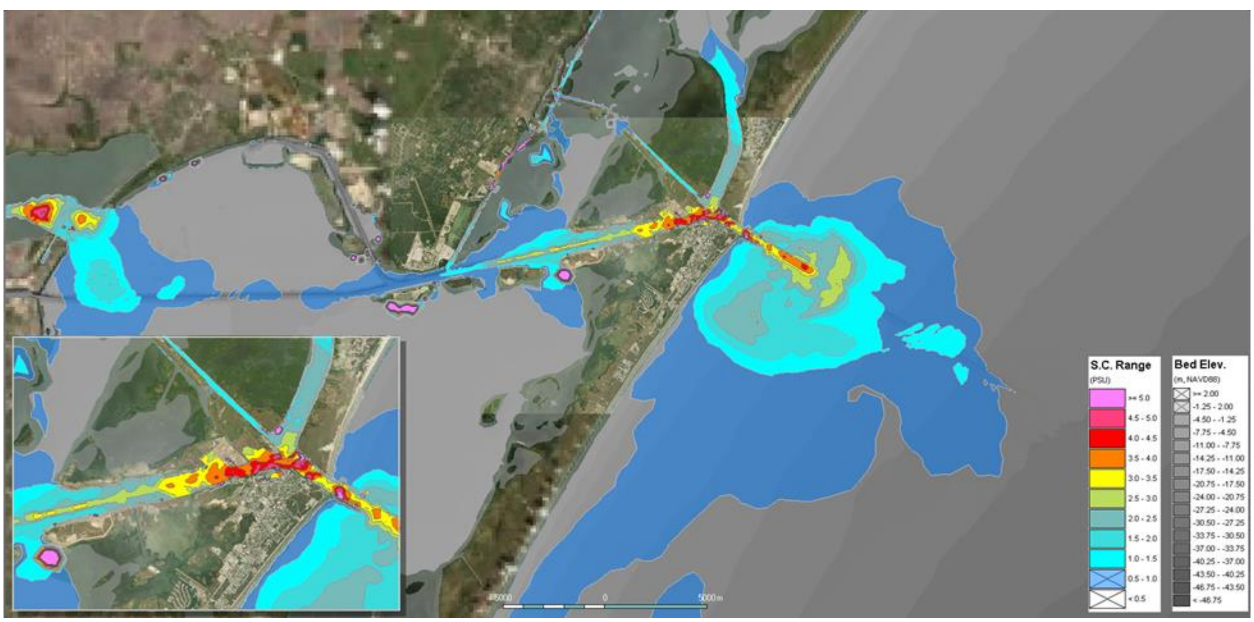


Figure 4.18: Range of salinity change (max change minus min change) caused by FWP in Period 2.

Table 4.7: Change of salinity caused by FWP at the selected stations in comparing with FWOP

Station	Salinity Change (PSU)			Percentage
	Mean	Minimum	Maximum	
Outer Channel	0.0	-1.1	1.9	0.0%
Aransas Pass	-0.1	-3.0	2.2	-0.2%
Inner Channel	-0.1	-2.7	1.2	-0.2%
Redfish Bay	0.0	-0.2	0.2	0.0%
Corpus Christi Bay	0.0	-0.1	0.1	0.0%
USS Lexington	0.0	-0.3	0.1	0.0%
Nueces Bay	0.0	-0.4	0.3	0.0%
Packery Channel	0.0	-0.2	0.1	-0.1%
Rockport	0.0	-0.1	0.1	0.0%

4.5 Long-term Impact Assessment

The above-mentioned impact assessment was based on the model runs in the selected three-month periods. Three-month simulation may be insufficient to cover the full ranges of tide fluctuation and the seasonal variations of meteorological-oceanographic conditions in the Gulf of Mexico. Three long-term model runs with the simulation period of one year were carried out to verify and extend the impact assessment for the scenarios of the existing condition (EC), FWOP, and FWP. The sensitivity tests indicate that the 2D model produces the results similar to the 3D model in term of depth average currents/salinity and water levels (see Section 3.4.3). Instead using the 3D version of MIKE3 (hereafter refer to the short-term 3D model), a 2D depth-average model of MIKE21 (hereafter refer to the long-term 2D model) was used to reduce the computational time. The simulation period is selected from June 1, 2018 to June 1, 2019, which includes Period 1 and Period 2 selected for the 3D model calibrations (see Section 3.3) and the production runs (see Section 4.1). All model settings, including grid, open boundary conditions, and model parameters, are the same as these used in the short-term 3D model. To remove any impact from the grid arrangement, the grids used for EC, FWOP, and FWP are the same but the bathymetries on the mesh nodes were modified according to these three configurations. The 2D model outputs water level, flow velocity, and salinity in one-hour interval. This section documents the impacts of FWP compared with FWOP from the long-term 2D model results.

4.5.1 Impacts to Water Levels

By using the same methodology as the 3D model, tide harmonic analysis on the hourly outputs of water levels from the long-term 2D model was carried out. Figure 4.19 shows the QQ plots of tide amplitudes for 26 major tide constituents predicted for the FWOP (shown in x-axis) and the FWP (shown in y-axis) at Inner Channel (approximately Channel Stationing +100+00) and Corpus Christi Bay (see locations in Figure 4.4). The QQ plots for other stations are attached in Appendix B. The percentage of tide amplitude increase is calculated as the subtraction of one from the slope of the fitting lines, which are listed in Table 4.8. The results show that the impacts of the FWP on tide amplitudes predicted by the long-term 2D model are consistent to that predicted by the short-term 3D model. The largest increase of tidal amplitudes occurs at the inner channel near Port Aransas (approximate Channel Stationing +100+00), which is an increase of approximately 15%. The increases in tidal amplitudes are approximately 10% in Redfish Bay, 9% in Corpus Christi Bay, 7% in Nueces

Bay, and 3% at Rockport. There is no significant change in tidal amplitudes in Aransas Pass and the outer channel.

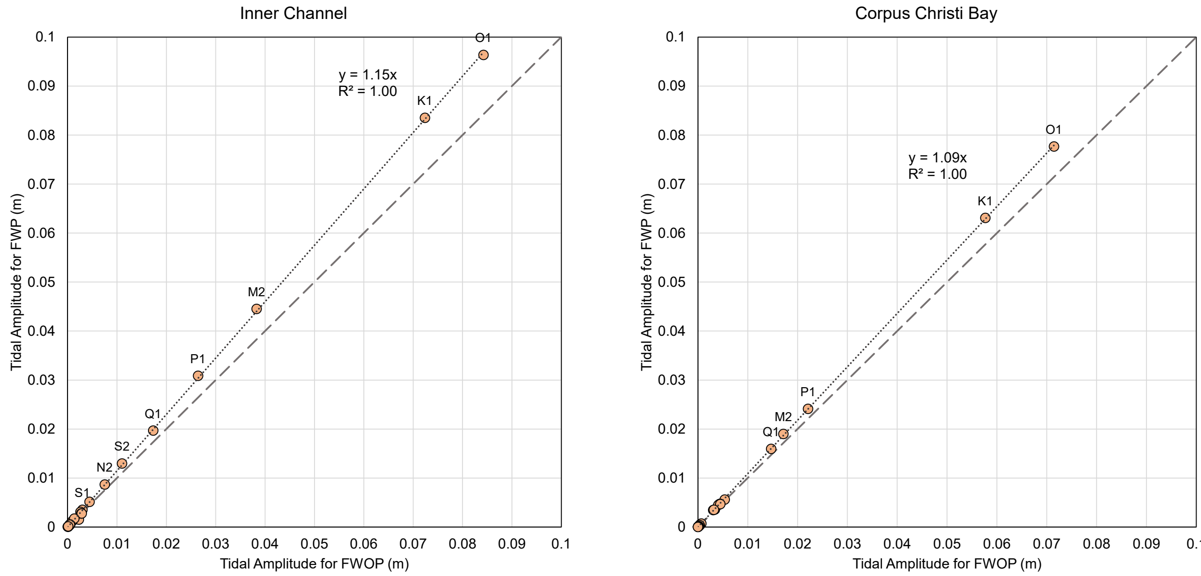


Figure 4.19: Increase of tidal amplitudes for FWP compared to FWOP in Inner Channel (left) and Corpus Christi Bay (right)

Tide ranges are also calculated from the hourly 2D model outputs. Figure 4.20 shows the average tidal range change in centimeters based on the long-term 2D model results. Table 4.8 lists the average tidal range increase with the minimum and maximum values predicted by the long-term 2D model. The model predicted that the average increase of tidal range is approximately 3.5 cm at the inner channel near Port Aransas, ranging from -0.1 cm to 8 cm. The average tidal range increase at Corpus Christi Bay and Redfish Bay is less than 2 cm, ranging from -0.2 cm to 4 cm. The result is consistent to that found from the short-term 3D model.

To better understand the impact of tide range on water levels, the change of tide ranges was extracted and plotted in Figure 4.22. The location of the profile and channel stationing number are shown in Figure 4.21. The envelop and heat map represents the envelope and distribution of tide range change at these points along the navigation channel. The largest tide range increase is found in the channels from Stationing 0+00 to 300+00.

Table 4.8: Change in Tide Range and Tide Amplitudes for 26 Major Tide Constituents for FWP compared to FWOP

Stations	Tide Range Change				Increase of Tide Amplitude (%)
	Mean (cm)	Minimum (cm)	Maximum (cm)	Percentage (%)	
Outer Channel	0.0	-1.8	1.3	0%	0%
Aransas Pass	0.0	-1.4	1.7	0%	0%

Inner Channel	3.4	-0.1	7.9	13%	15%
Redfish Bay	1.8	-0.2	3.8	8%	10%
Corpus Christi Bay	1.8	-0.2	3.5	8%	9%
USS Lexington	1.8	-0.4	3.6	8%	9%
Nueces Bay	1.2	-0.6	2.7	6%	7%
Packery Channel	0.5	-0.7	1.6	6%	8%
Rockport	0.2	-0.3	0.6	1%	3%

Figure 4.20: Mean tide range change caused by the FWP relating to the FWOP

Figure 4.21: Longitudinal profile along the navigation channel to Corpus Christi Bay. The red dot is the location to which the channel stationing refers (positive channel stationing is the channel towards Corpus Christi Bay)

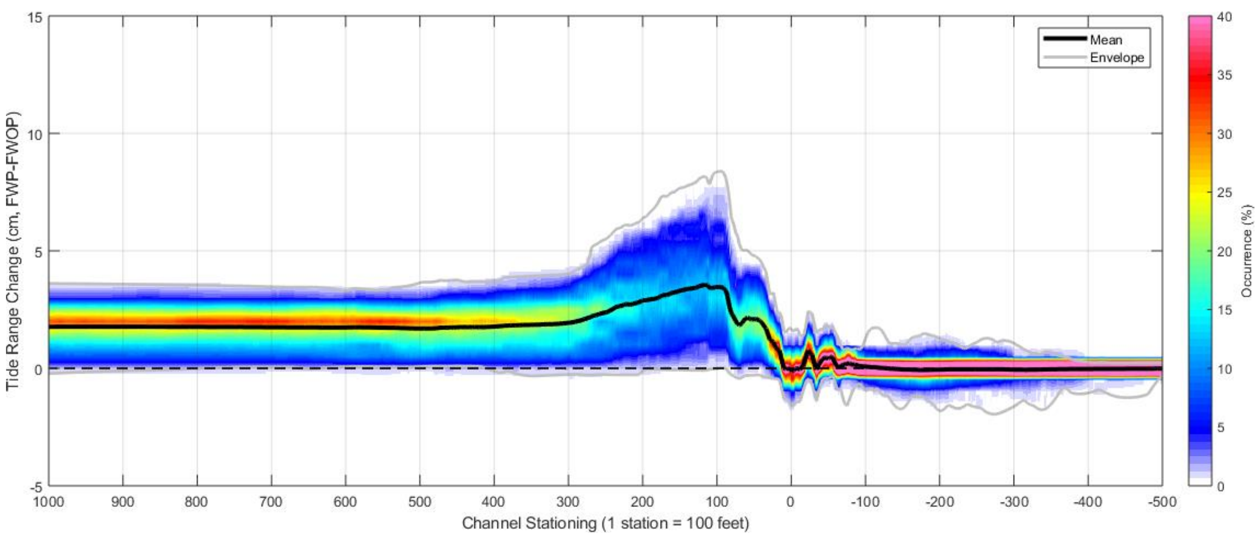


Figure 4.22: Tide range change caused by the FWP in comparing with the FWOP along the navigation channel. The thick black line represents the average change. The envelope enclosed by two grey lines represents the minimum and maximum changes found in the one-year model run. The heat map represents the distribution of the changes. Dash horizontal line represents no change

4.5.2 Impacts to Current Speed

The change in depth-average current speed comparing the FWP to the FWOP was calculated as from the long-term 2D model results. Statistical analysis for hourly current speed changes was also carried out. Figure 4.23 shows the mean change in depth-average current speed comparing the FWP to FWOP. The impact to the current speed predicted by the long-term 2D model is consistent with the short-term 3D model. The impact is focused along the proposed dredged areas and the navigation channel extending about 15 km to Port Ingleside from the proposed dredge area. There is no significant impact on currents in Corpus Christi Bay, Redfish Bay, and Nueces Bay. In average, the FWP will reduce current speeds through the proposed dredge area and increase the current speed in the Corpus Christi Channel from Port Aransas to Port Ingleside where the water depth remains unchanged.

Increases in current speed may affect navigation and modeled currents have been integrated into the vessel maneuvering simulations conducted for the project by others. Figure 4.24 shows the mean change in the depth-average current speed comparing the FWP to the FWOP. The envelope and heat map shown in the plot represents the minimum and maximum change to the current speed comparing the FWP to FWOP and their distribution. The large envelope in the outer channel (at approximate channel stationing -200+00) likely results from the eddy location change in that area where the currents from Aransas Pass meet with the Gulf longshore currents.

Figure 4.23: The change of depth-averaged speed caused by the FWP compared with the FWOP

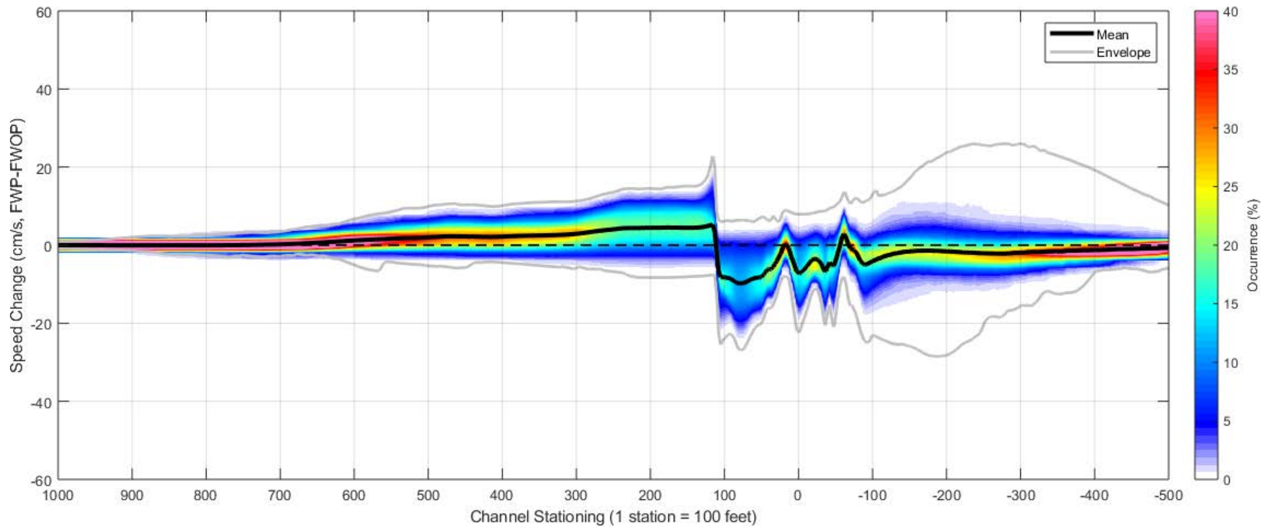


Figure 4.24: Depth-averaged current speed change caused by the FWP in comparing with the FWOP along the navigation channel. The thick black line represents the average change. The envelope enclosed by two grey lines represents the minimum and maximum changes found in the one-year model run. The heat map represents the distribution of the changes. Dash horizontal line represents no change

4.5.3 Impacts to Salinity

Like the findings from the short-term 3D model, the FWP would not cause significant salinity change on average (see Figure 4.25) but it may cause short term changes in the range of +/- 3 PSU in the proposed dredge area and the connected navigation channels (see Figure 4.26). Figure 4.27 shows the mean salinity change and the distribution of salinity changes along the navigation channel.

Figure 4.25: Average salinity change comparing FWP compared with the FWOP

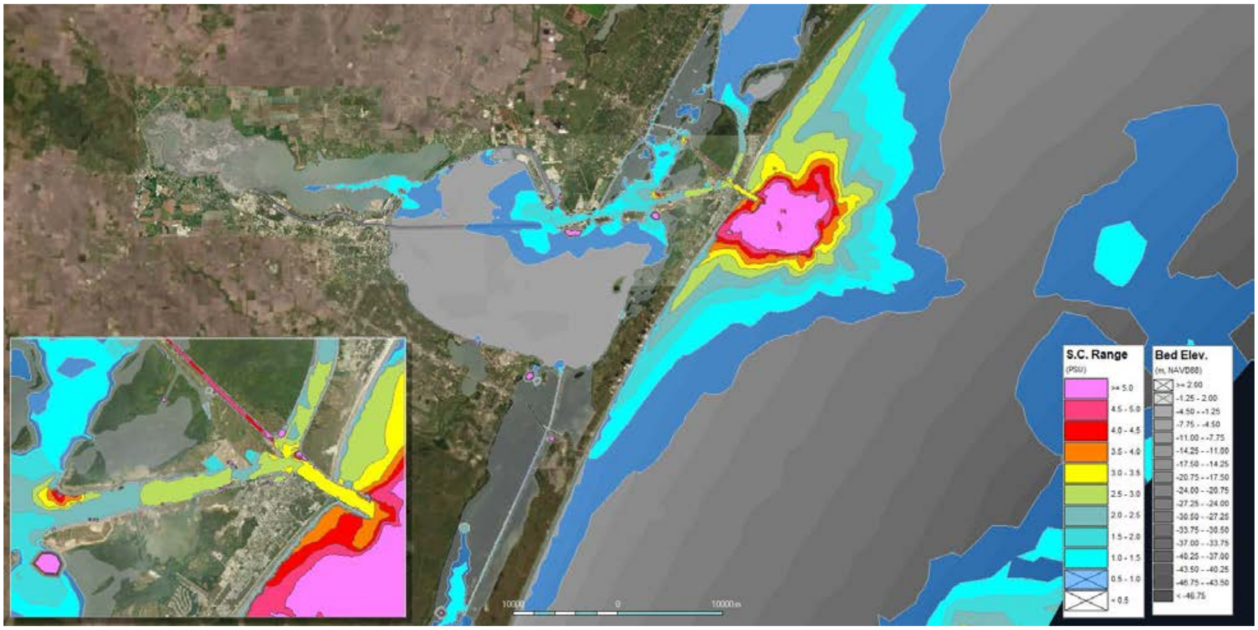


Figure 4.26: Range of salinity change (max change minus min change) comparing the FWP with the FWOP

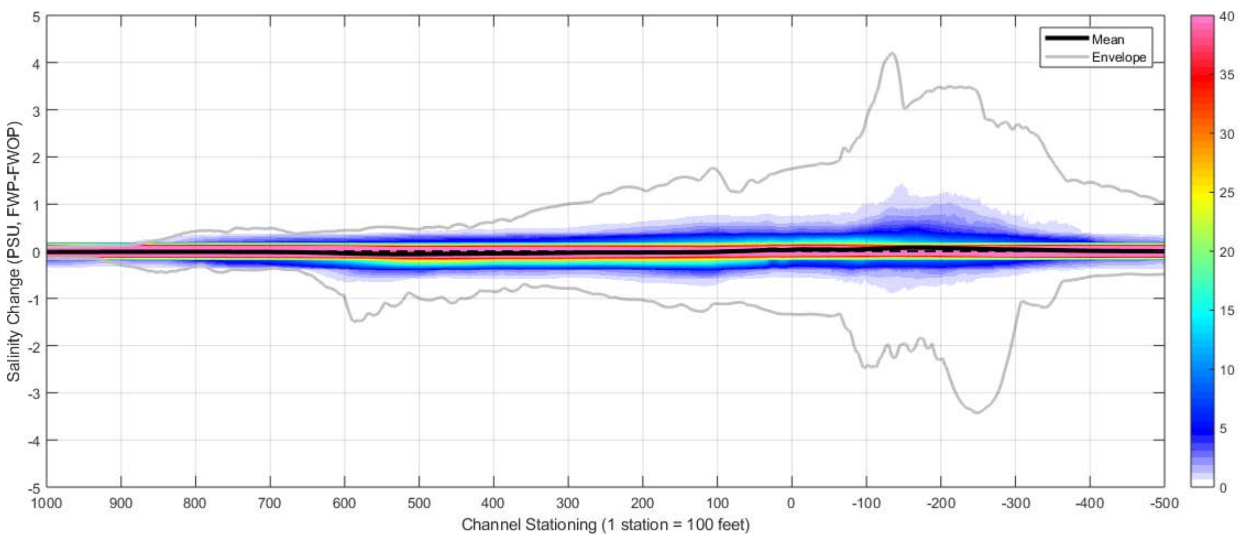


Figure 4.27: Depth-averaged salinity change caused by the FWP in comparing with the FWOP along the navigation channel. The thick black line represents the average change. The envelope enclosed by two grey lines represents the minimum and maximum changes found in the one-year model run. The heat map represents the distribution of the changes. Dash horizontal line represents no change

5. Impact Assessment for Future Without Project

The Future Without Project (FWOP) is currently in construction. The impacts caused by the FWOP were also evaluated to compare the results from the long-term 2D model with these for the existing conditions. The approaches used for impact assessment for FWP (see Section 4) were also used for this assessment.

5.1 Impacts to Water Levels

By comparing with the existing condition, the FWOP may cause a slight drop (less than 1 cm) in mean water level in the Corpus Christi Bay and its surround waters (see Figure 5.1), a small increase (less than 1 cm) on high tide (see Figure 5.2), and a slight drop on low tide (less than 2 cm) (see Figure 5.3).

Figure 5.1: Impact of FWOP on mean water levels compared with existing conditions

Figure 5.2: The average increase of high tide caused by FWOP compared with existing conditions

Figure 5.3: The average drop in low tide caused by FWOP compared with existing conditions

Through tide harmonic analysis, the impacts of the FWOP on tidal amplitudes at the two selected stations of Inner Channel (approximately Channel Stationing +100+00) and Corpus Christi Bay are shown in Figure 5.4. Similar plots for other selected stations are attached in Appendix C. Note that the slopes of the linear fitting lines (without intercept) shown in the plots indicates the degree of relative increase in tidal amplitude if the slopes are larger than one. The relative increases of tidal amplitudes calculated from the fitting lines are listed in Table 5.1. This indicates that the FWOP could cause the tidal amplitude increases about 15% in Redfish Bay, about 16% in Corpus Christi Bay, and about 13% in Nueces Bay. There is no significant increase of tide amplitude at Rockport. The tidal amplitude at Inner Channel (Channel Stationing 100+00) has the greatest increase which is about 18%.

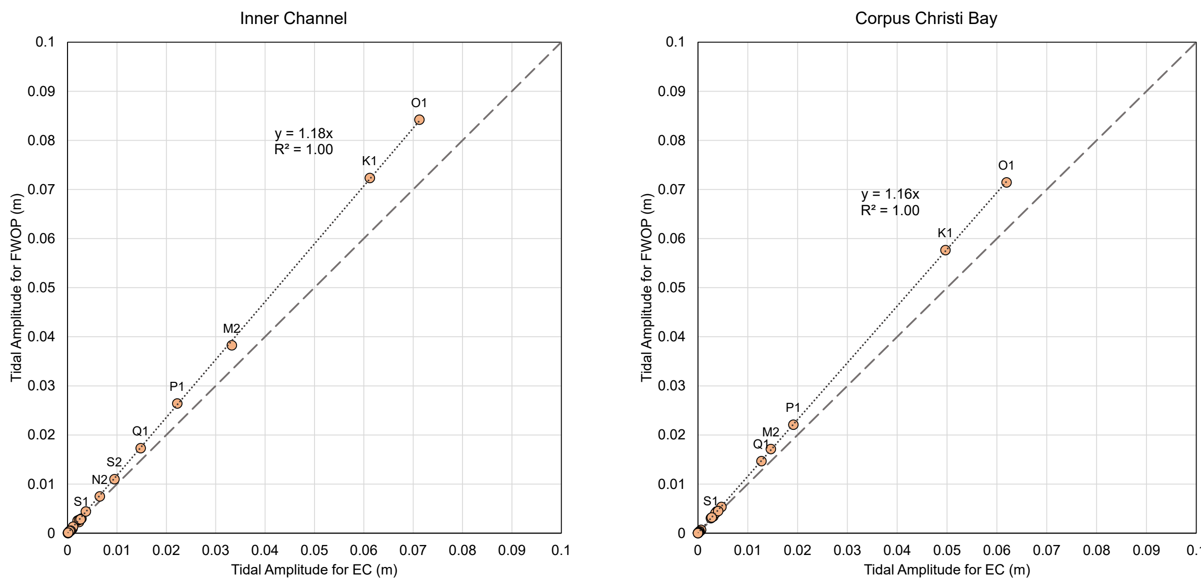


Figure 5.4: Increase of tidal amplitude caused by FWOP at Inner Channel and Corpus Christi Bay

To quantitively evaluate the impact of FWOP on tide range, the tide ranges were calculated from the hourly output of water levels produced by the one-year model runs and the statistical analysis on tide range changes were carried out. The results are shown in Figure 5.5 and listed Table 5.1. The FWOP results in approximately 3 cm increase in tide range in Corpus Christi Bay and its sounding areas but results in less impact on Rockport.

Table 5.1: Change of tide range and tidal amplitudes caused by the FWOP relating to the EC

Stations	Tide Range Change				Tidal Amplitude Increase (%)
	Mean (cm)	Minimum (cm)	Maximum (cm)	Percentage (%)	
Outer Channel	-0.1	-0.8	0.7	0%	0%
Aransas Pass	-0.4	-1.4	0.8	-1%	-1%
Inner Channel	3.4	-0.1	6.5	15%	18%
Redfish Bay	2.3	-0.4	4.4	12%	15%
Corpus Christi Bay	2.6	-0.7	4.7	14%	16%
USS Lexington	2.5	-0.7	4.7	13%	16%

Stations	Tide Range Change				Tidal Amplitude Increase (%)
	Mean (cm)	Minimum (cm)	Maximum (cm)	Percentage (%)	
Nueces Bay	1.8	-1.3	3.9	9%	13%
Packery Channel	0.8	-0.9	2.5	9%	14%
Rockport	0.0	-0.4	0.3	0%	1%

Figure 5.5: Average change of tide range caused by the FWOP in comparison of the existing condition

Figure 5.6 shows the average, the envelope, and distribution of tide range change comparing the FWOP to existing conditions along the navigation channel. It shows that most tide range increase is in the areas adjacent to the navigation channel from 100+00 to 300+00. There is slight decrease in Aransas Pass and no change in the outer channels beyond the jetties.

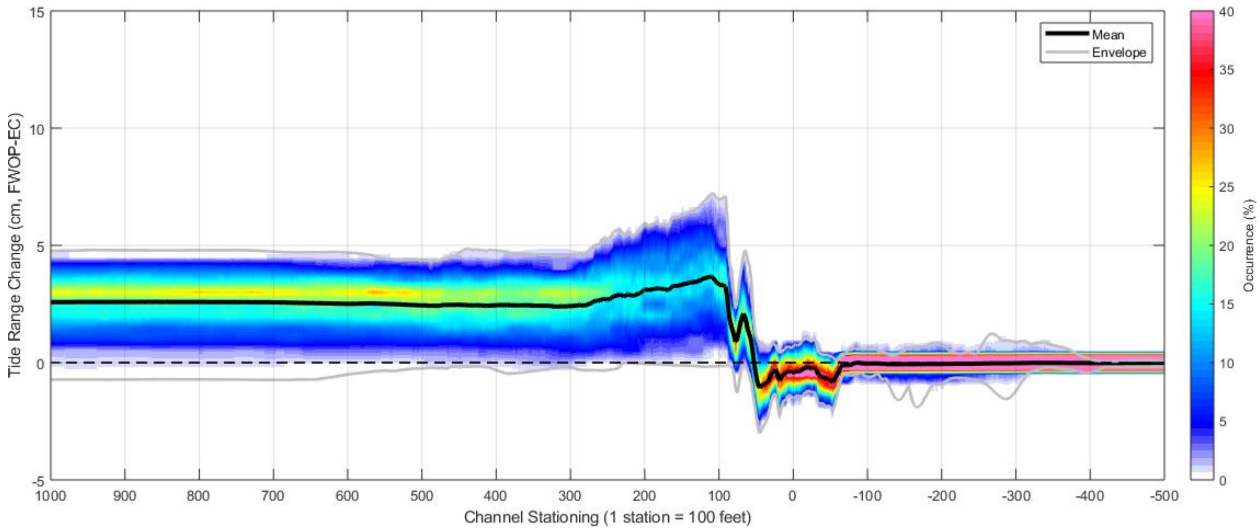


Figure 5.6: Tide range change caused by the FWOP in comparing with the existing conditions along the navigation channel. The thick black line represents the average change. The envelope enclosed by two grey lines represents the minimum and maximum changes found in the one-year model run. The heat map represents the distribution of the changes. Dash horizontal line represents no change

5.2 Impacts to Current Speed

Figure 5.7 shows the average change in depth-average current speed comparing the FWOP to the existing conditions. The current speed changes along the navigation channel are plotted in Figure 5.8. In the average, the FWOP could cause the flow velocity increases from Station +100+00 to the Corpus Christi Bay, but the speed decreases in the inner channel where there are two basins proposed. The flow velocity in Aransas Pass could slightly increase but no change is expected in the outer channel.

Figure 5.7: The change in depth-averaged speed comparing the FWOP with existing conditions

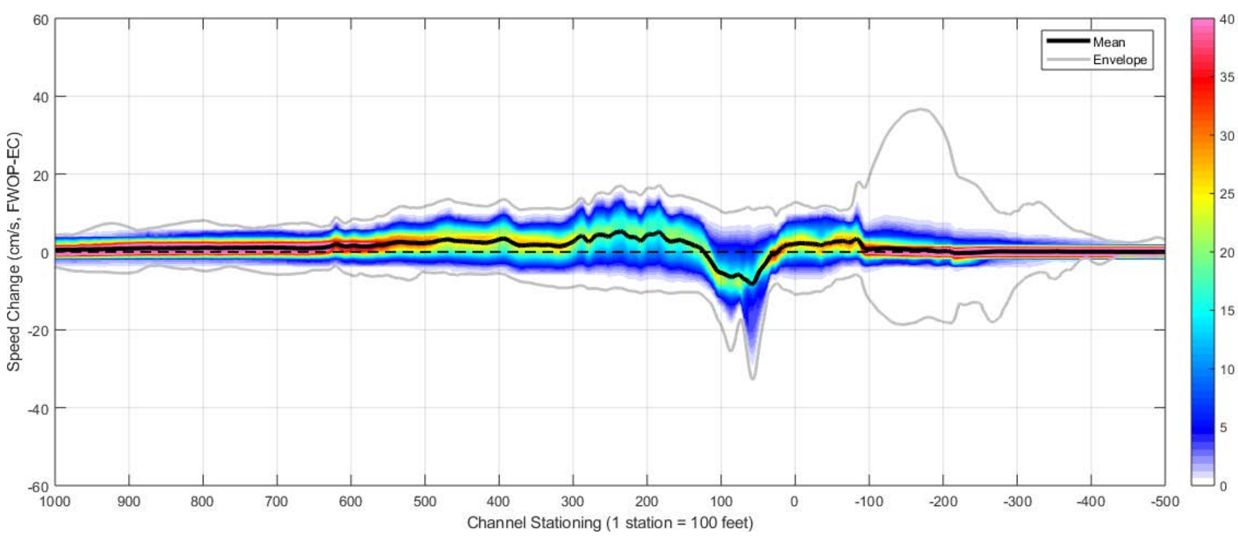


Figure 5.8: Depth-averaged current speed change caused by the FWOP in comparing with the existing conditions along the navigation channel. The thick black line represents the average change. The envelope enclosed by two grey lines represents the minimum and maximum changes found in the one-year model run. The heat map represents the distribution of the changes. Dash horizontal line represents no change

5.3 Impacts to Salinity

Figure 5.9 shows the mean of salinity change comparing the FWOP with existing conditions. It indicates that there is no significant salinity change. However, like the FWP, the FWOP could cause some short term change in salinity which is less than 3 PSU in the navigation channels and in the nearshore areas around the outer channel (see Figure 5.10). The profile of salinity change along the navigation channel are shown in Figure 5.11.

Figure 5.9: Average salinity change comparing FWOP with existing conditions

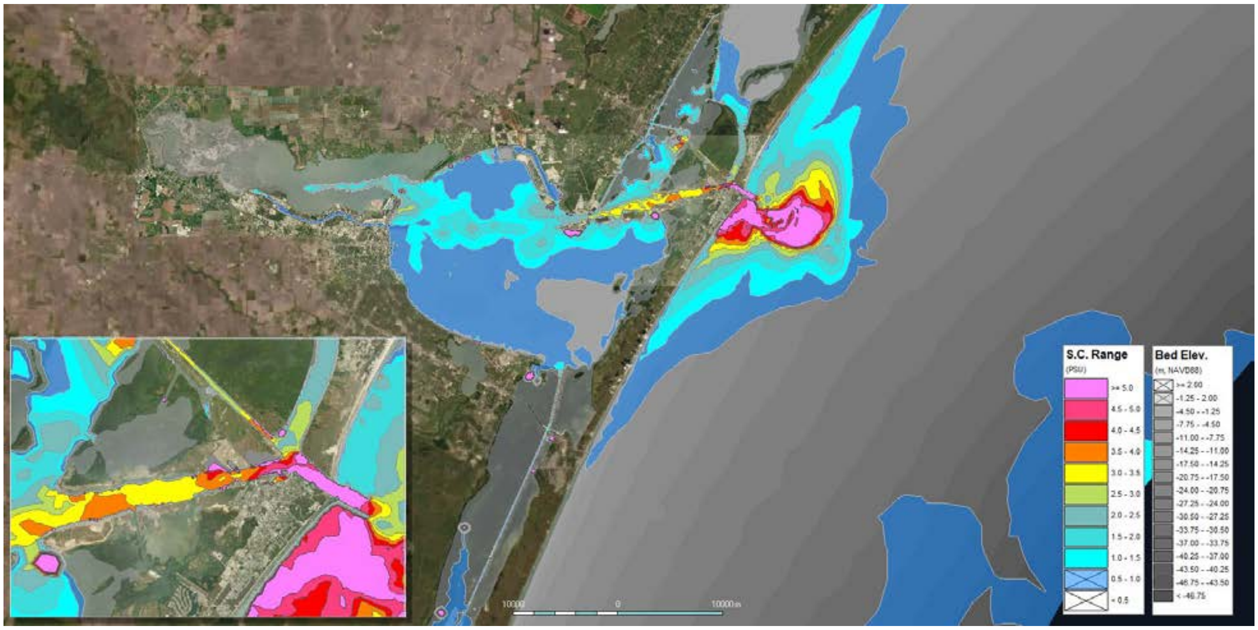


Figure 5.10: Range of salinity change (max change minus min change) comparing the FWOP with existing conditions

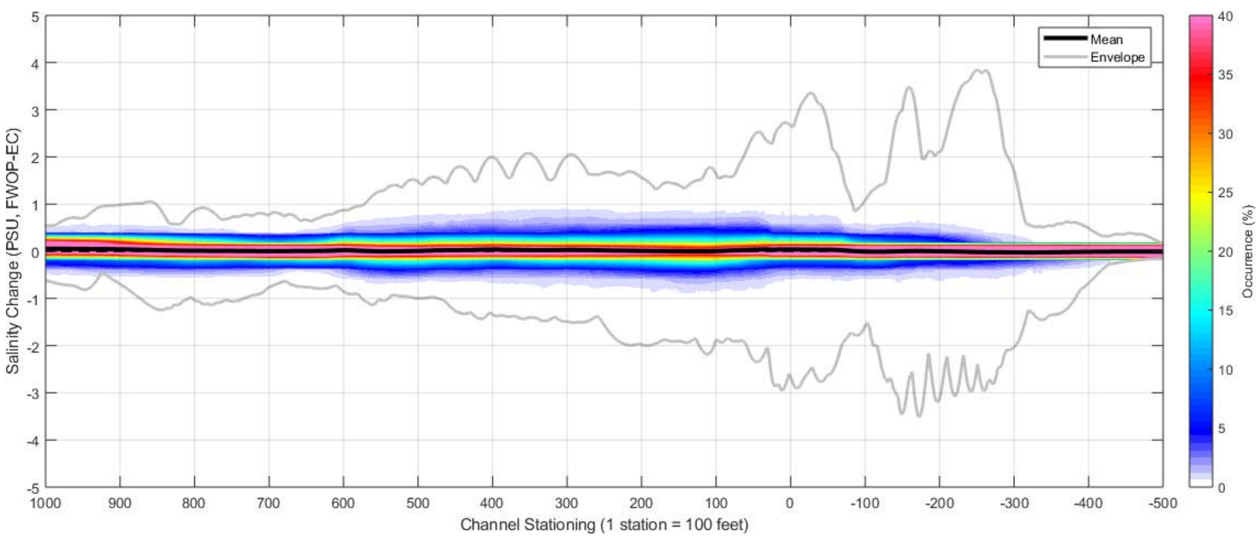


Figure 5.11: Depth-averaged salinity change caused by the FWOP in comparing with the existing conditions along the navigation channel. The thick black line represents the average change. The envelope enclosed by two grey lines represents the minimum and maximum changes found in the one-year model run. The heat map represents the distribution of the changes. Dash horizontal line represents no change

6. Cumulative Impacts for Future With Project

The impacts of FWP on tide range and current speed in the navigation channels could be accumulated from the two stages of channel deepening projects since these two projects (i.e., FWOP and FWP) have similar impacts on tide range and current speed, as described in Section 4 and Section 5. The impact can be assessed by comparing the model results for FWP with these for the existing conditions. The cumulative impacts may become significant.

Figure 6.1 shows the comparison of tide amplitudes for 26 major tide constituents predicted for the FWP and for the existing conditions at the inner channel and Corpus Christi Bay. The comparison plot of tide amplitudes for the other stations are attached in Appendix D. The tide amplitude increases about 36% at the inner channel and about 26% in Corpus Christi Bay. Table 6.1 shows the cumulative impacts of the FWP on tide range and tide amplitudes in comparing with the existing conditions at the selected stations. The cumulative impacts of the FWP to tide ranges along the navigation channels are shown Figure 6.2. The model results indicate that the cumulative impacts caused by the FWP is almost equal to the summary of the FWP impacts (*vs* FWOP) and the FWOP impacts (*vs* the existing condition). The greatest impact on tide ranges appears at the inner channel (Channel Stationing 100+00), where the tide range increases about 7 cm on average and about 14 cm in maximum. In Corpus Christi Bay and Redfish Bay, the tide range increases about 4 cm in average and 8 cm in maximum.

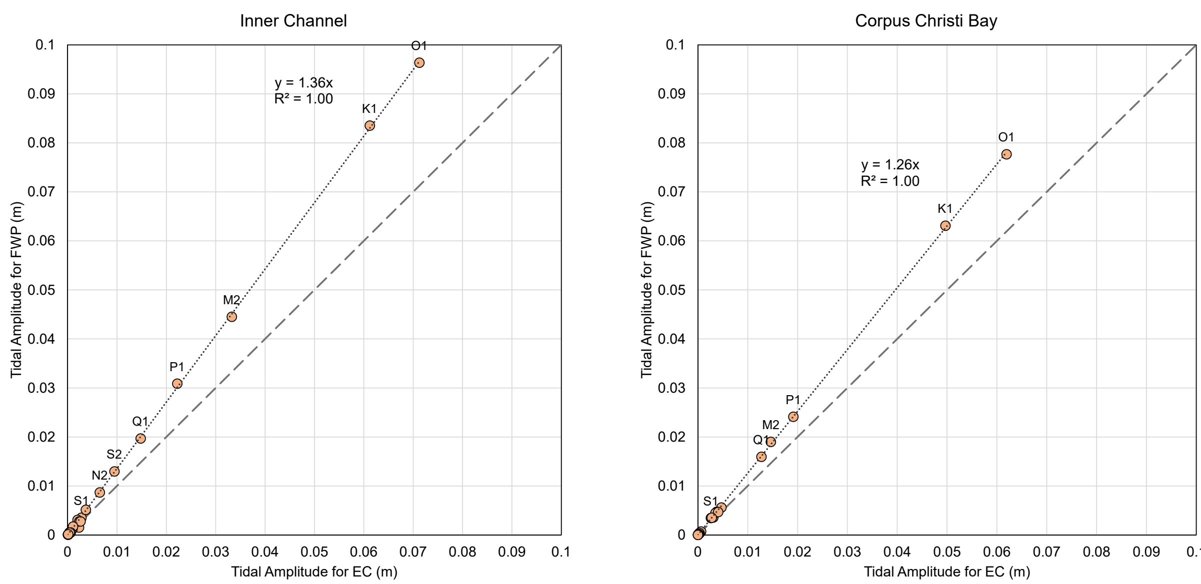


Figure 6.1: Cumulative increase of tidal amplitude caused by FWP in comparing with the existing conditions at Inner Channel and Corpus Christi Bay

Table 6.1: Cumulative impacts of FWP on tide range and tide amplitudes compared with the existing conditions

Stations	Tide Range Change				Tide Amplitude Increase (%)
	Mean (cm)	Minimum (cm)	Maximum (cm)	Percentage (%)	
Outer Channel	-0.1	-2.4	1.3	0%	0%
Aransas Pass	-0.4	-2.1	1.1	-1%	-1%
Inner Channel	6.8	0.6	14.1	29%	36%
Redfish Bay	4.1	-0.4	8.1	21%	27%
Corpus Christi Bay	4.3	-0.9	8.1	23%	26%
USS Lexington	4.3	-1.1	8.2	22%	26%
Nueces Bay	3.0	-1.8	6.6	15%	21%
Packery Channel	1.4	-1.5	4.1	15%	22%
Rockport	0.2	-0.4	0.8	2%	3%

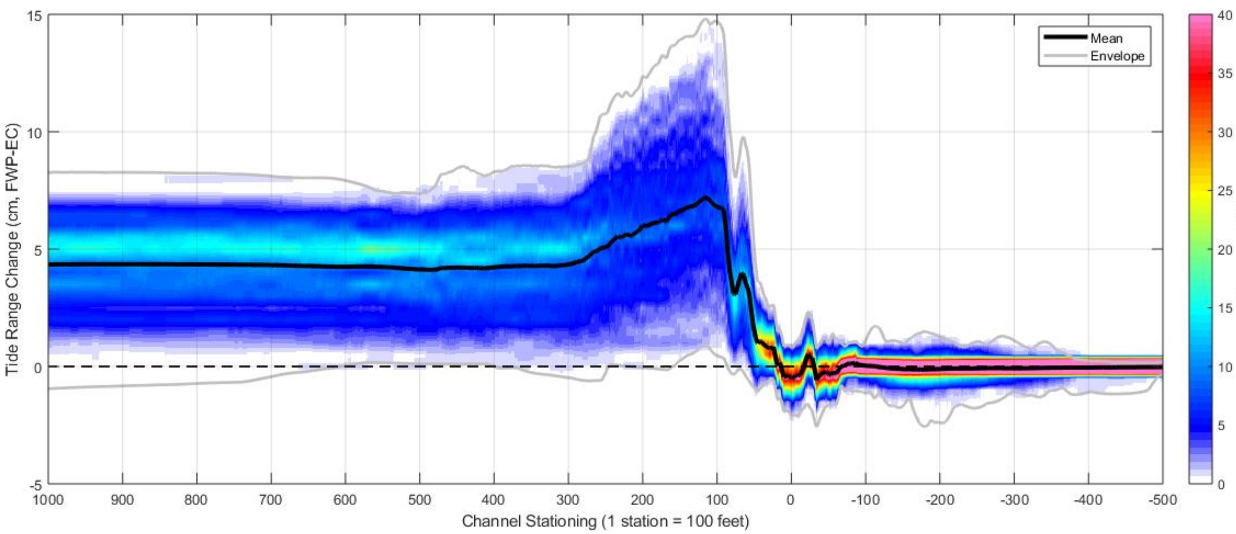


Figure 6.2: Tide range change caused by the FWP in comparing with the existing conditions along the navigation channel. The thick black line represents the average change. The envelope enclosed by two grey lines represents the minimum and maximum changes found in the one-year model run. The heat map represents the distribution of the changes. Dash horizontal line represents no change

Figure 6.3 shows the cumulative impact of the FWP on the depth-average current speed compared to existing conditions along the navigation channel. The greatest impact to the current speed appears around Channel Stationing 200+00. The depth-average current speed increases about 10 cm/s in average and about 30 cm/s in maximum. The current speed decreases about 18 cm/s in average and 50 cm/s in maximum in the proposed dredge basins in the channel segment from Channel Stationing 100+00 to 50+00. The flow speed in Aransas Pass to the gulf reduces slightly in average.

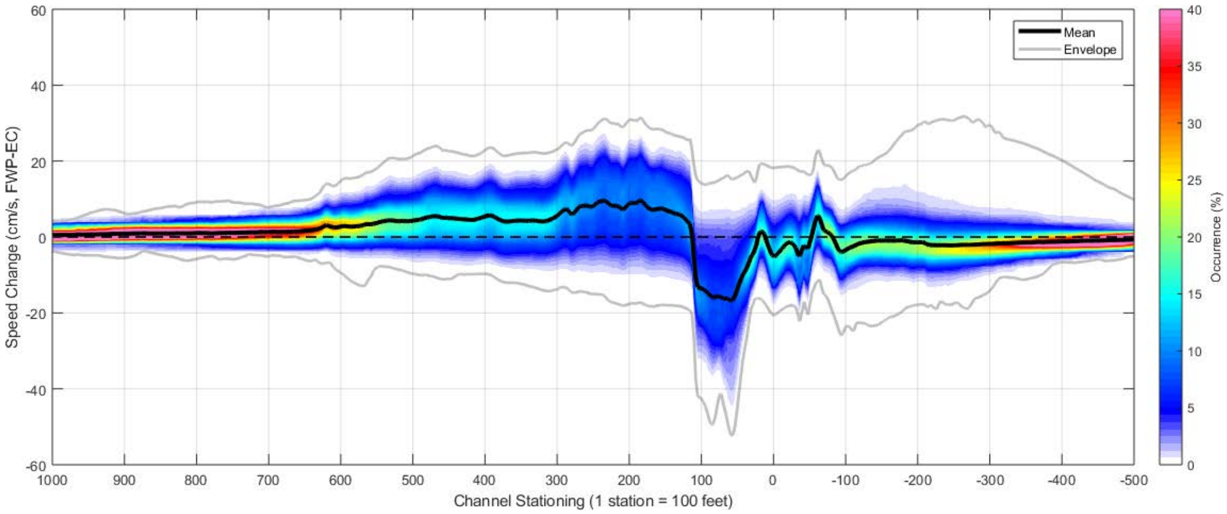


Figure 6.3: Depth-averaged current speed change caused by the FWP in comparing with the existing conditions along the navigation channel. The thick black line represents the average change. The envelope enclosed by two grey lines represents the minimum and maximum changes found in the one-year model run. The heat map represents the distribution of the changes. Dash horizontal line represents no change

Figure 6.4 shows the cumulative change of salinity caused by the FWP along the navigation channel. The average salinity change is insignificant (< 1 PSU). However, the range of salinity change, i.e., the instantaneous change of salinity over one year, is about +/- 4 PSU.

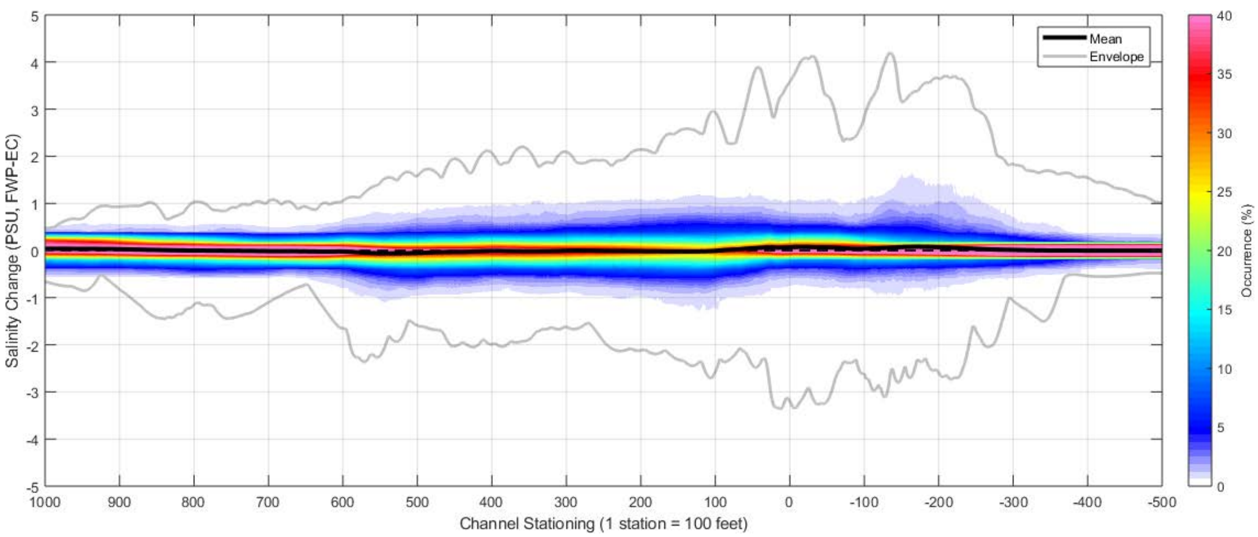


Figure 6.4: Depth-averaged salinity change caused by the FWP in comparing with the existing conditions along the navigation channel. The thick black line represents the average change. The envelope enclosed by two grey lines represents the minimum and maximum changes found in the one-year model run. The heat map represents the distribution of the changes. Dash horizontal line represents no change

7. Conclusions and Uncertainties

7.1 Conclusions

The following conclusions are made from this modeling assessment.

7.1.1 Impact on Water Levels

The impact of the Future With Project (FWP) scenario on water levels was assessed by comparing the model predicted water levels with the Future Without Project (FWOP) scenario. The findings are summarized below:

- The FWP is unlikely to cause changes to the mean water level in the subtropical secondary bays, which are connected to Aransas Pass, including Corpus Christi Bay, Nueces Bay, Redfish Bay, Packery Channel, and Aransas Bay. There is a slight reduction of less than one centimeter (cm), in mean water level in these bays;
- The FWP may increase tidal range in the subtropical secondary bays, depending on the distance from Aransas Pass. The model predicts increases in tidal range up to 2 cm in Corpus Christi Bay and Redfish Bay. The increase of tidal range decreases with the distance from Aransas Pass. The greatest impact on tidal range is limited in the Corpus Christi Navigation channel from Point Mustang to Humble Basin. The model predicts that the tidal range in this area increases about by 4 cm ranging from 0.3 cm to 9 cm;
- In the FWP, the tidal amplitudes of the selected tide constituents increase in the subtropical bays. The relative increases of tidal amplitudes are about 11% in Redfish Bay, 8% in Corpus Christi Bay, 7% in Nueces Bay, and less than 5% in Packery Channel and Aransas Bay. The greatest increase of tidal amplitudes (about 17%) is in the Corpus Christi Channel near Humble Basin;
- The FWP may cause a slight rise in high tide, which is less than 1 cm on average and at most 2 cm in the bays of interest. The rate of increase in high tide decreases with distance from Aransas Pass;
- The FWP may also cause a slight drop of low tide, which is less than 1 cm on average and 4 cm at maximum in the bays of interest connected to Aransas Pass. The amount of lowering of tides decreases with the distance from Aransas Pass;
- Overall, the impact of FWP on water level is insignificant. It is unlikely to increase the flood risk associated with changes in high tide or navigation risk associated with the changes in low tide and mean sea level in the Corpus Christi Bay. The impact on water level should be limited to the segment of the navigation channel from Point Mustang to Humble Basin.

7.1.2 Impact on Current Speeds

The impact of FWP on current speed was assessed by comparing current speeds in both FWP and FWOP scenarios in 3D space and the discharges at the selected cross-sections around the inner basin. The findings are summarized below:

- The impact of FWP on current speed in Corpus Christi Bay, Nueces Bay, Redfish Bay, Aransas Bay is insignificant. The change in current speed caused by the FWP is less than 1 cm/s;
- The FWP causes a reduction of the current speeds in the proposed dredge areas from Humble Basin to the outer channel in the GOM. The current speed in Aransas Pass reduces about 14% overall, ranging from -19 cm/s (reduction) to 9 cm/s (increase) with an average of -7 cm/s. This is a result of the deepened navigation channel, which increases the cross-sectional area in Aransas Pass by about 20%. The reduction of current speed may result in significant morphological change in the pass which is assessed in the other tasks;

- The FWP causes an increase in current speed in the navigation channels that connect to the Aransas Pass but will not be dredged in the FWP. The current speed in the Corpus Christi Navigation Channel near Humble Basin increases by 8%, which is about 3 cm/s on average and ranging from -6 cm/s to 11 cm/s. This likely results from the increase in discharge (about 8% increase) through the channel while the cross-section area remains unchanged. The increase in current speed reduces gradually from Humble Basin to Point Mustang.

7.1.3 Impact on Salinity

The impact of the FWP on salinity was assessed by comparing model predicted salinity in both FWP and FWOP scenarios in 3D space. The findings are summarized below:

- The FWP would not cause the significant change of salinity in the subtropical secondary bays. The average change of salinity caused by the FWP is less than 1 PSU;
- The FWP may result in a small disturbance change in salinity (about ±3 PSU) in the vicinity of the proposed dredged area;
- When the river flow in the Nueces River is large, the FWP may cause some small disturbance change in salinity (about ±3 PSU) at the outlet of Nueces Bay.

7.2 Uncertainties

The following uncertainties were found through this modeling analysis which are summarized below:

- A significant data gap for the model development is the bathymetry in Nueces Bay. There is limited bathymetric data for Nueces Bay. The bathymetry in Nueces Bay is important to calculate tide exchange between Nueces Bay and Corpus Christi Bay. This data gap was addressed by developing a model through constructing representative bathymetry of Nueces Bay based on available information to achieve good model calibration and validation;
- There is limited information on the amount of salt stored in Nueces Delta. The stored salt is a salt source for salinity in Nueces Bay. During a large rainfall event, these salts are dissolved by the rain and carried by the runoff to the bay. During a large river flow events that causes significant flooding in the delta, the flooding also dissolves the salt and results in a high salinity level in Nueces Bay. The model was developed to overcome this uncertainty by constructing the boundary conditions for salinity from Nueces River and Delta runoff based on the measured salinity data at SALT05 and NUDE3 stations (both are on the delta) to achieve a better salinity calibration in Nueces Bay;
- There is a large temporal data gap in the measured salinity data in Aransas Bay. The salinity at the open boundary of Aransas Bay has been identified to be a salinity source to Corpus Christi Bay. The model was developed to address this uncertainty by filling the data gaps using measured data on further northeast stations along the ICW (e.g., CHKN in San Antonio Bay);
- By comparing with measured data at TABS-D in the GOM, the HYCOM model significantly underpredicted the longshore current speed in the GOM. Since HYCOM model result was used for offshore boundary conditions in this model, the uncertainty may impact the model prediction of current speed at the outer channel.

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Appendix A

Calibration Figures

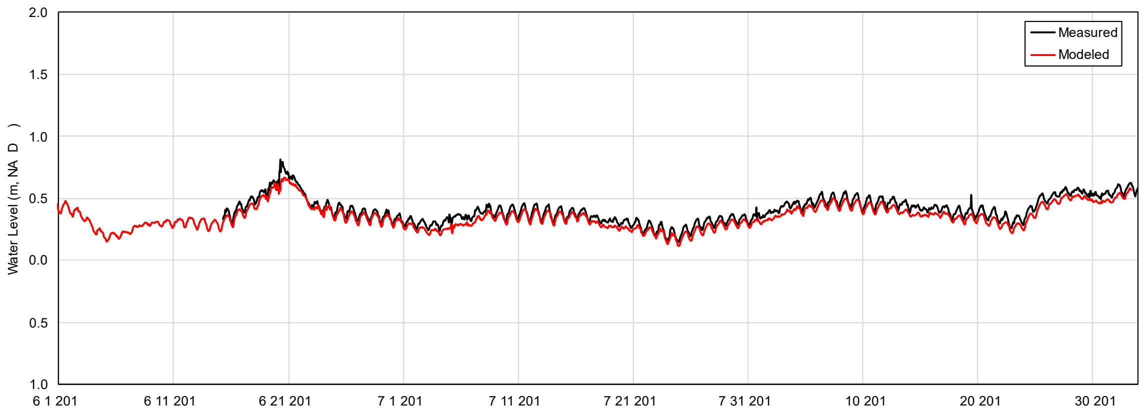


Figure A.1: Comparison of the model predicted water level (red) to the measured water level (black) at Rockport during Period 1

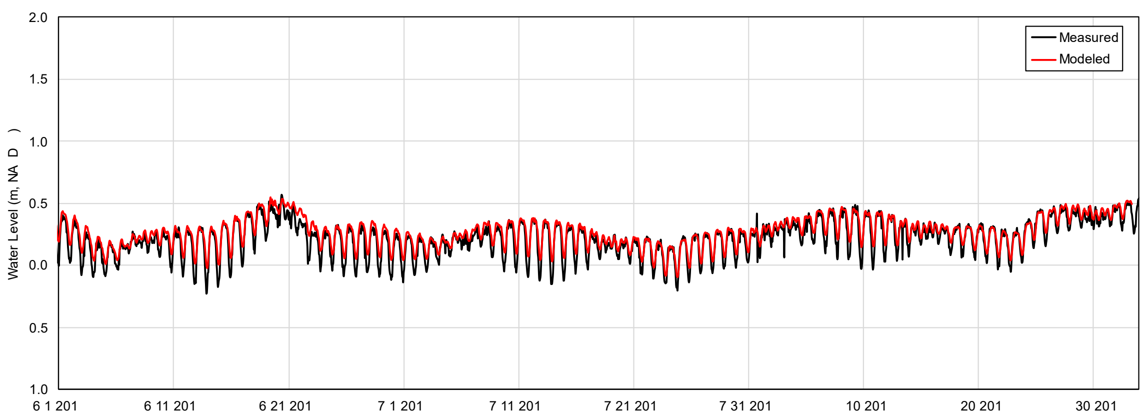


Figure A.2: Comparison of the model predicted water level (red) to the measured water level (black) at Port Aransas during Period 1

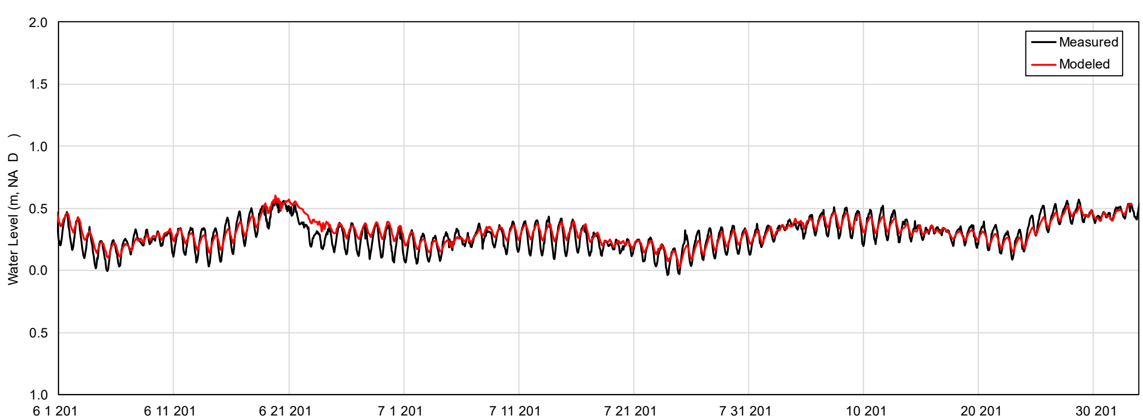


Figure A.3: Comparison of the model predicted water level (red) to the measured water level (black) at USS Lexington during Period 1

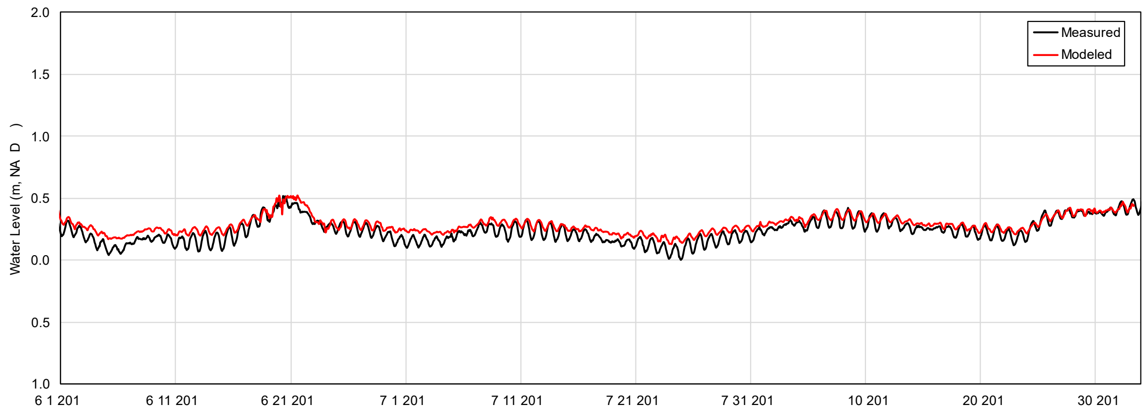


Figure A.4: Comparison of the model predicted water level (red) to the measured water level (black) at Packery Channel during Period 1

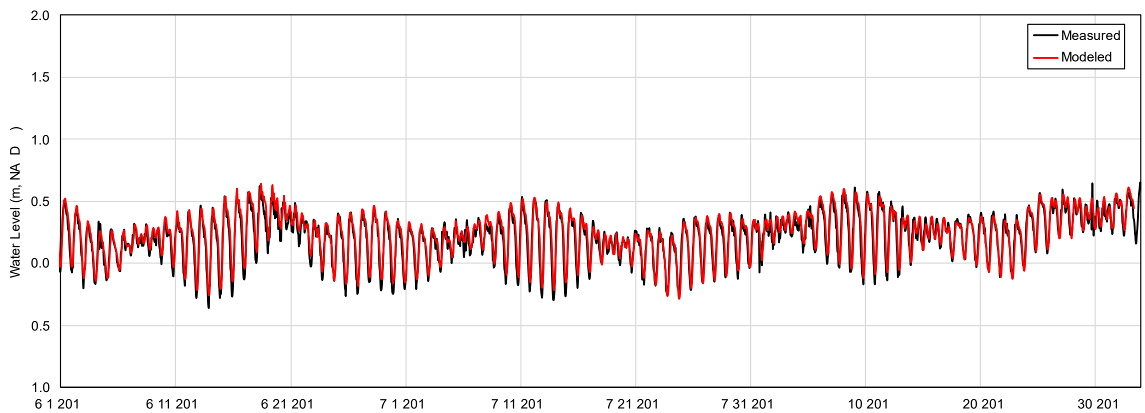


Figure A.5: Comparison of the model predicted water level (red) to the measured water level (black) at Bob Hall Pier during Period 1

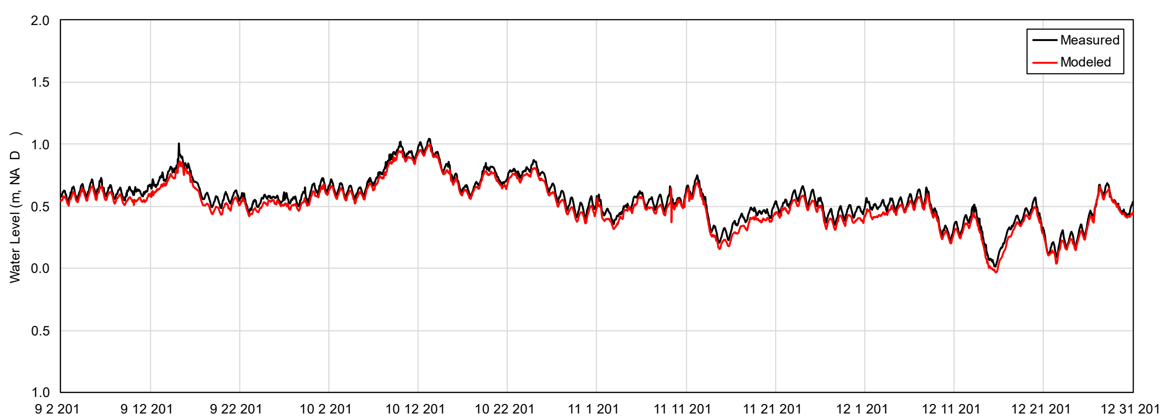


Figure A.6: Comparison of the model predicted water level (red) to the measured water level (black) at Rockport during Period 2

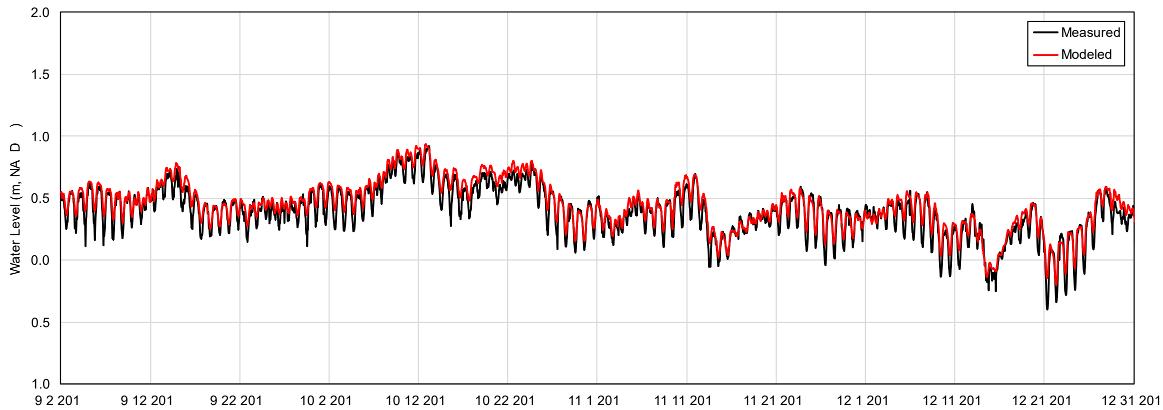


Figure A.7: Comparison of the model predicted water level (red) to the measured water level (black) at Port Aransas during Period 2

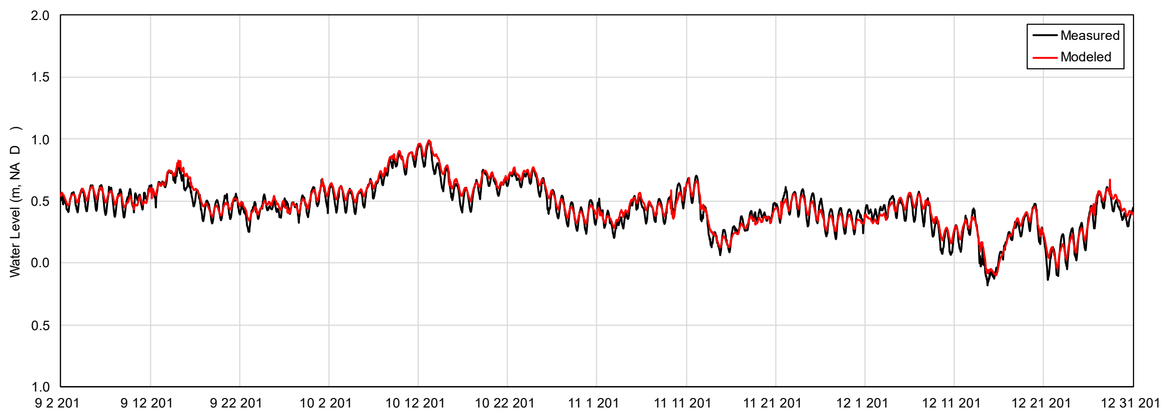


Figure A.8: Comparison of the model predicted water level (red) to the measured water level (black) at USS Lexington during Period 2

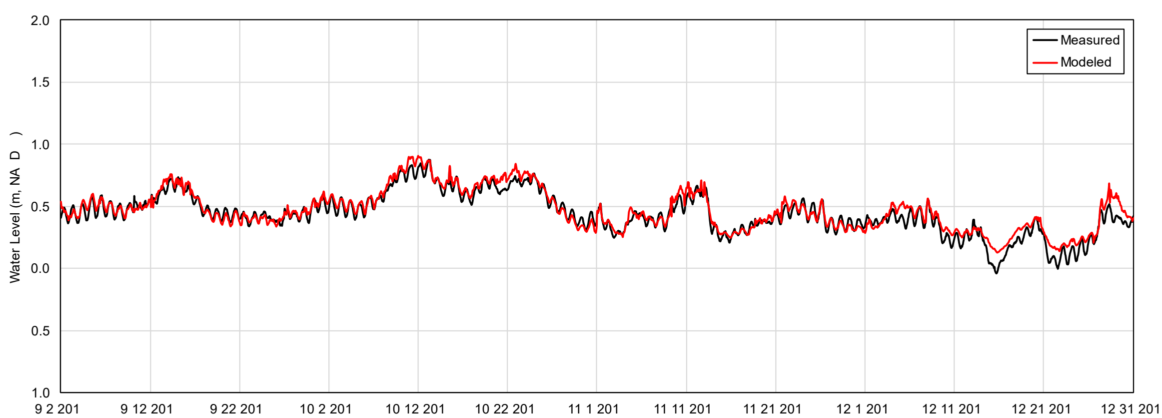


Figure A.9: Comparison of the model predicted water level (red) to the measured water level (black) at Packery Channel during Period 2

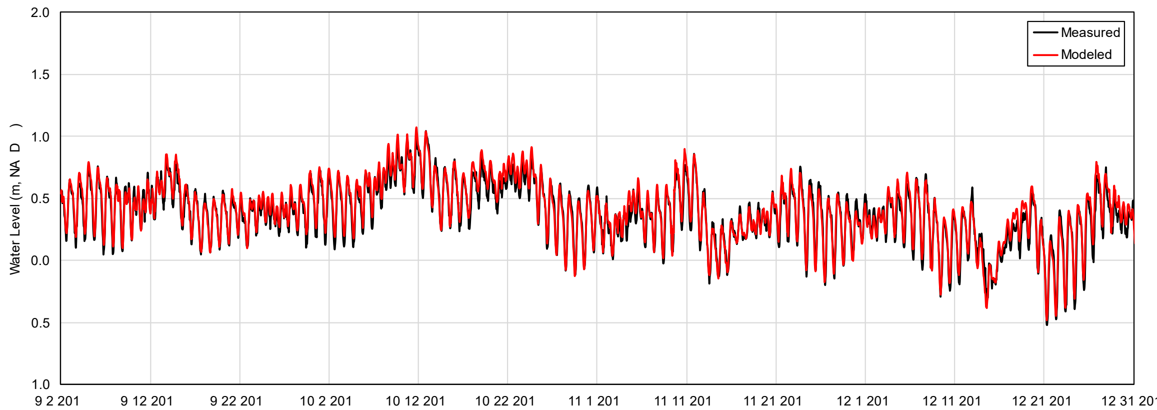


Figure A.10: Comparison of the model predicted water level (red) to the measured water level (black) at Bob Hall Pier during Period 2

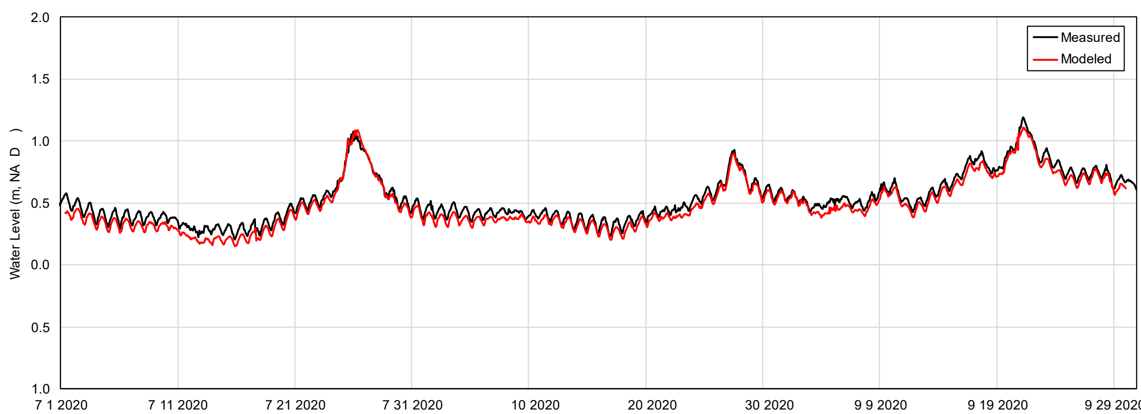


Figure A.11: Comparison of the model predicted water level (red) to the measured water level (black) at Rockport during Period 3

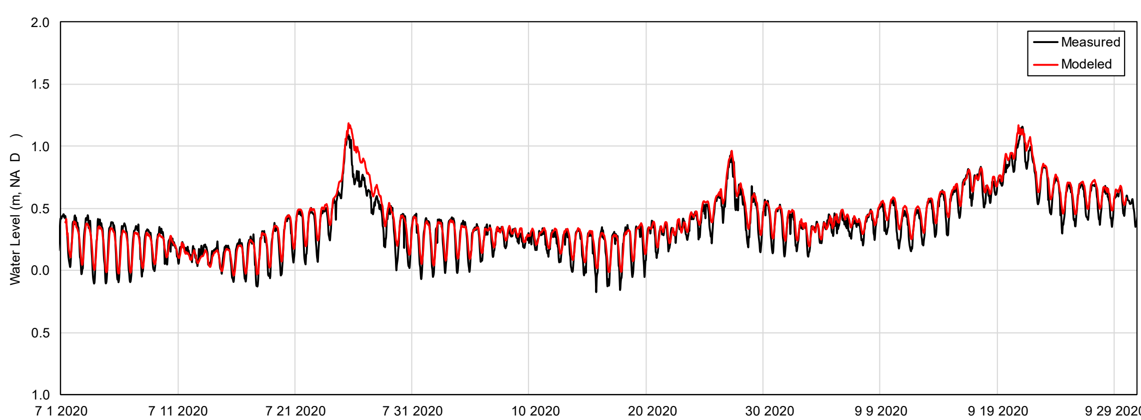


Figure A.12: Comparison of the model predicted water level (red) to the measured water level (black) at Port Aransas during Period 3

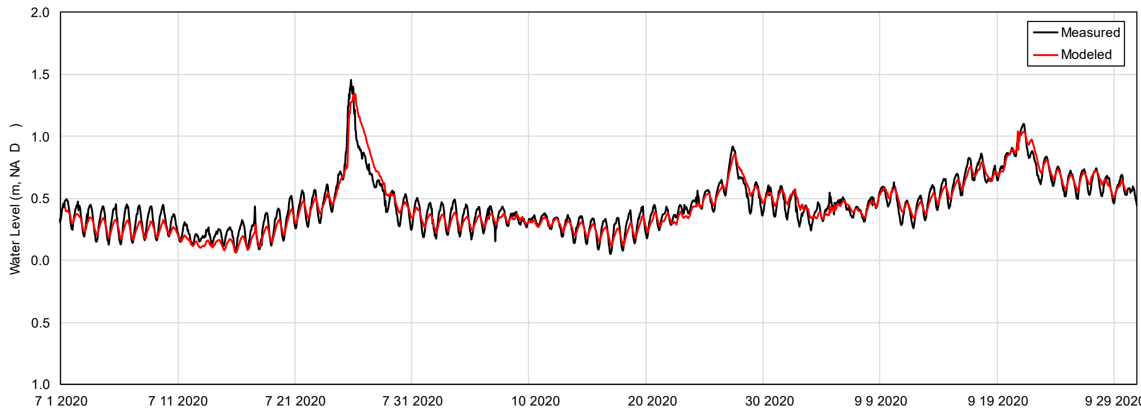


Figure A.13: Comparison of the model predicted water level (red) to the measured water level (black) at USS Lexington during Period 3

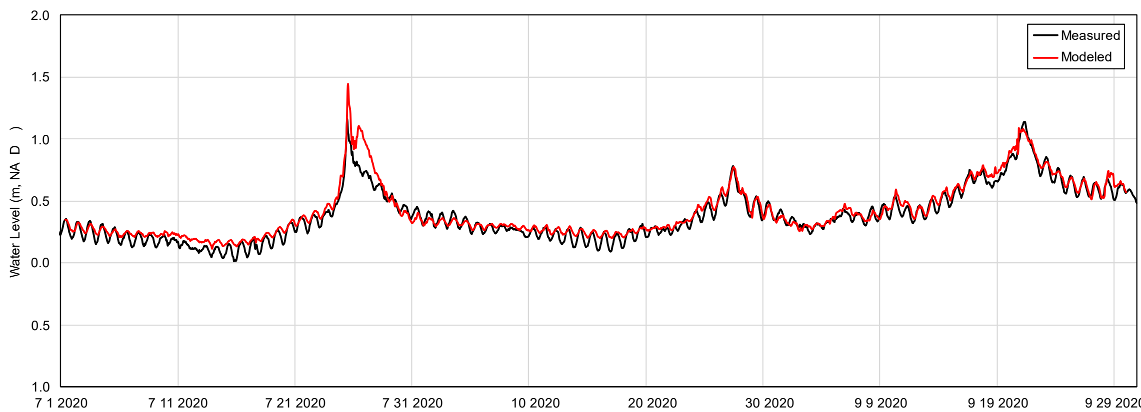


Figure A.14: Comparison of the model predicted water level (red) to the measured water level (black) at Packery Channel during Period 3

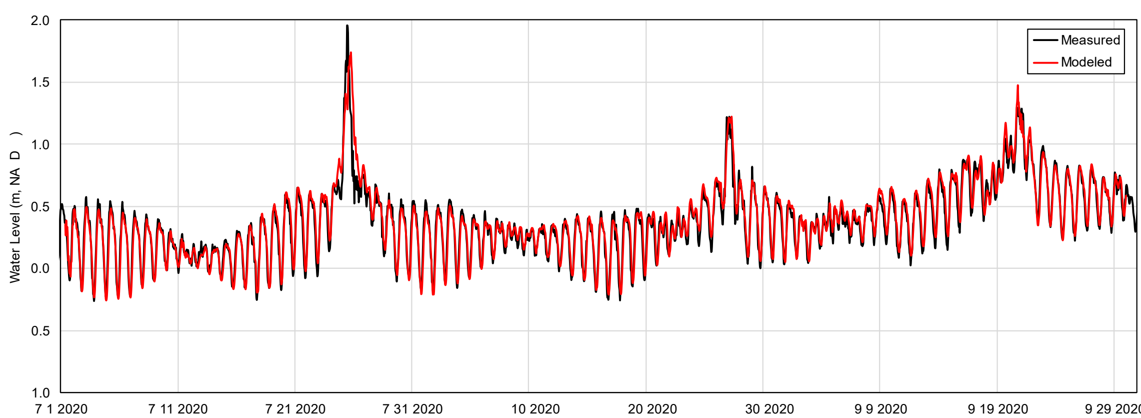
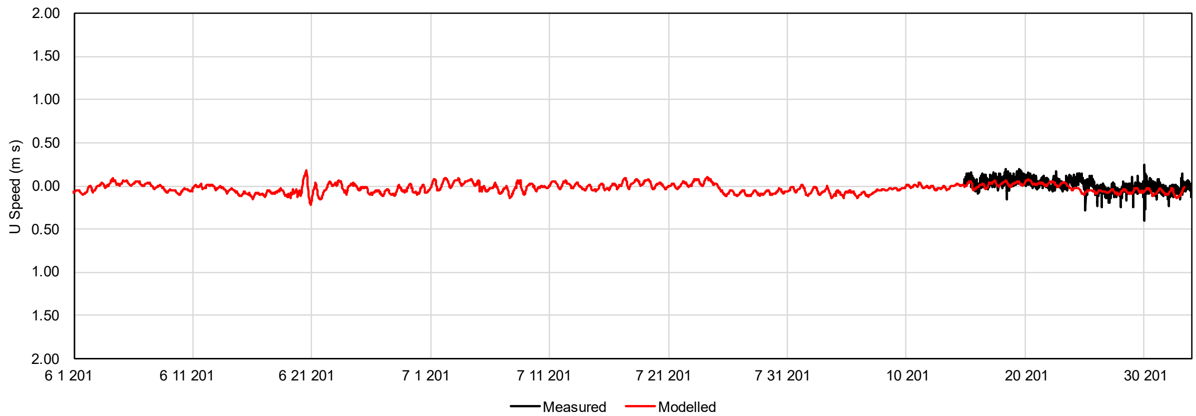


Figure A.15: Comparison of the model predicted water level (red) to the measured water level (black) at Bob Hall Pier during Period 3



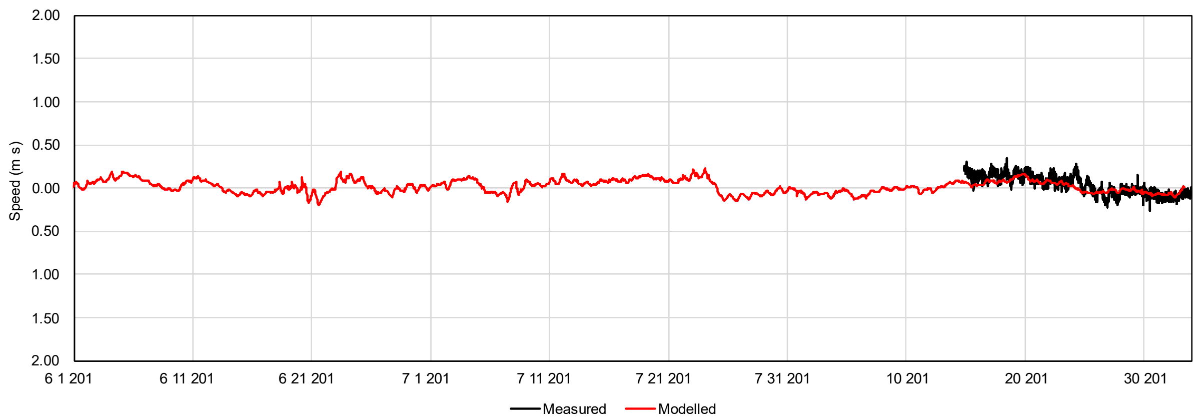
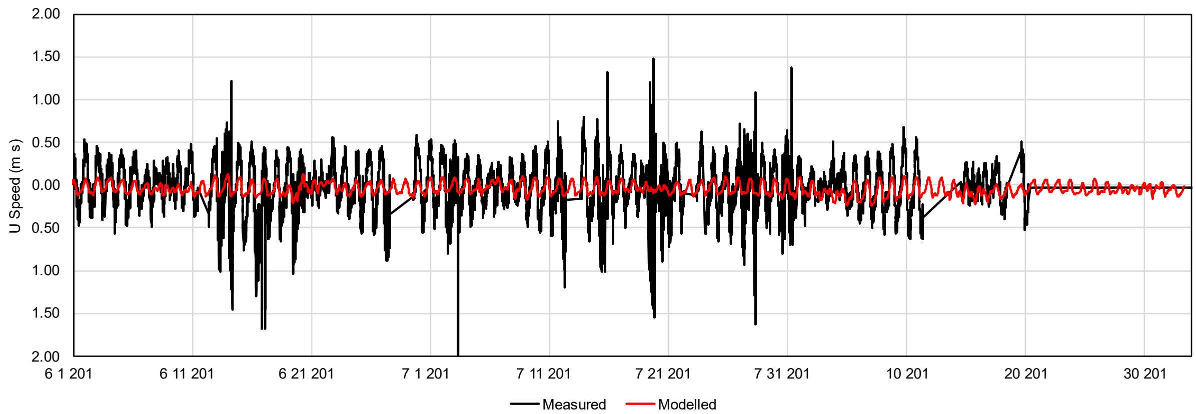


Figure A.16: Comparison of model predicted flow velocity components, U (east) and V (north), with the measured data at CC0101 during Period 1



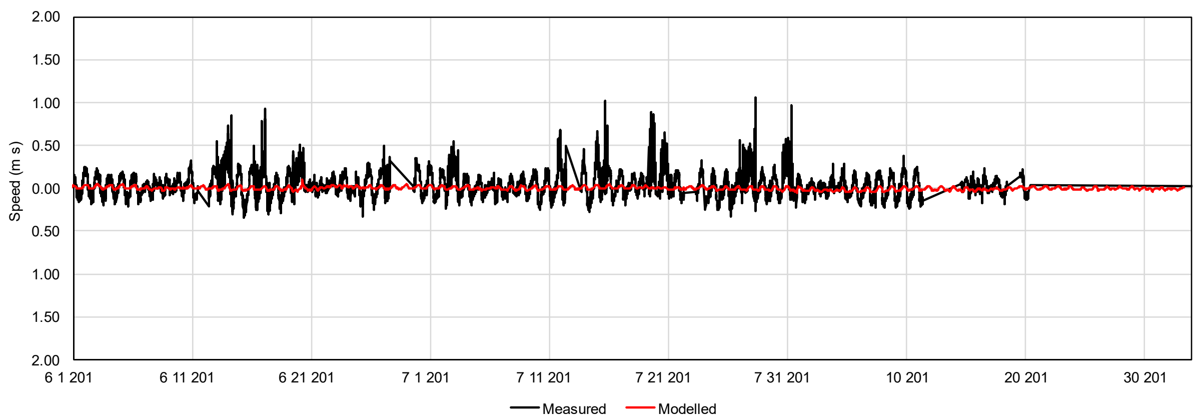
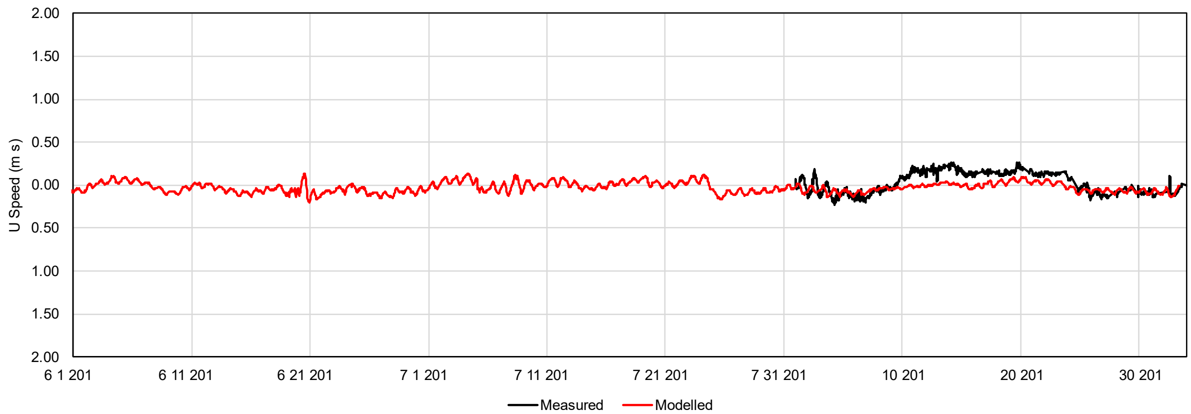


Figure A.17: Comparison of model predicted flow velocity components, U (east) and V (north), with the measured data at CC0401 during Period 1



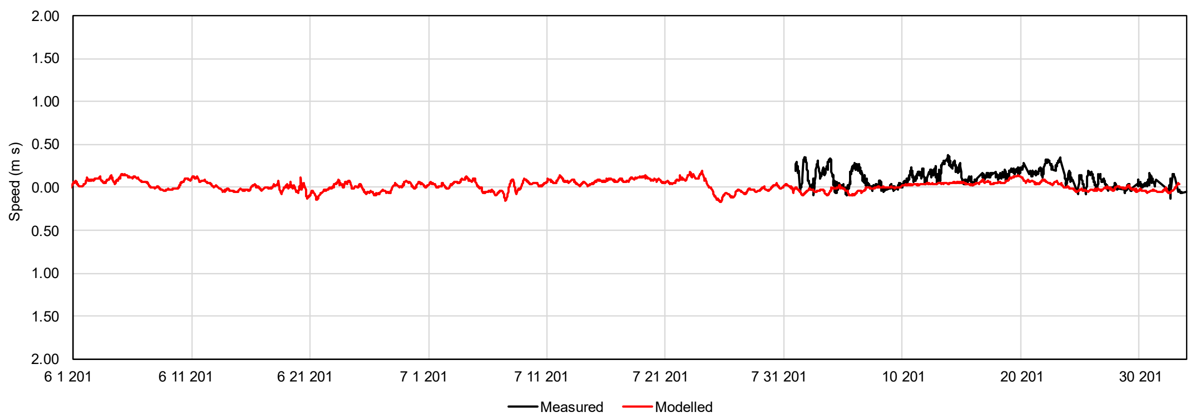
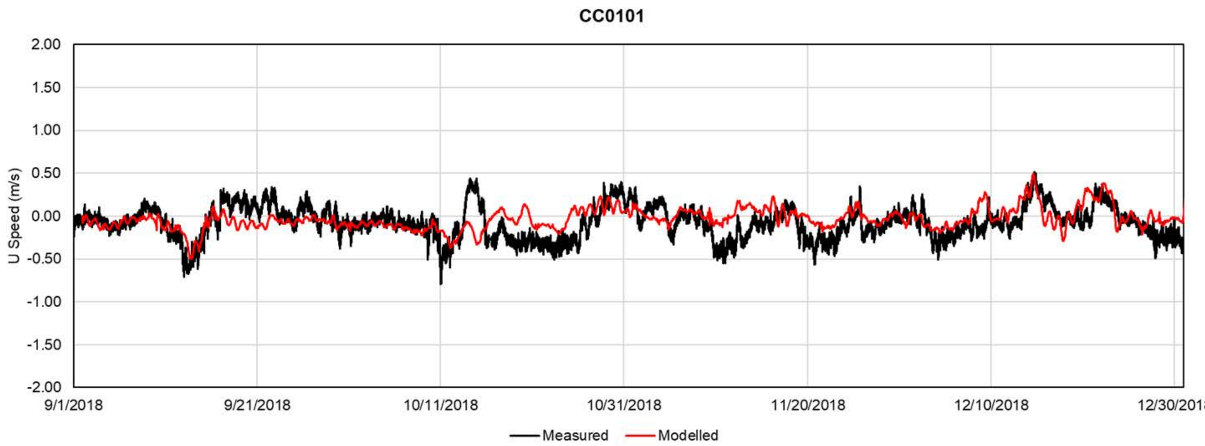


Figure A.18: Comparison of model predicted flow velocity components, U (east) and V (north), with the measured data at TABS-D during Period 1



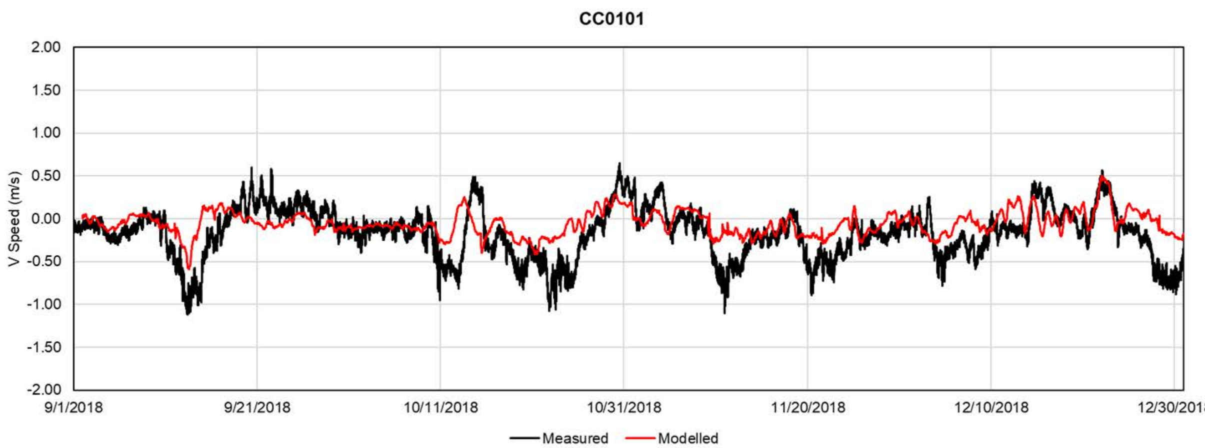
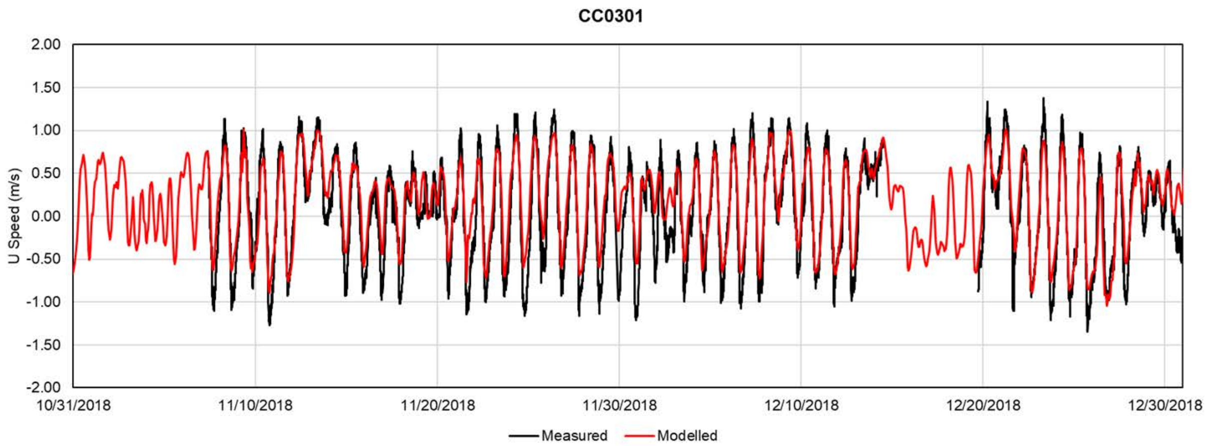


Figure A.19: Comparison of model predicted flow velocity components, U (east) and V (north), with the measured data at CC0101 during Period 2



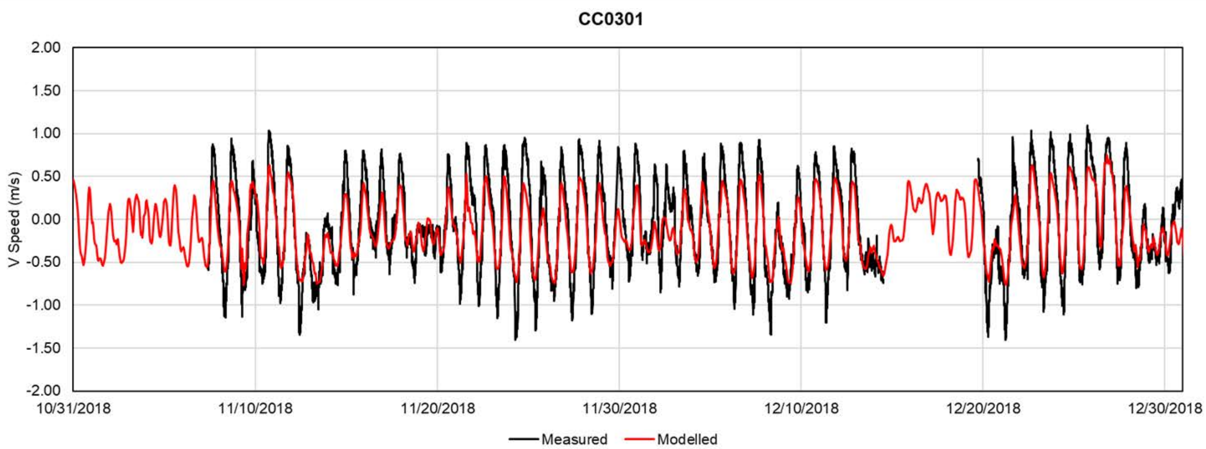
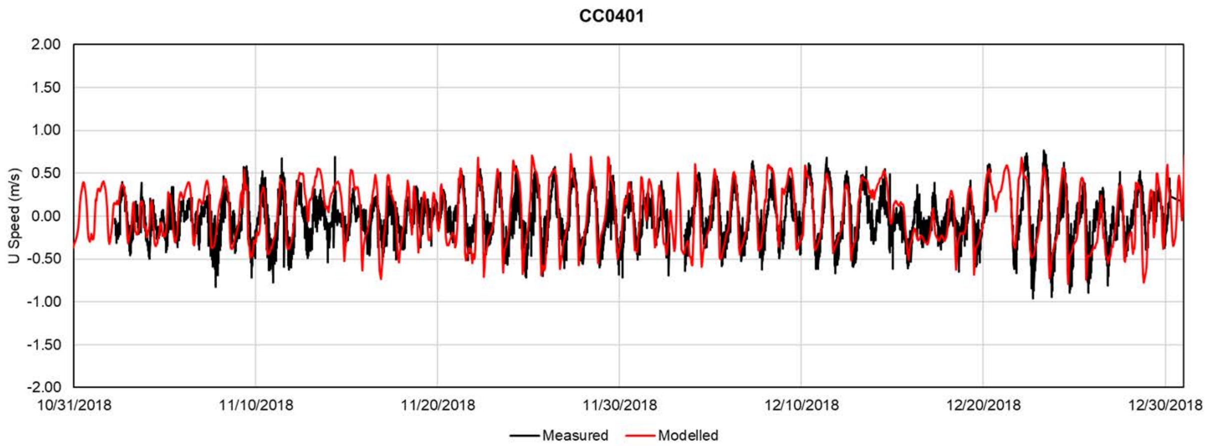


Figure A.20: Comparison of model predicted flow velocity components, U (east) and V (north), with the measured data at CC0301 during Period 2



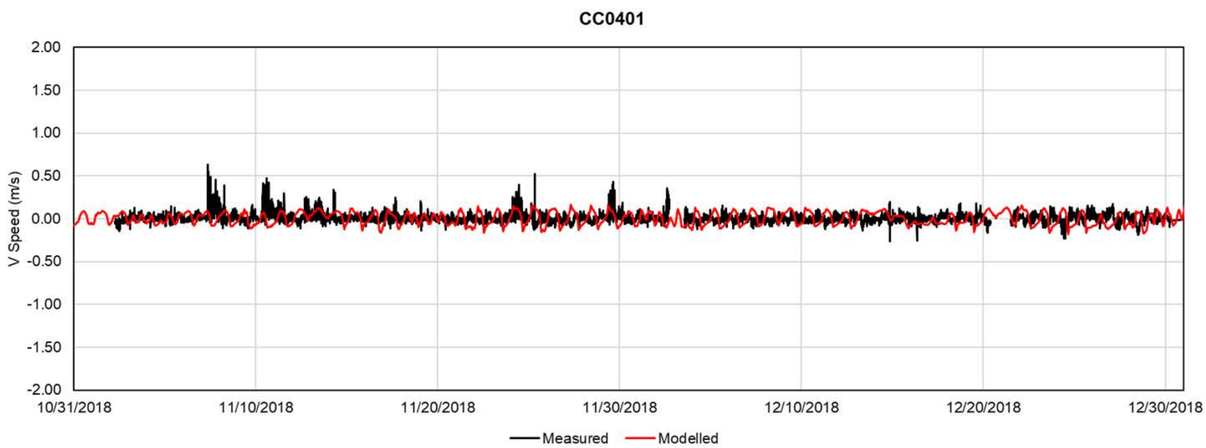
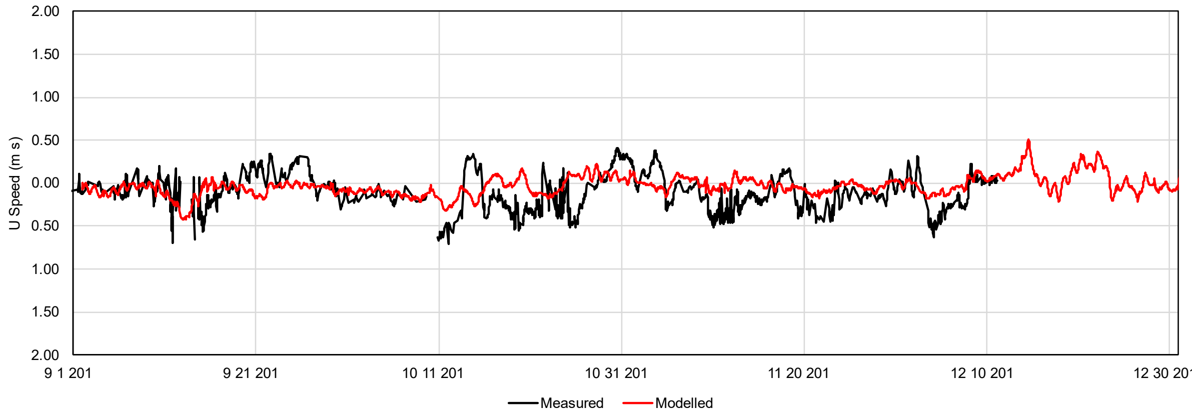


Figure A.21: Comparison of model predicted flow velocity components, U (east) and V (north), with the measured data at CC0401 during Period 2



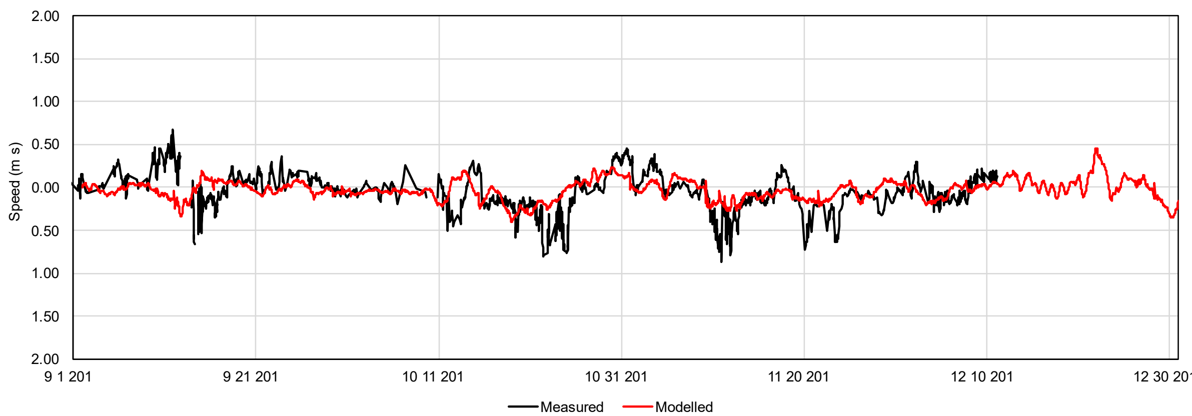
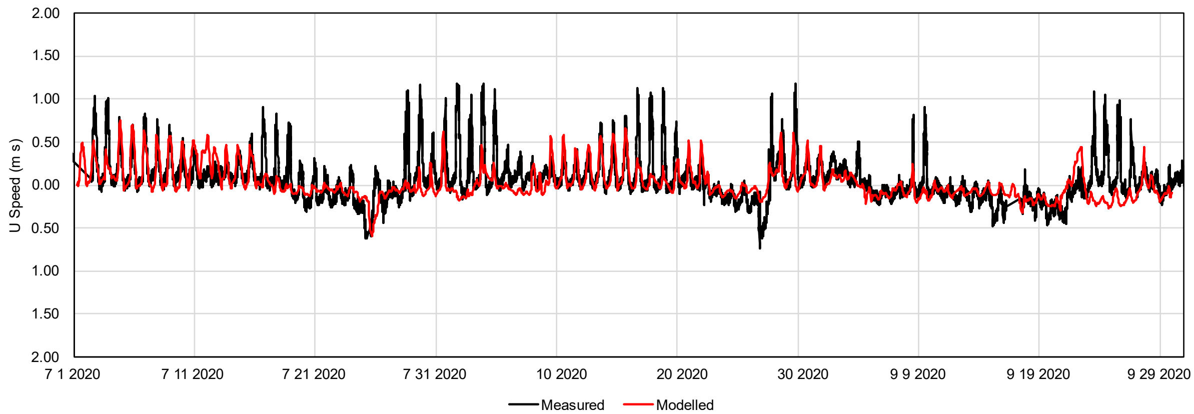


Figure A.22: Comparison of model predicted flow velocity components, U (east) and V (north), with the measured data at TABS-D during Period 2



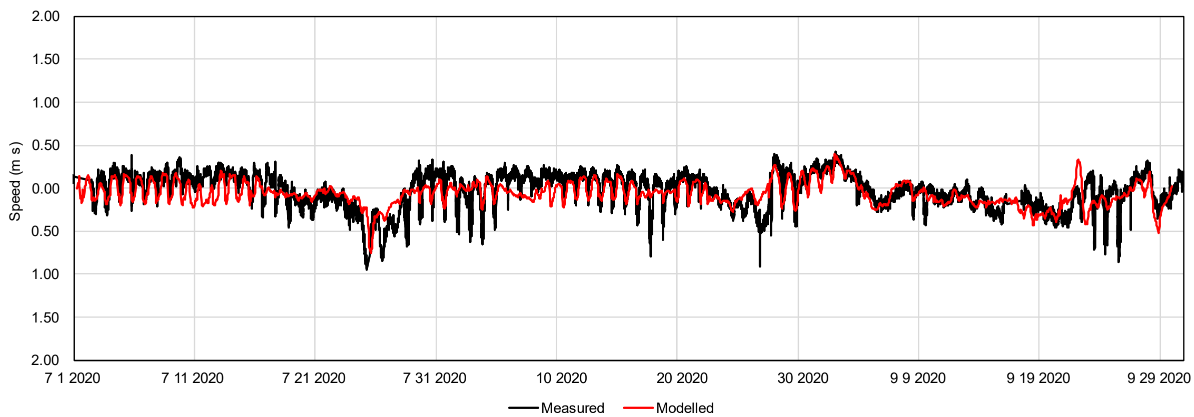
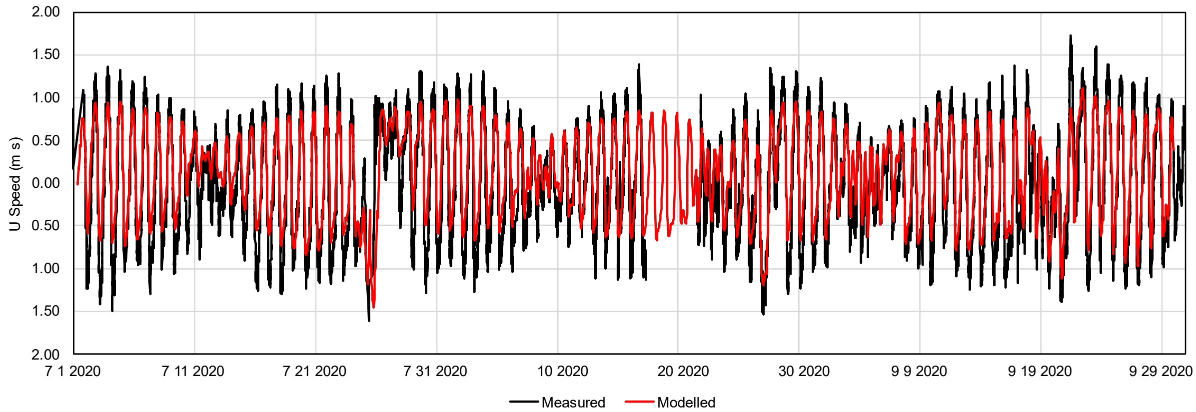


Figure A.23: Comparison of model predicted flow velocity components, U (east) and V (north), with the measured data at CC0201 during Period 3



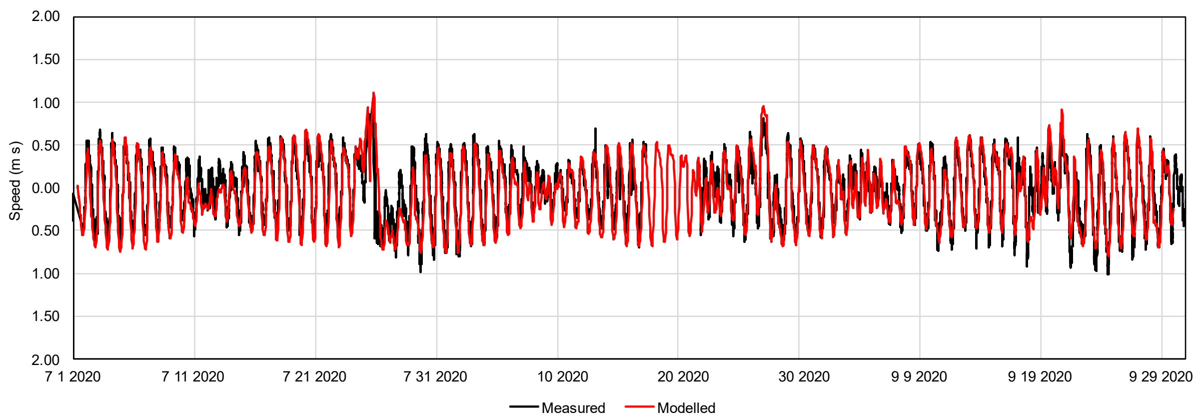
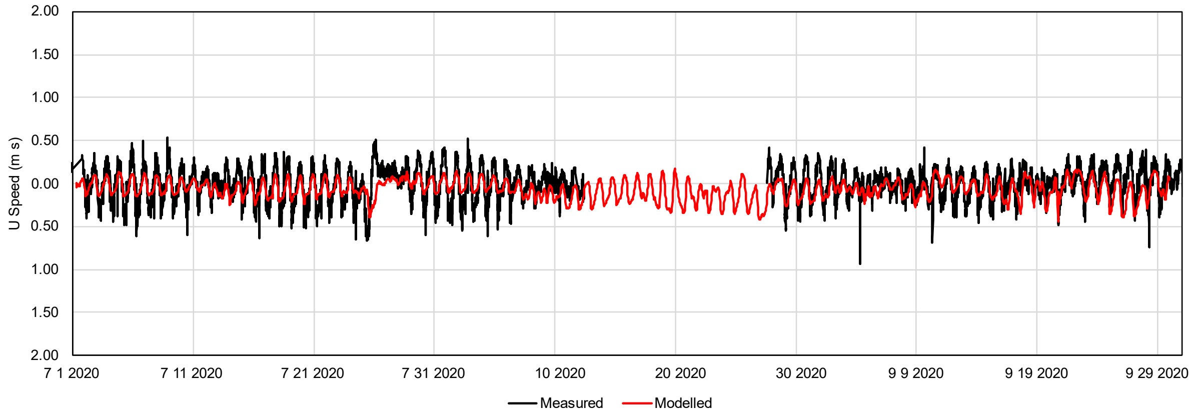


Figure A.24: Comparison of model predicted flow velocity components, U (east) and V (north), with the measured data at CC0301 during Period 3



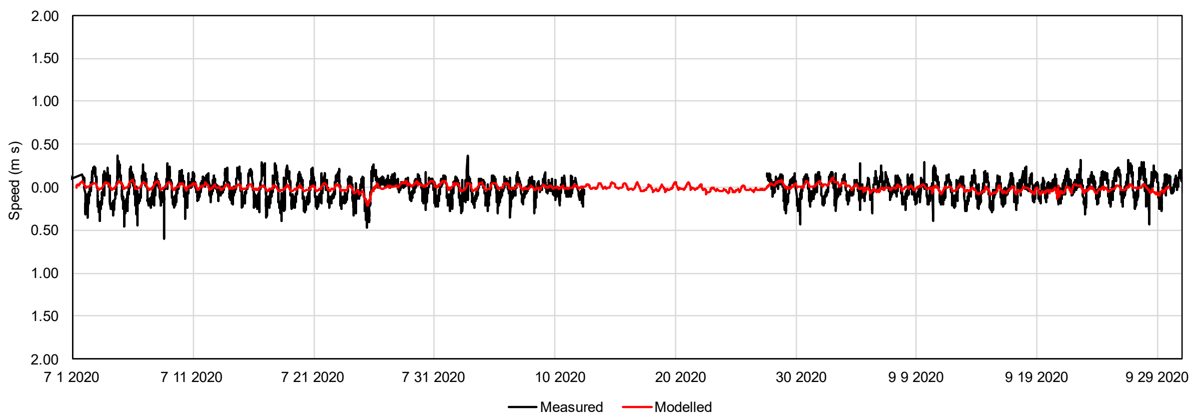
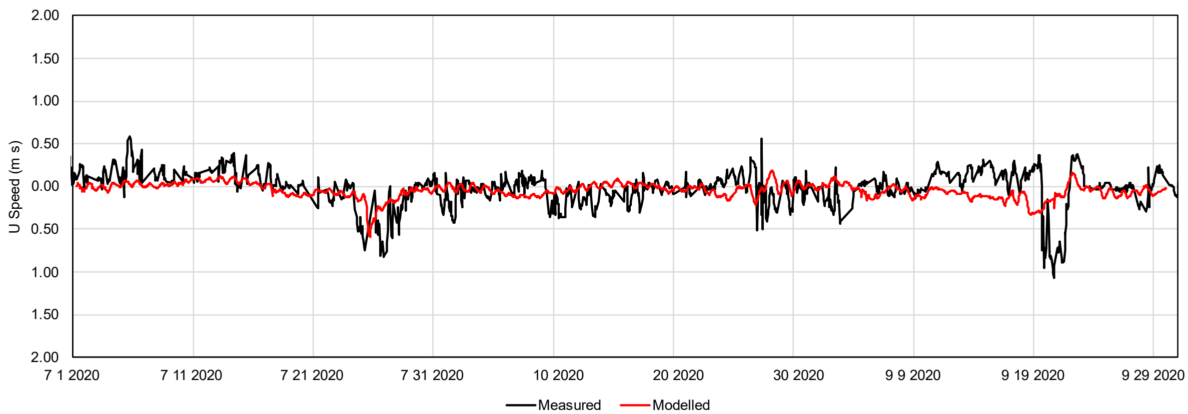


Figure A.25: Comparison of model predicted flow velocity components, U (east) and V (north), with the measured data at CC0401 during Period 3



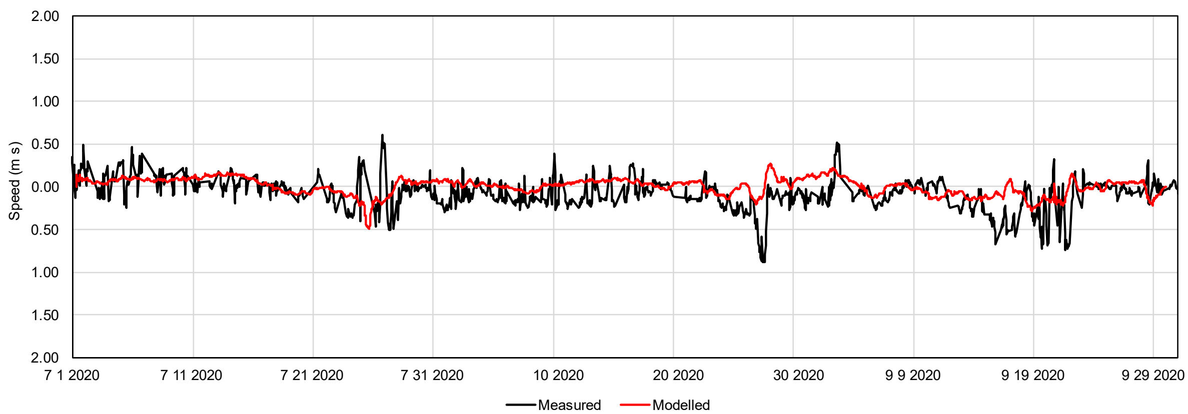


Figure A.26: Comparison of model predicted flow velocity components, U (east) and V (north), with the measured data at TABS-D during Period 3

Appendix B

Impact of Future With Project

B.1 Impacts on Water Level

B.1.1 Mean Water Level

Figure B.1: Change of mean water level caused by the FWP in Period 1

Figure B.2: Change of mean water level caused by the FWP in Period 2

Figure B.3: Change of mean water level caused by the FWP in Period 3

B.1.2 High Tide and Low Tide

Figure B.4: Average change of high tide caused by the FWP in Period 1

Figure B.5: Average change of high tide caused by the FWP in Period 2

Figure B.6: Average change of high tide caused by the FWP in Period 3

Figure B.7: Average change of low tide caused by the FWP in Period 1

Figure B.8: Average change of low tide caused by the FWP in Period 2

Figure B.9: Average change of low tide caused by the FWP in Period 3

B.1.3 Tide Range

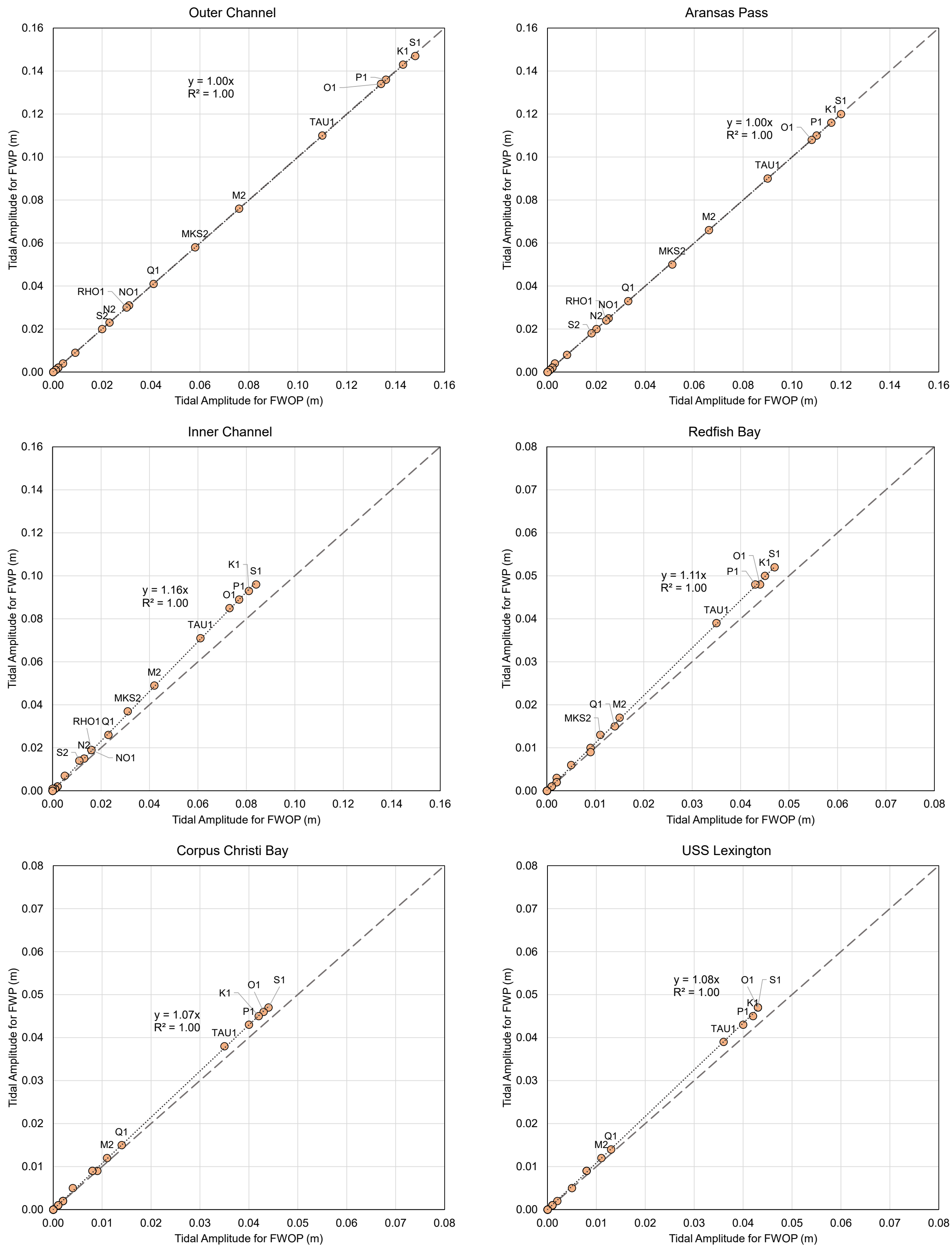


Figure B.10: Comparison of tide amplitudes between FWP and FWOP in Period 1

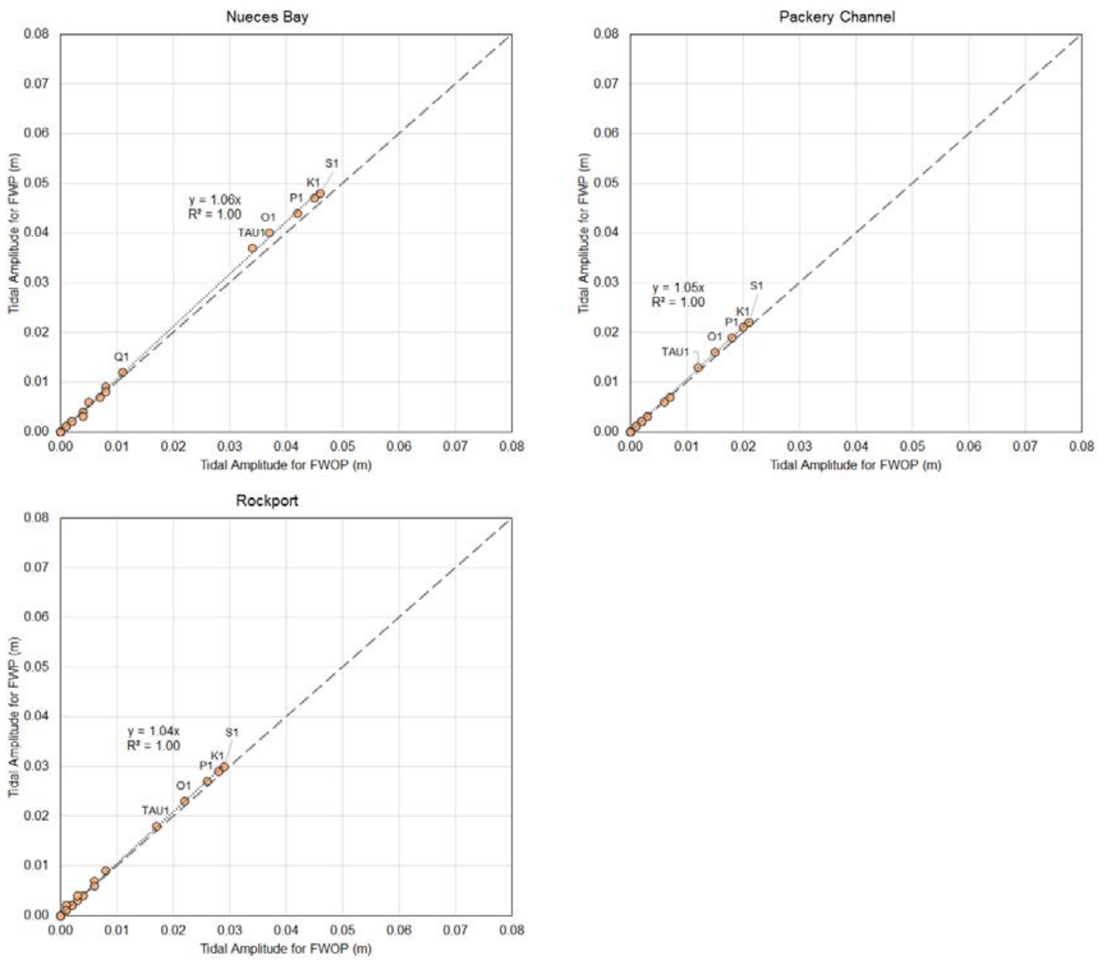


Figure B.11: Comparison of tide amplitudes between FWP and FWOP in Period 1 (continued)

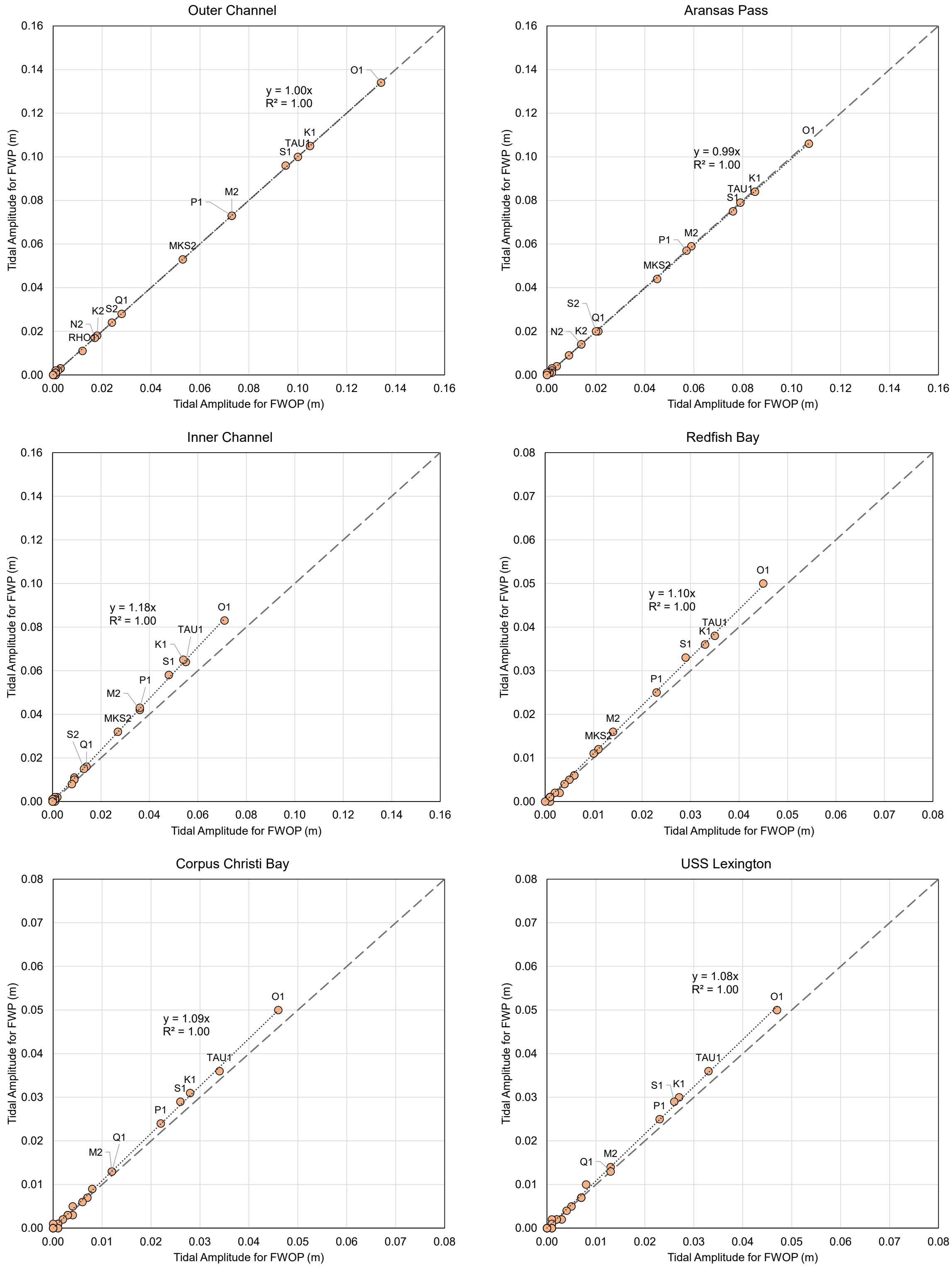


Figure B.12: Comparison of tide amplitudes between FWP and FWOP in Period 2

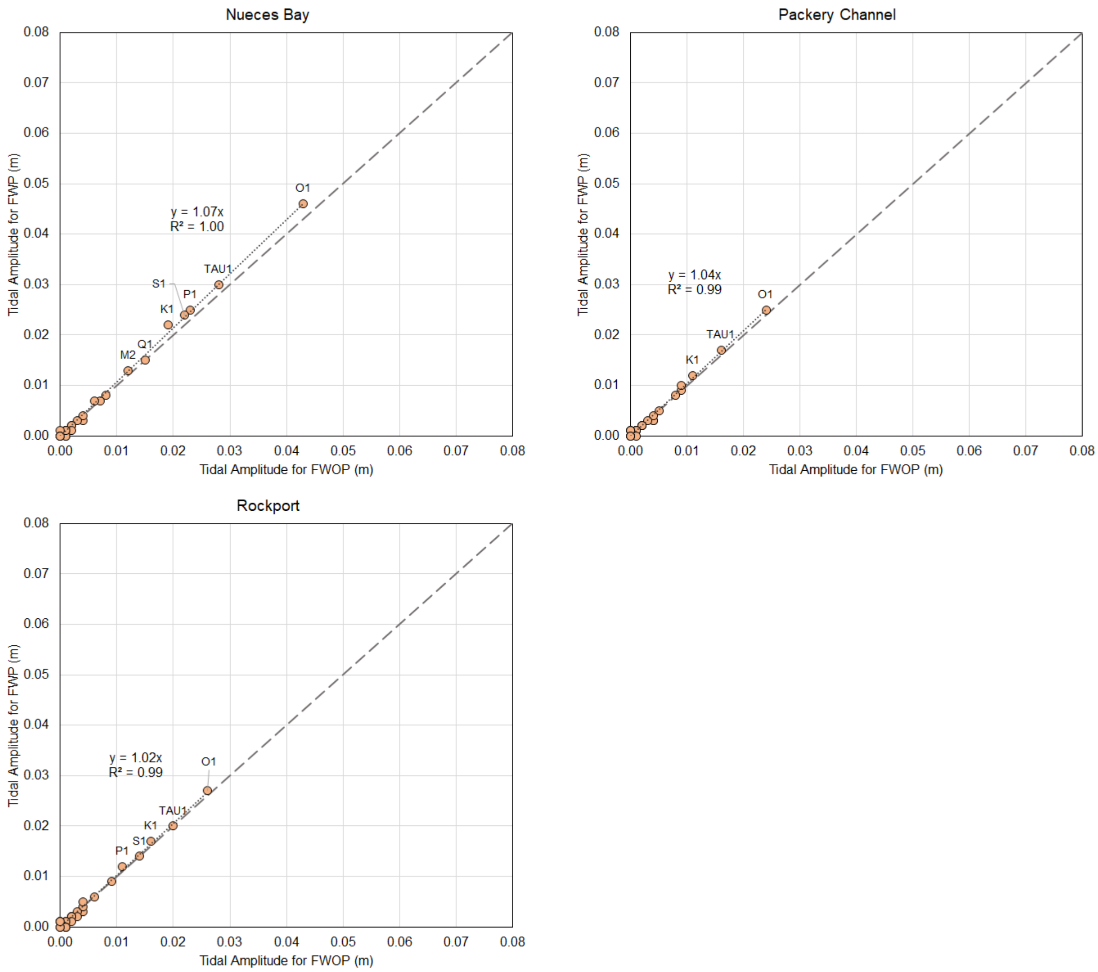


Figure B.13: Comparison of tide amplitudes between FWP and FWOP in Period 2 (continued)

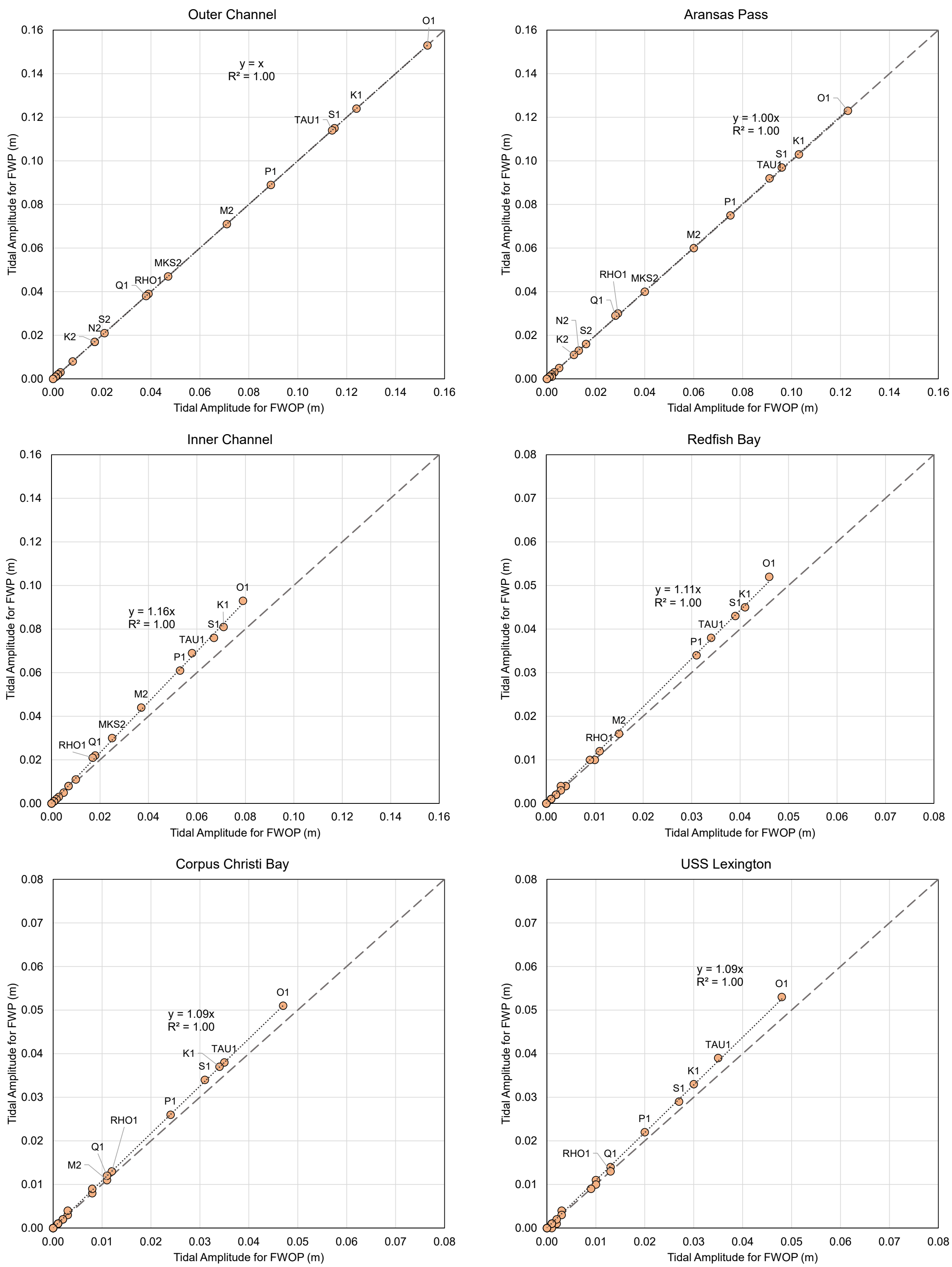


Figure B.14: Comparison of tide amplitudes between FWP and FWOP in Period 3

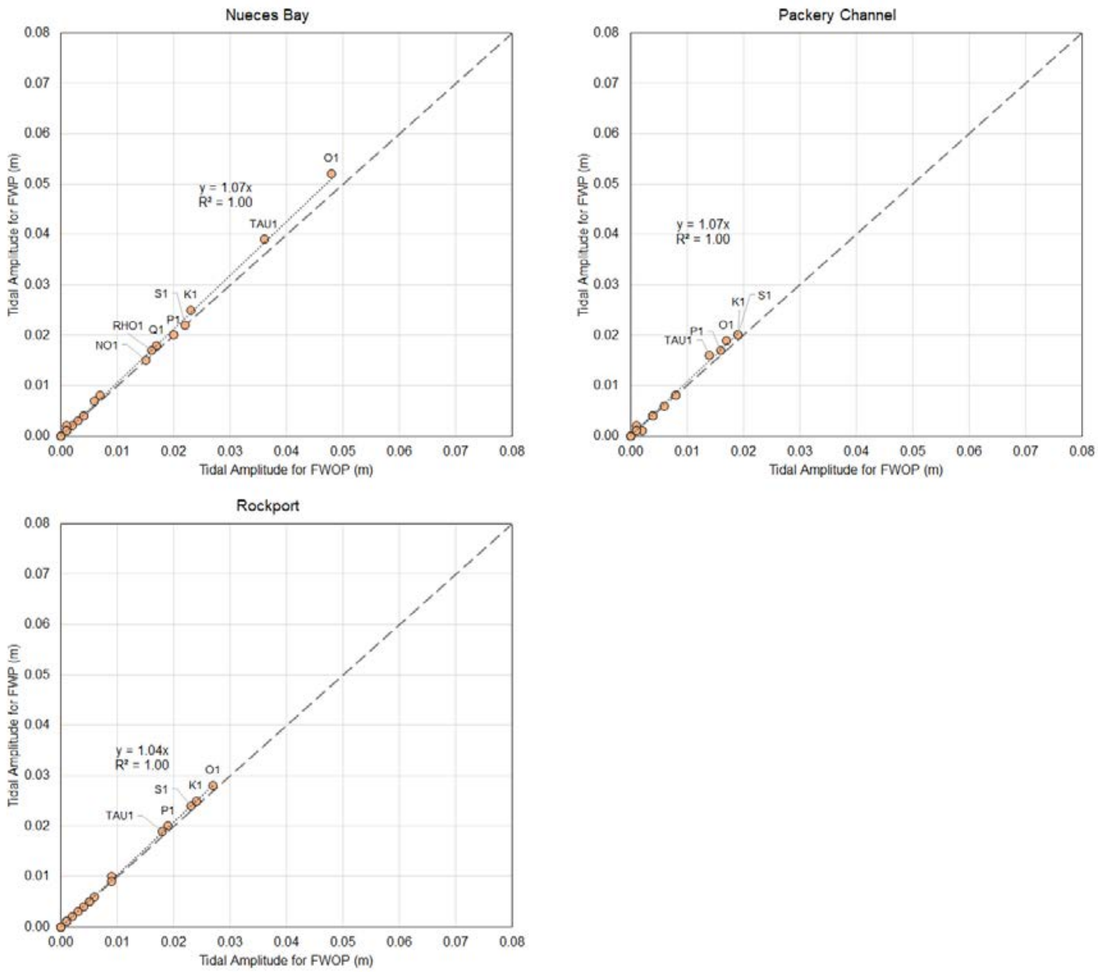


Figure B.15: Comparison of tide amplitudes between FWP and FWOP in Period 3 (continued)

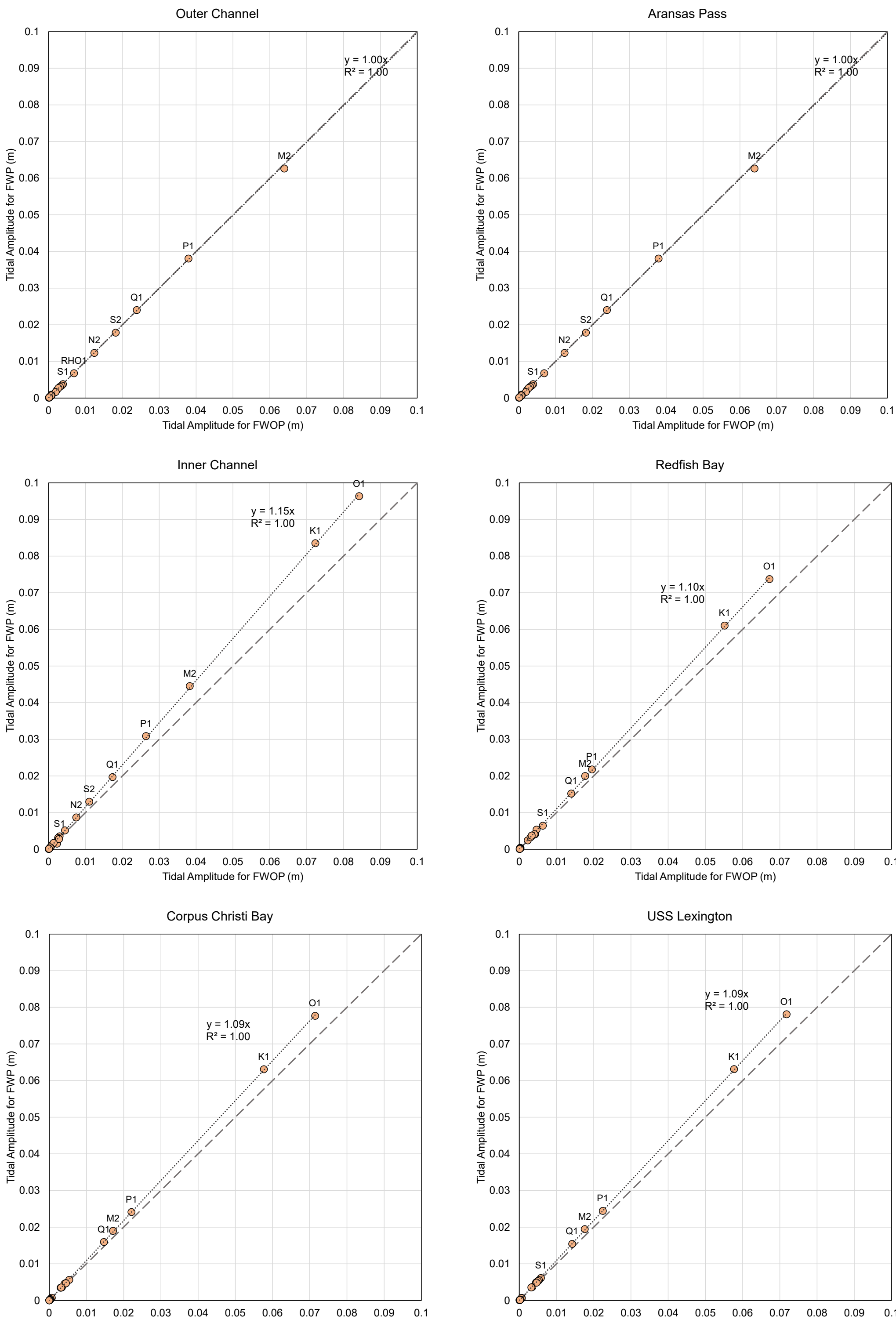


Figure B.16: Comparison of tide amplitudes between FWP and FWOP from one-year run

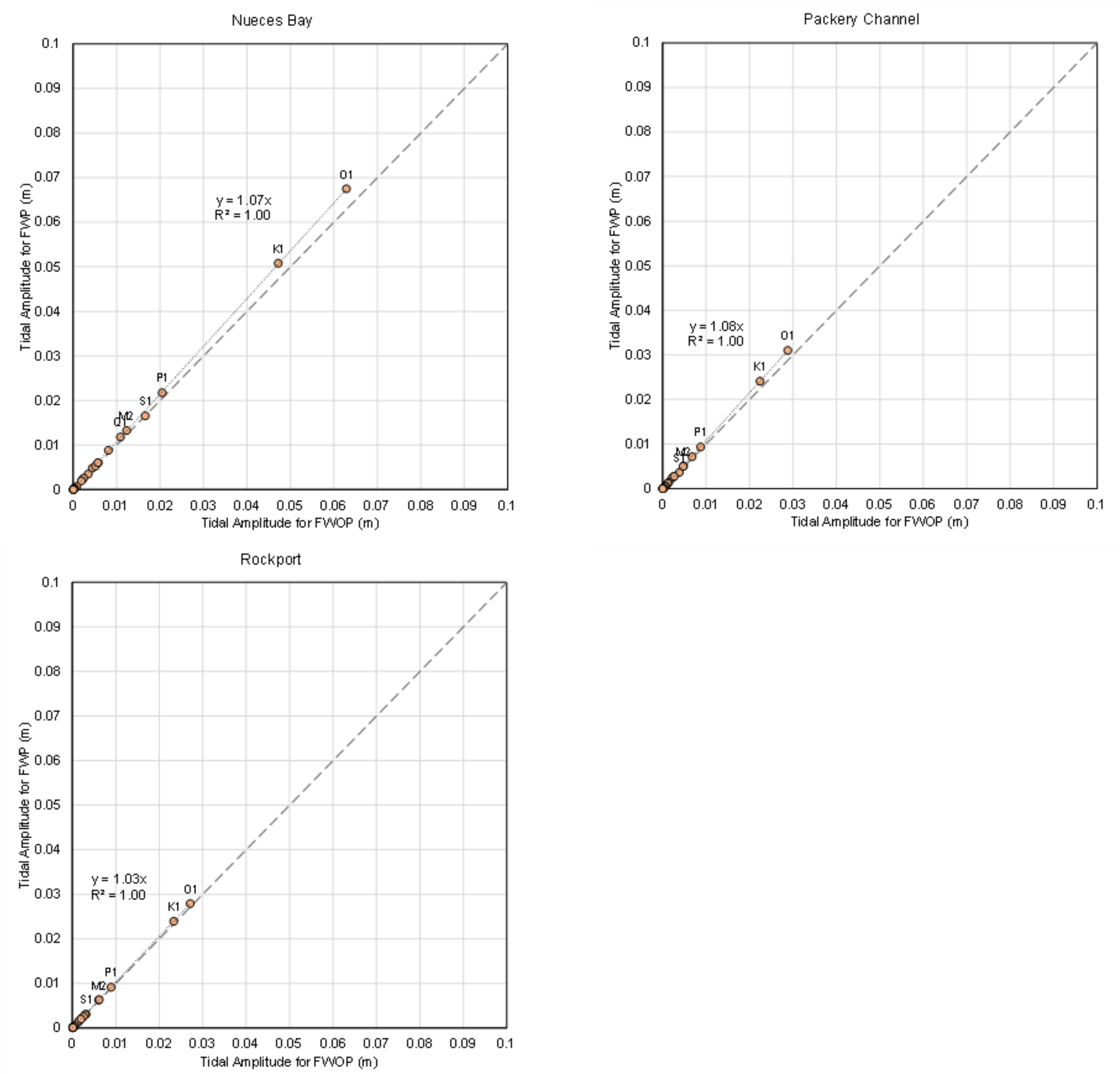


Figure B.17: Comparison of tide amplitudes between FWP and FWOP from one-year run (continued)

Figure B.18: Average Change of Tide Range Caused by FWP in Period 1

Figure B.19: Average Change of Tide Range Caused by FWP in Period 2

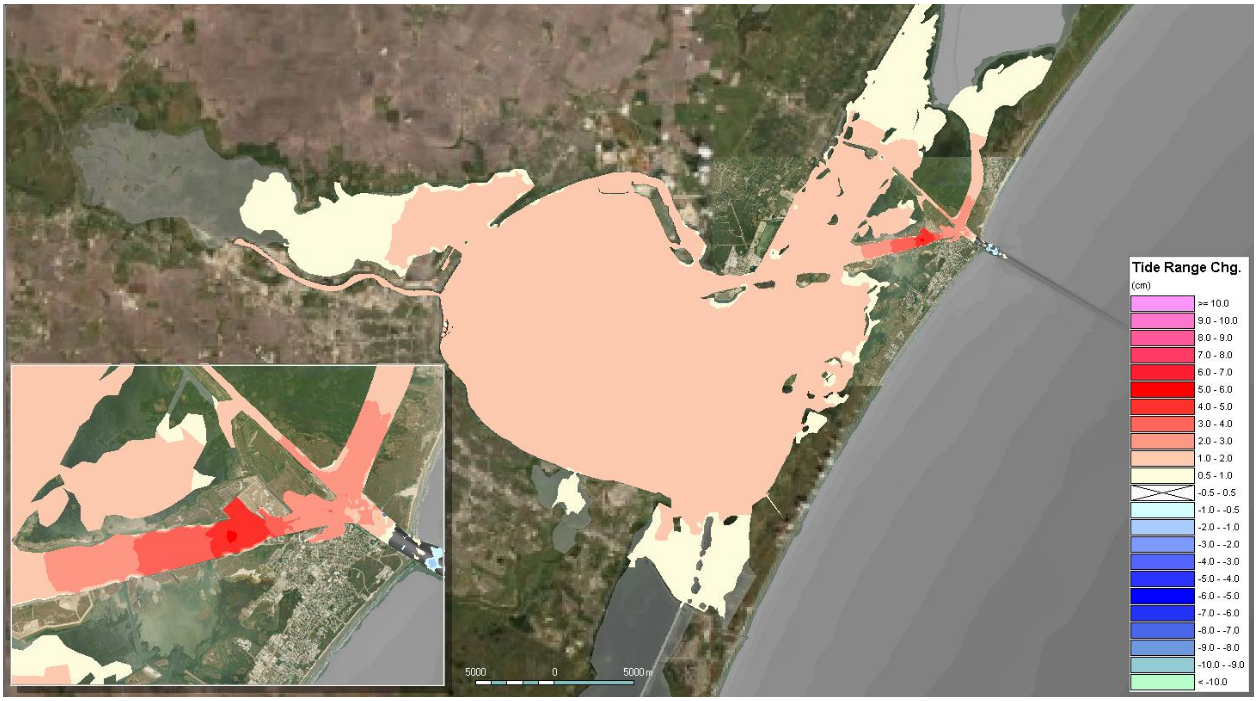


Figure B.20: Average Change of Tide Range Caused by FWP in Period 3

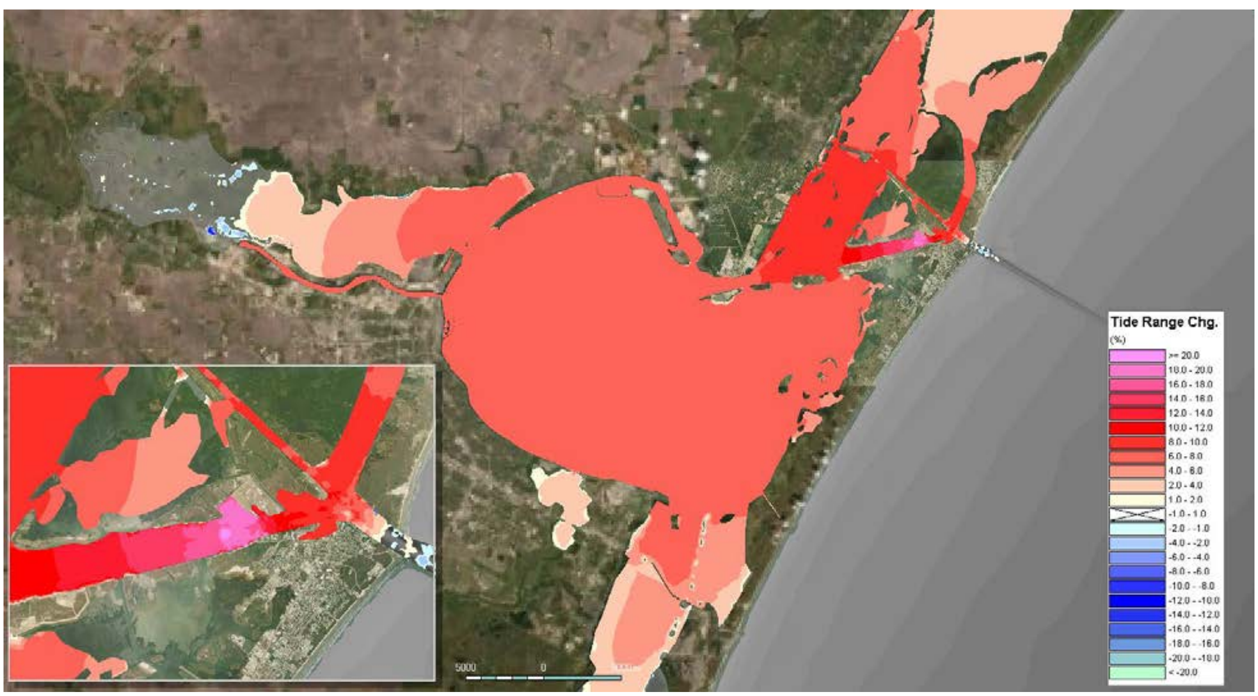


Figure B.21: Percentage of tide range change caused by the FWP in Period 1

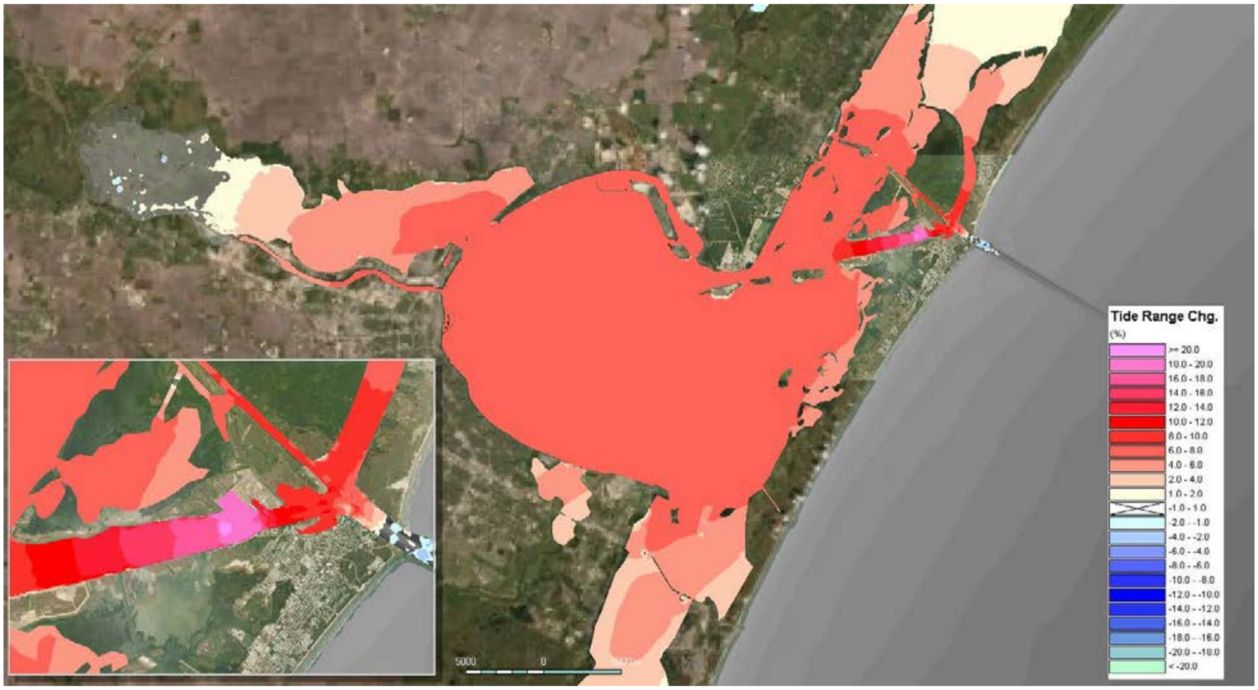


Figure B.22: Percentage of tide range change caused by the FWP in Period 2

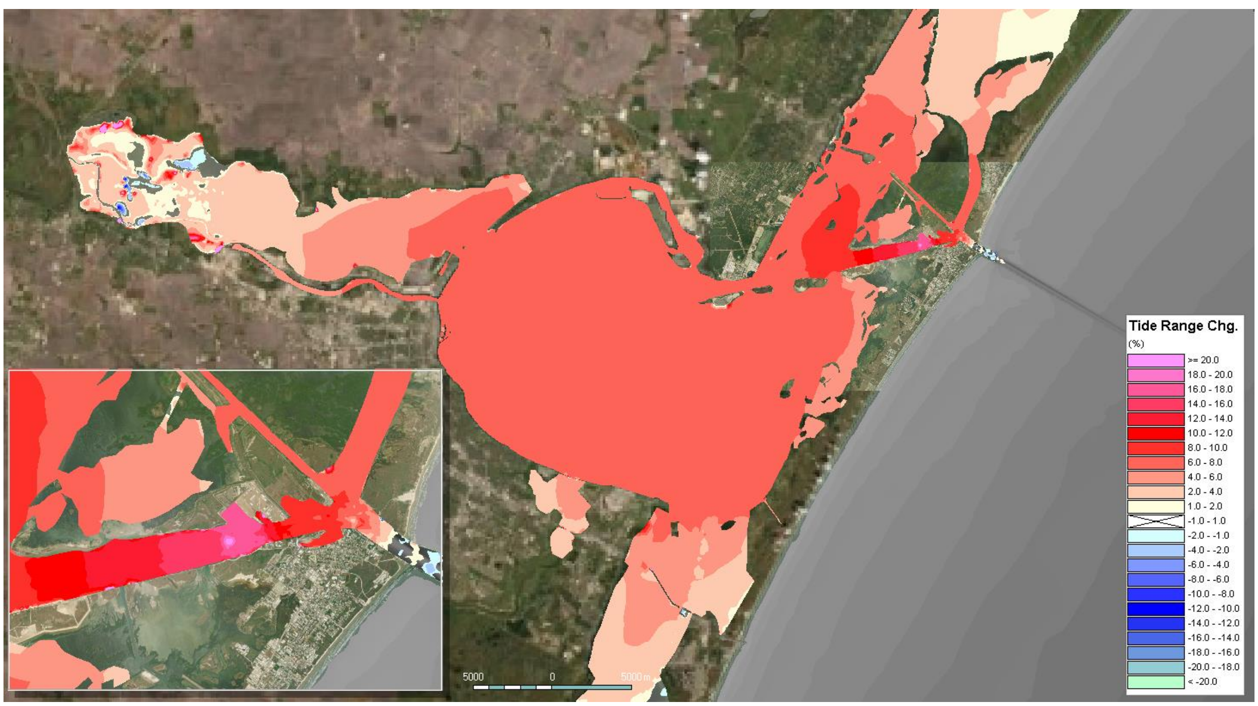


Figure B.23: Percentage of tide range change caused by the FWP in Period 3

B.2 Impact on Currents

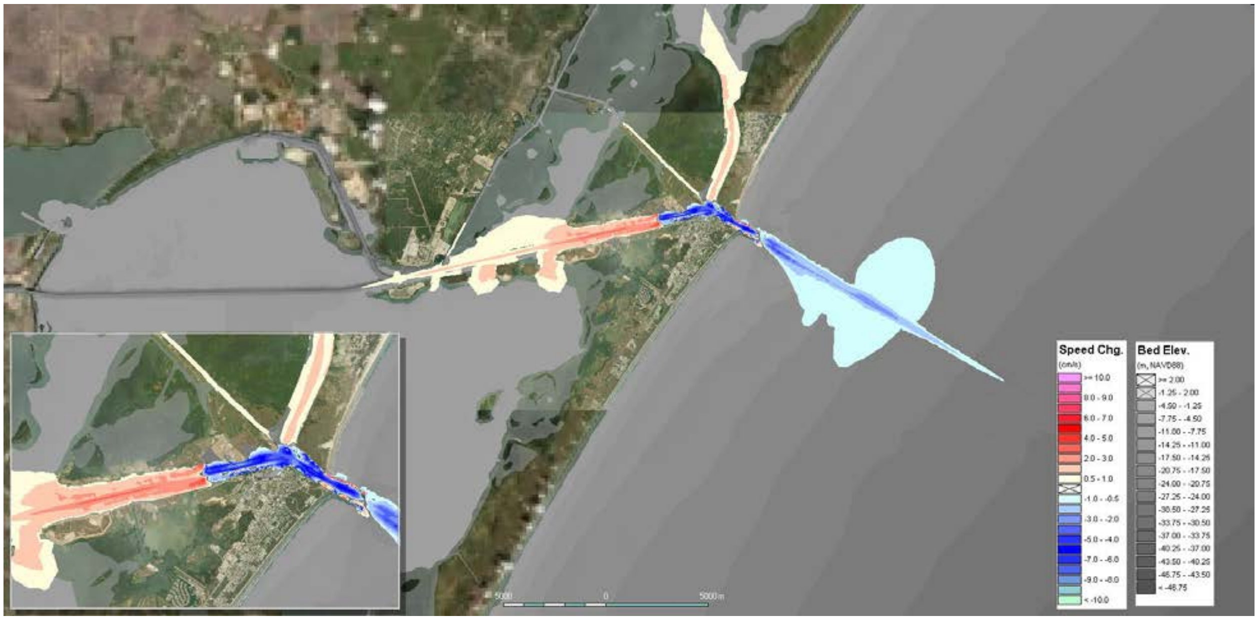


Figure B.24: Depth averaged speed change caused by the FWP in Period 1

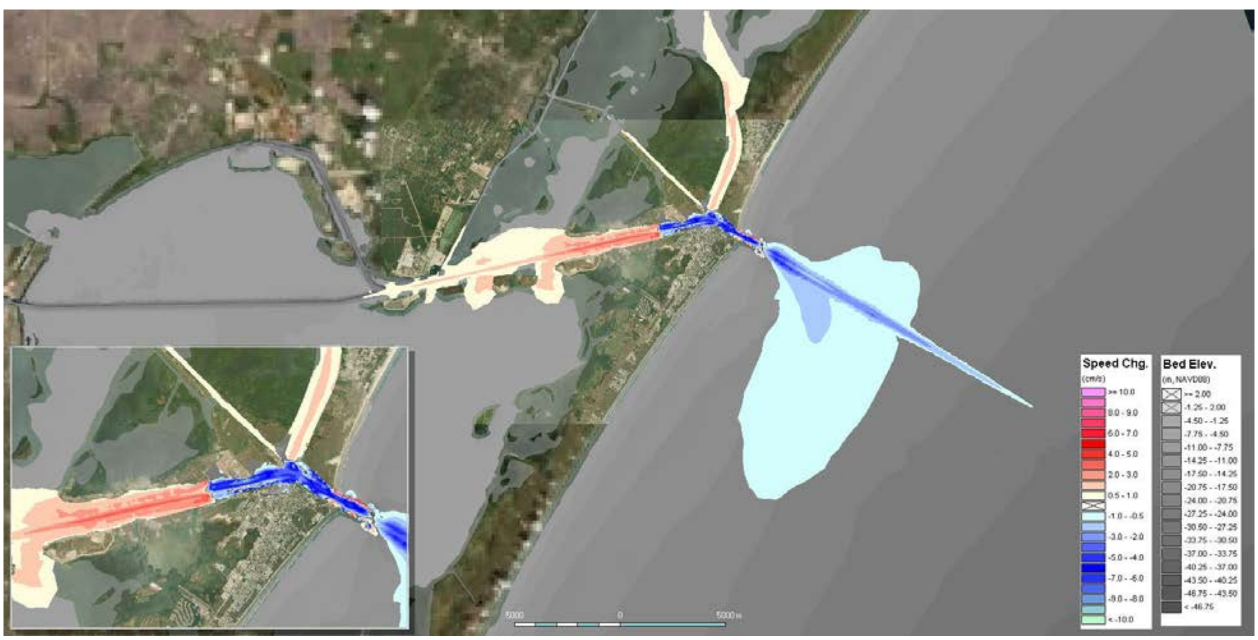


Figure B.25: Depth averaged speed change caused by the FWP in Period 2

Figure B.26: Depth averaged speed change caused by the FWP in Period 3

Figure B.27: Average flow speed change on water surface in Period 1

Figure B.28: Average flow speed change at the elevation of -5 m (NAVD88) in Period 1

Figure B.29: Average flow speed change at the elevation of -10 m (NAVD88) in Period 1

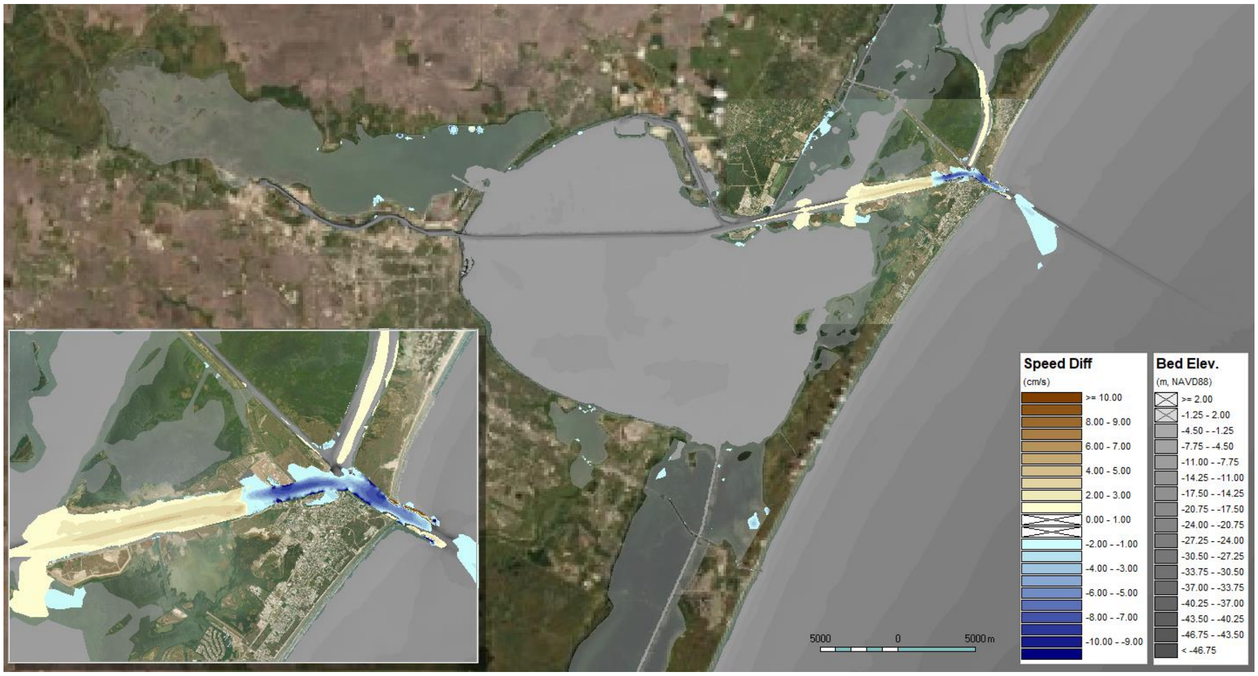


Figure B.30: Average flow speed change on water surface in Period 2

Figure B.31: Average flow speed change at the elevation of -5 m (NAVD88) in Period 2

Figure B.32: Average flow speed change at the elevation of -10 m (NAVD88) in Period 2

Figure B.33: Average flow speed change on water surface in Period 3

Figure B.34: Average flow speed change at the elevation of -5 m (NAVD88) in Period 3

Figure B.35: Average flow speed change at the elevation of -10 m (NAVD88) in Period 3

B.3 Impact on Salinity

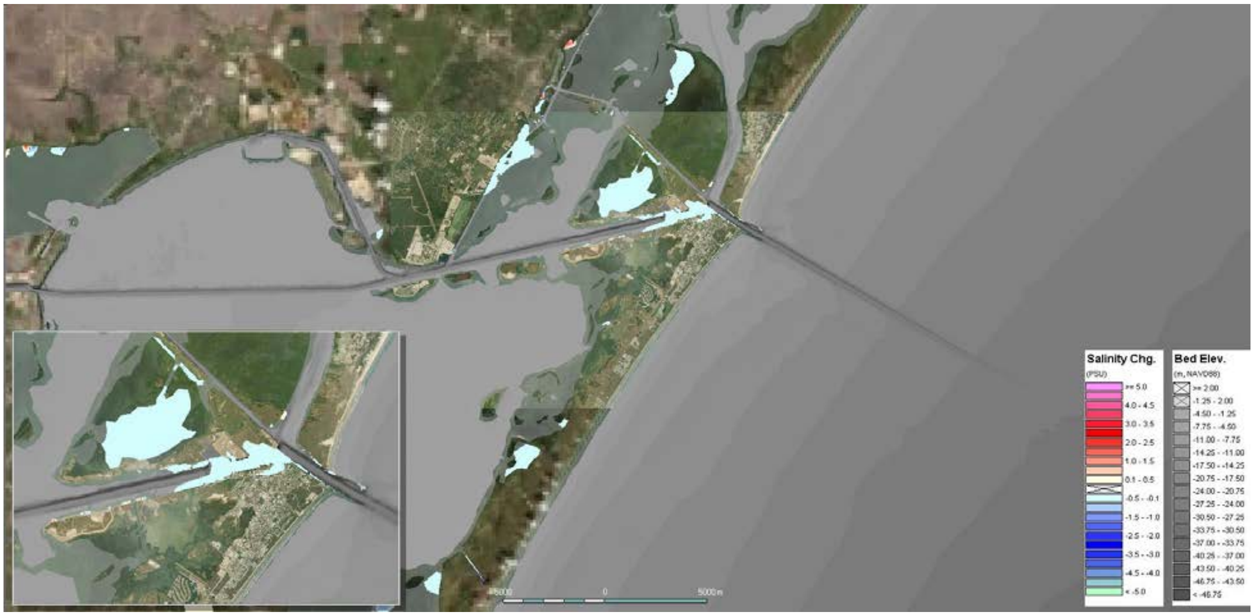


Figure B.36: Average salinity change caused by FWP in Period 1

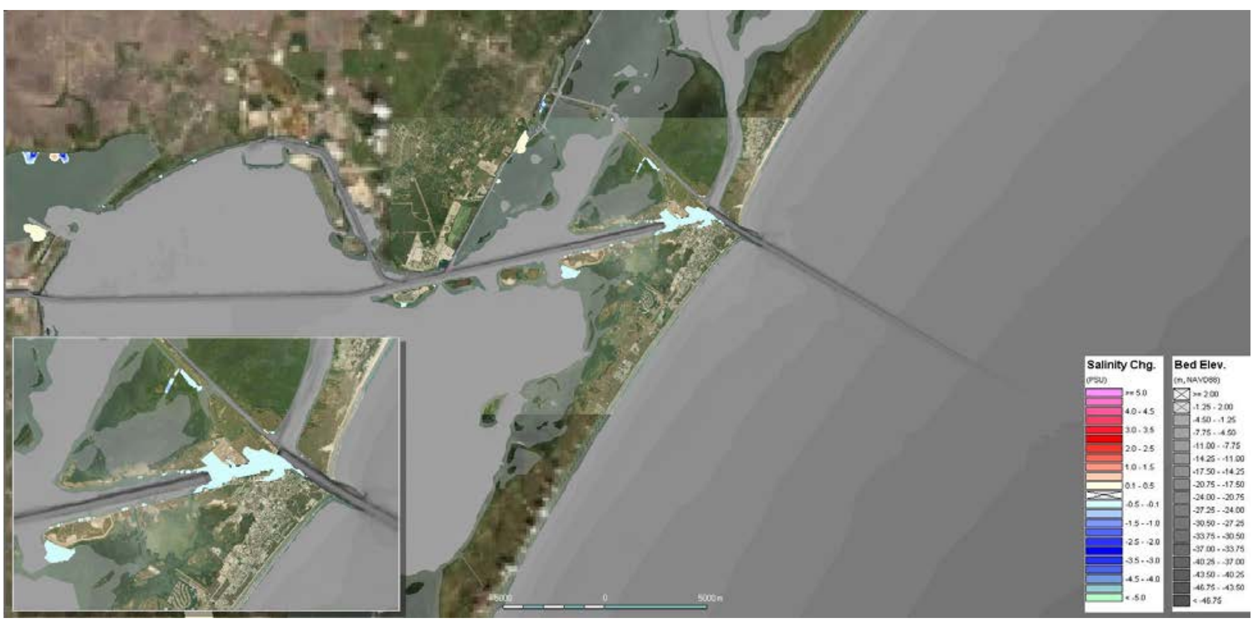


Figure B.37: Average salinity change caused by FWP in Period 2

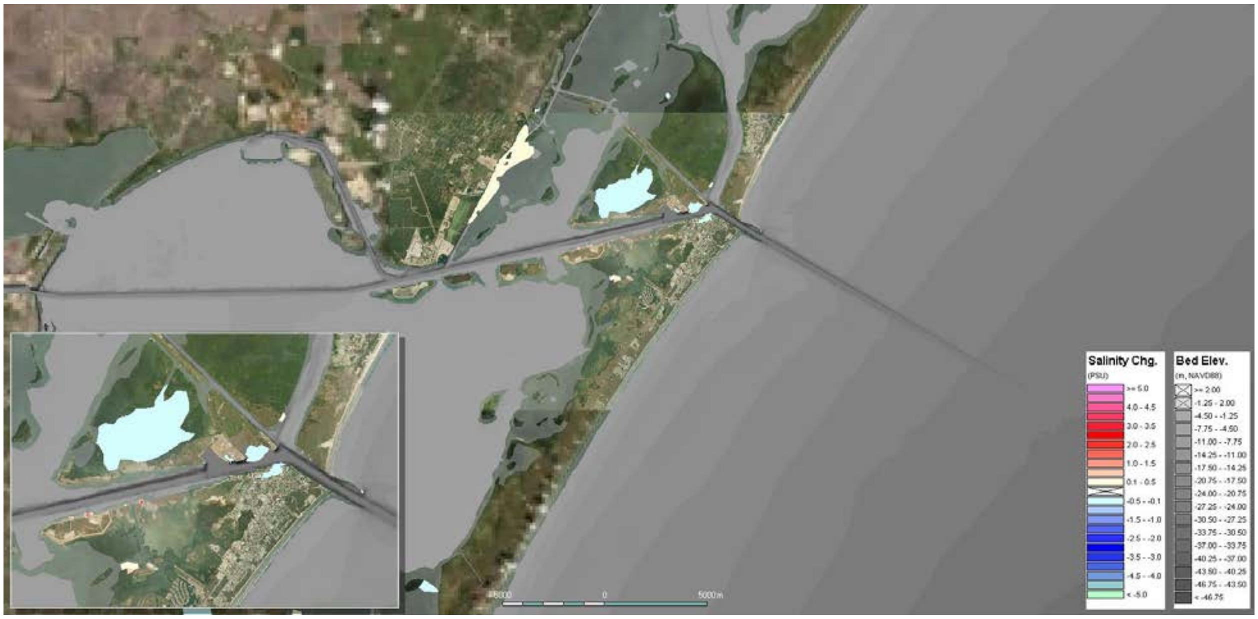


Figure B.38: Average salinity change caused by FWP in Period 3

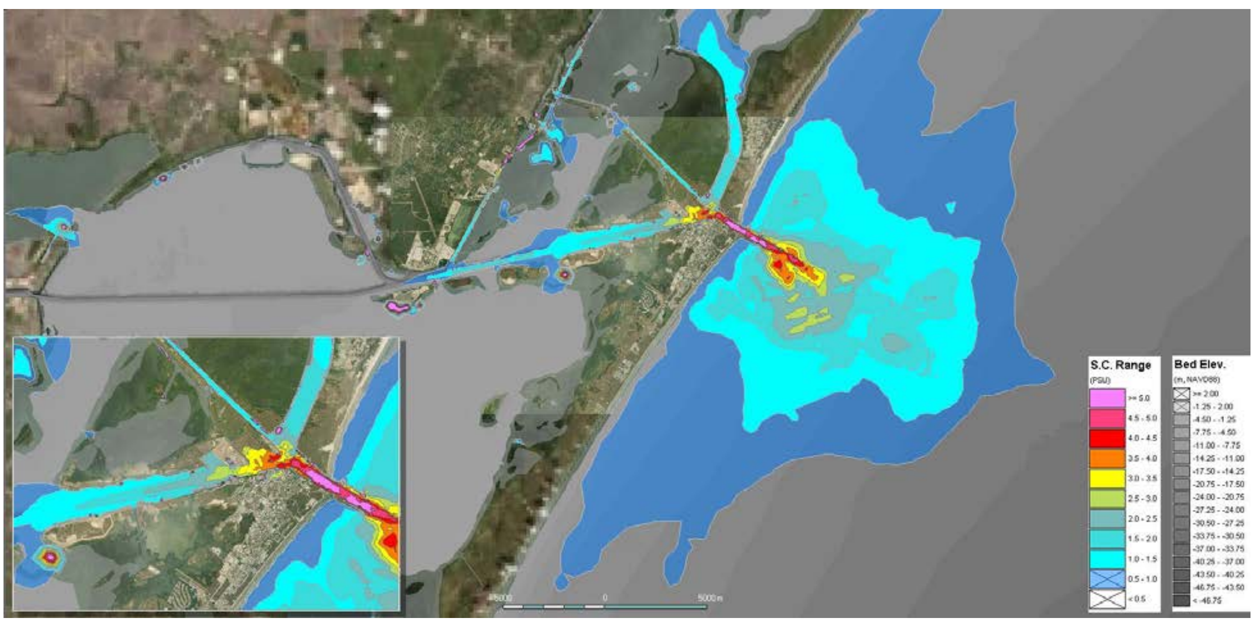


Figure B.39: Range of salinity change caused by FWP in Period 1

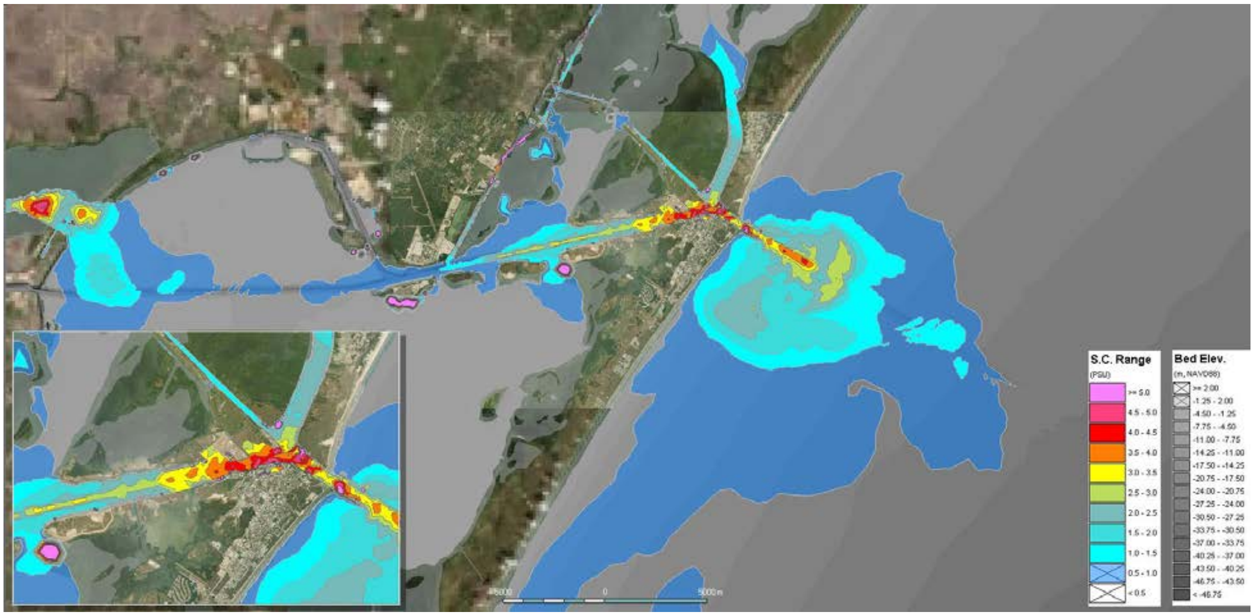


Figure B.40: Range of salinity change caused by FWP in Period 2

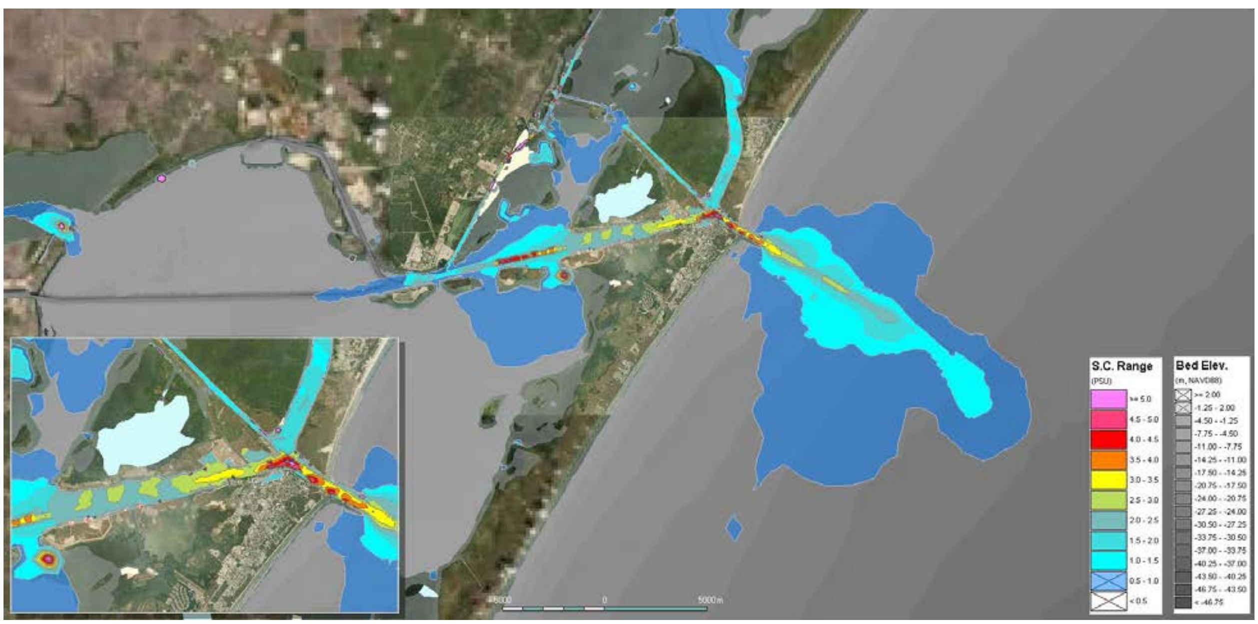


Figure B.41: Range of salinity change caused by FWP in Period 3

Appendix C

Impact of Future Without Project

C.1 Impacts on Water Level

C.1.1 Comparison of Tide Amplitudes between FWOP and EC

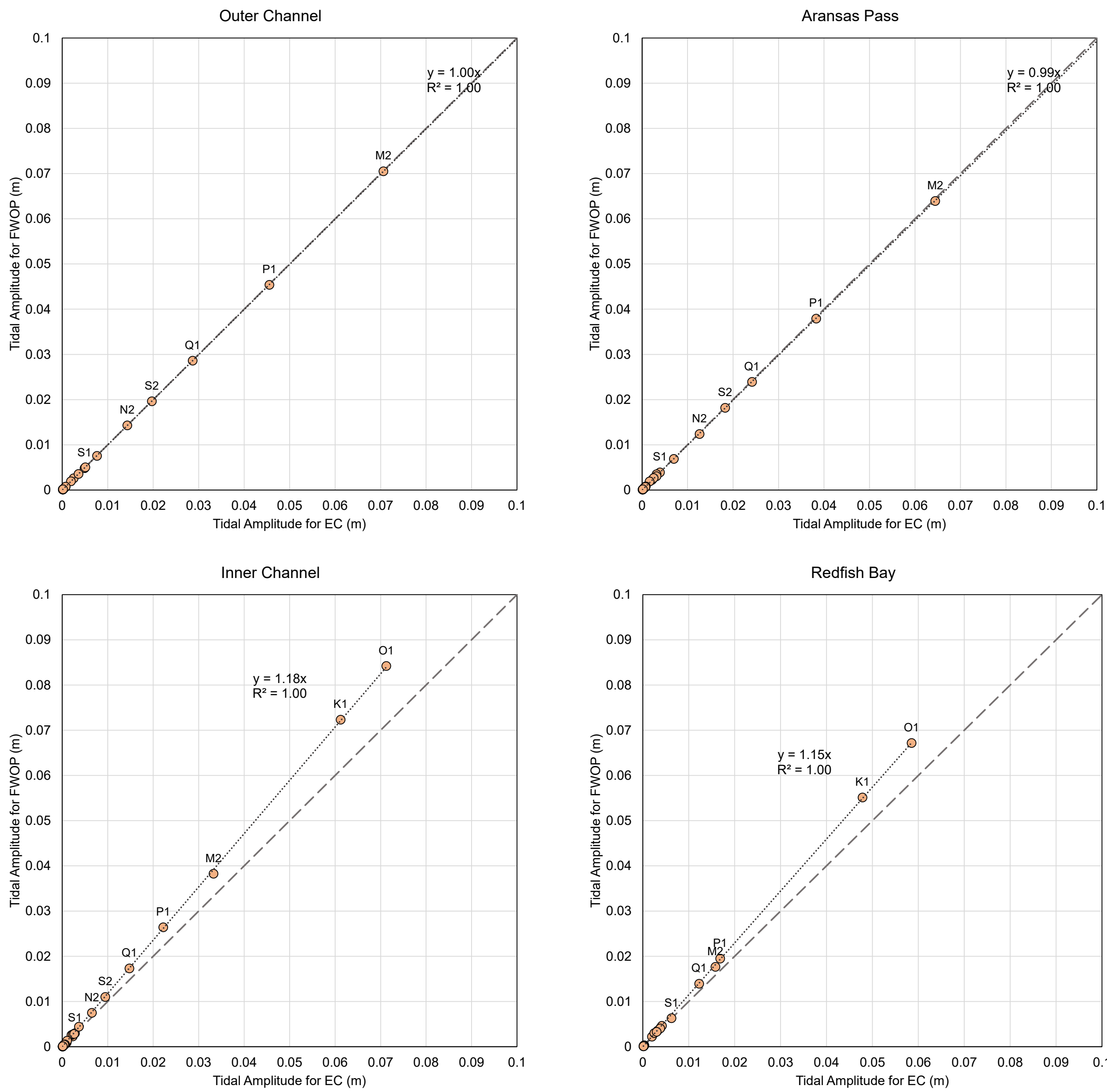


Figure C.1: Comparison of tide amplitudes FWOP with the existing condition from one-year run

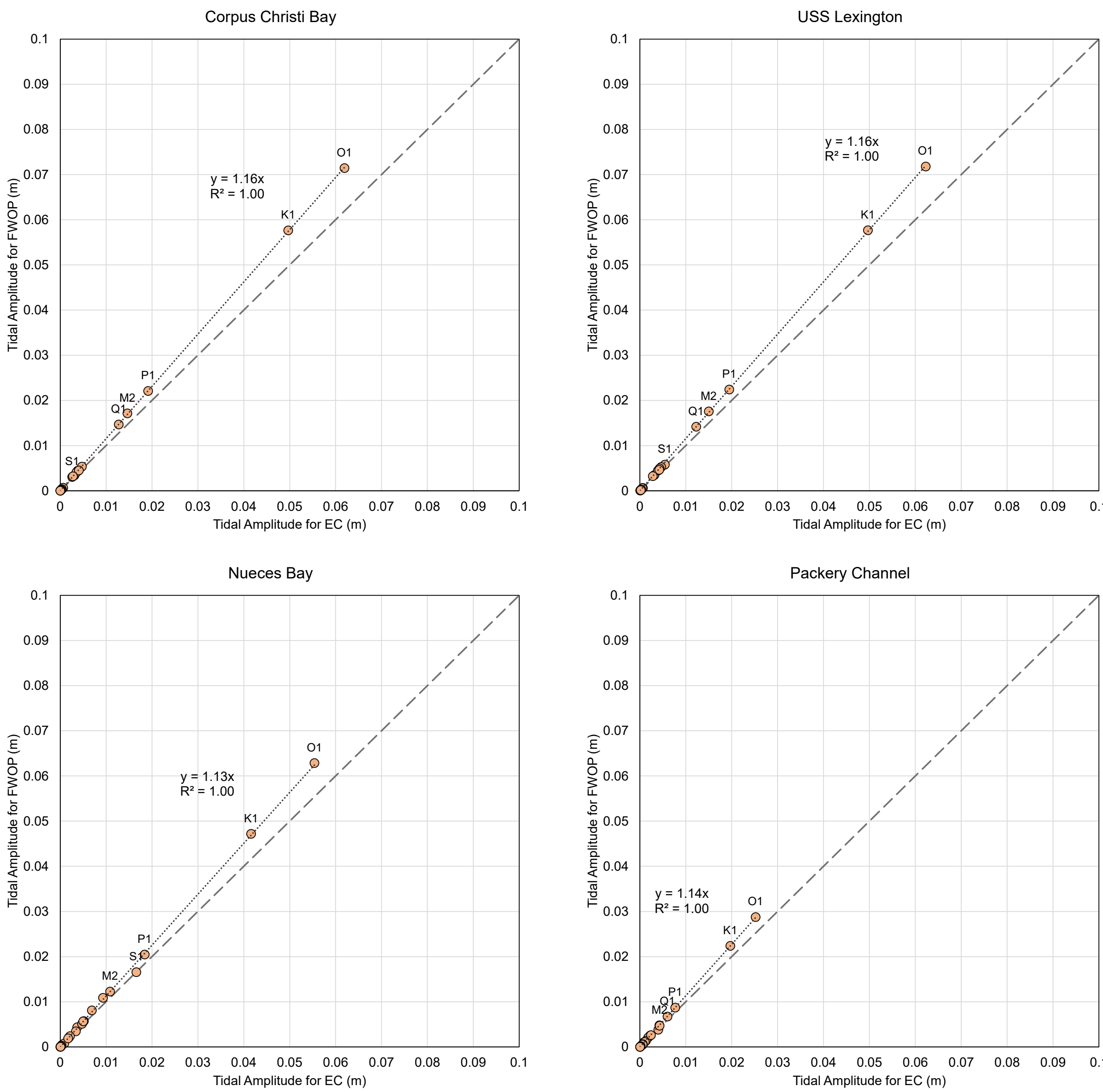


Figure C.2: Comparison of tide amplitudes FWOP with the existing condition from one-year run

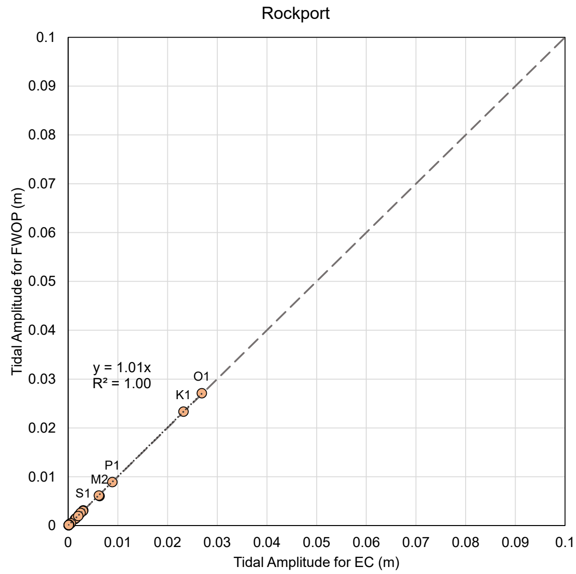


Figure C.3: Comparison of tide amplitudes FWOP with the existing condition from one-year run

Appendix D

Cumulative Impacts of Future With Project

D.1 Cumulative Impacts on Water Level

D.1.1 Comparison of Tide Amplitudes between FWP and EC

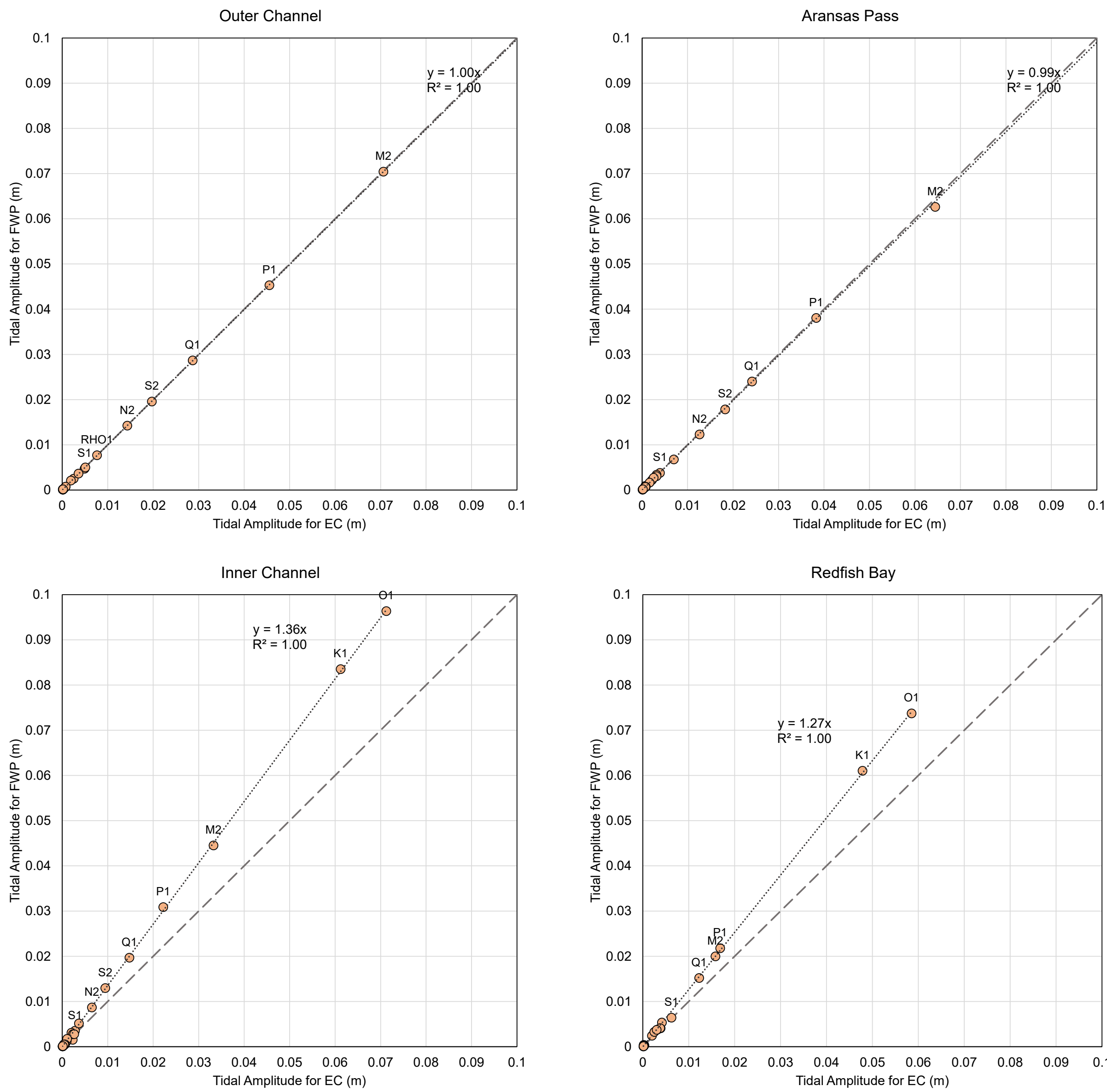


Figure D.1: Comparison of tide amplitudes FWP with the existing condition from one-year run

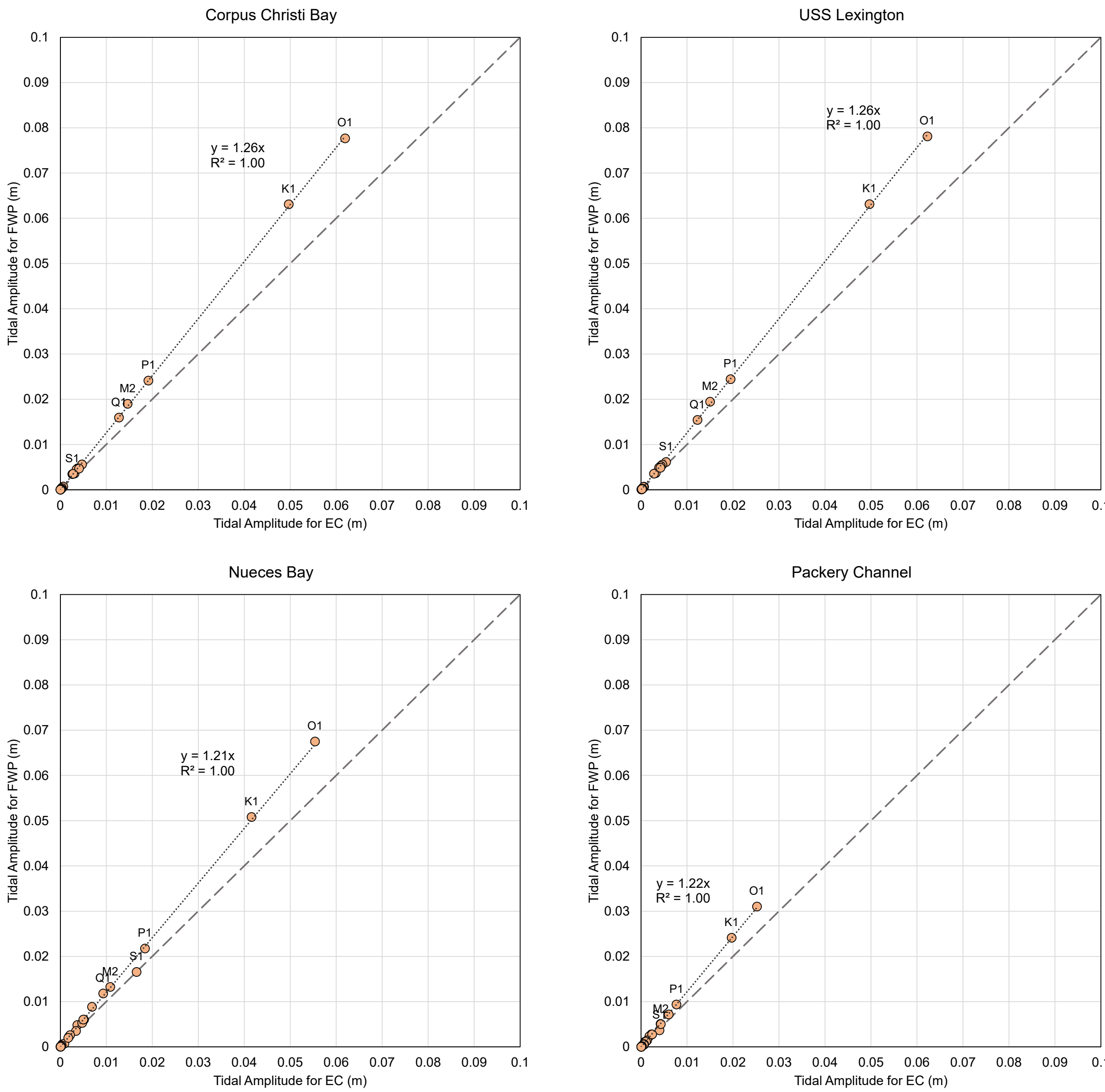


Figure D.2: Comparison of tide amplitudes FWP with the existing condition from one-year run

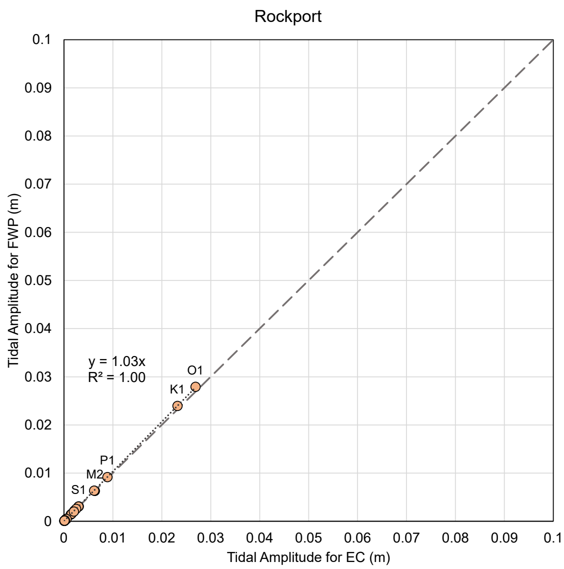


Figure D.3: Comparison of tide amplitudes FWP with the existing condition from one-year run

Appendix J

MPRSA Section 103 Sampling Analysis Plan

Note: The Section 508 amendment of the Rehabilitation Act of 1973 requires that the information in Federal documents be accessible to individuals with disabilities. The USACE has made every effort to ensure that the information in this appendix is accessible. However, this appendix is not fully compliant with Section 508, and readers with disabilities are encouraged to contact Mr. Jayson Hudson at the USACE at (409) 766-3108 or at SWG201900067@usace.army.mil if they would like access to the information.

Job No. PCA20166

FINAL

STATEMENT OF WORK AND SAMPLING ANALYSIS PLAN

MPRSA SECTION 103 EVALUATION OF SEDIMENT FROM THE PORT OF CORPUS CHRISTI AUTHORITY CHANNEL DEEPENING PROJECT, CORPUS CHRISTI, TEXAS

Prepared for:

U.S. Army Corps of Engineers
and
U.S. Environmental Protection Agency

Prepared by:

Freese and Nichols, Inc.
10431 Morado Circle, Suite 300
Austin, Texas 78759

July 2021 – Version 2

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Acronyms and Abbreviations

°C	degrees Centigrade
CCSC	Corpus Christi Ship Channel
CCSCIP	Corpus Christi Ship Channel Improvement Project
CDP	Channel Deepening Project
CFR	Code of Federal Regulations
DMMU	Dredge Material Management Unit
DOC	dissolved organic carbon
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
ERL	effects range low
FDA	U.S. Food and Drug Administration
FSP	Field Sampling Plan
HSP	Health and Safety Plan
ITM	Inland Testing Manual
LPC	limiting permissible concentration
LRL	Laboratory Reporting Limit
MDL	Method Detection Limits
MLLW	mean lower low water
MPRSA	Marine Protection, Research, and Sanctuaries Act
NELAC	National Environmental Laboratory Association Conference
NOAA	National Oceanic and Atmospheric Administration
ODMDS	Ocean Dredged Material Disposal Site
OTM	Ocean Testing Manual
PAH	polyaromatic hydrocarbons
PCB	polychlorinated biphenyls
PCCA	Port of Corpus Christi Authority
ppt	parts per thousand
QA	Quality Assurance
QC	Quality Control
RIA	Regional Implementation Agreement
SAP	Sampling and Analysis Plan
SD	sediment
SOPs	Standard Operating Procedures
SOW	Statement of Work
SPP	Suspended Particulate Phase
SRM	Standard Reference Material
SVOC	semi-volatile volatile organic compounds
SW	surface water

TDL	target detection limit
TOC	total organic carbon
ug/L	micrograms per liter
USACE	U.S. Army Corps of Engineers
VLCC	very large crude carriers
VOC	volatile organic compounds

1.0 PROJECT OVERVIEW

1.1 INTRODUCTION

The Port of Corpus Christi Authority (PCCA) applied to the U.S. Army Corps of Engineers (USACE), Galveston District under Section 10 of the Rivers and Harbors Act of 1899, Section 404 of the Clean Water Act (CWA), and Section 103 of the Marine Protection, Research and Sanctuaries Act for deepening of the Corpus Christi Ship Channel (CCSC).

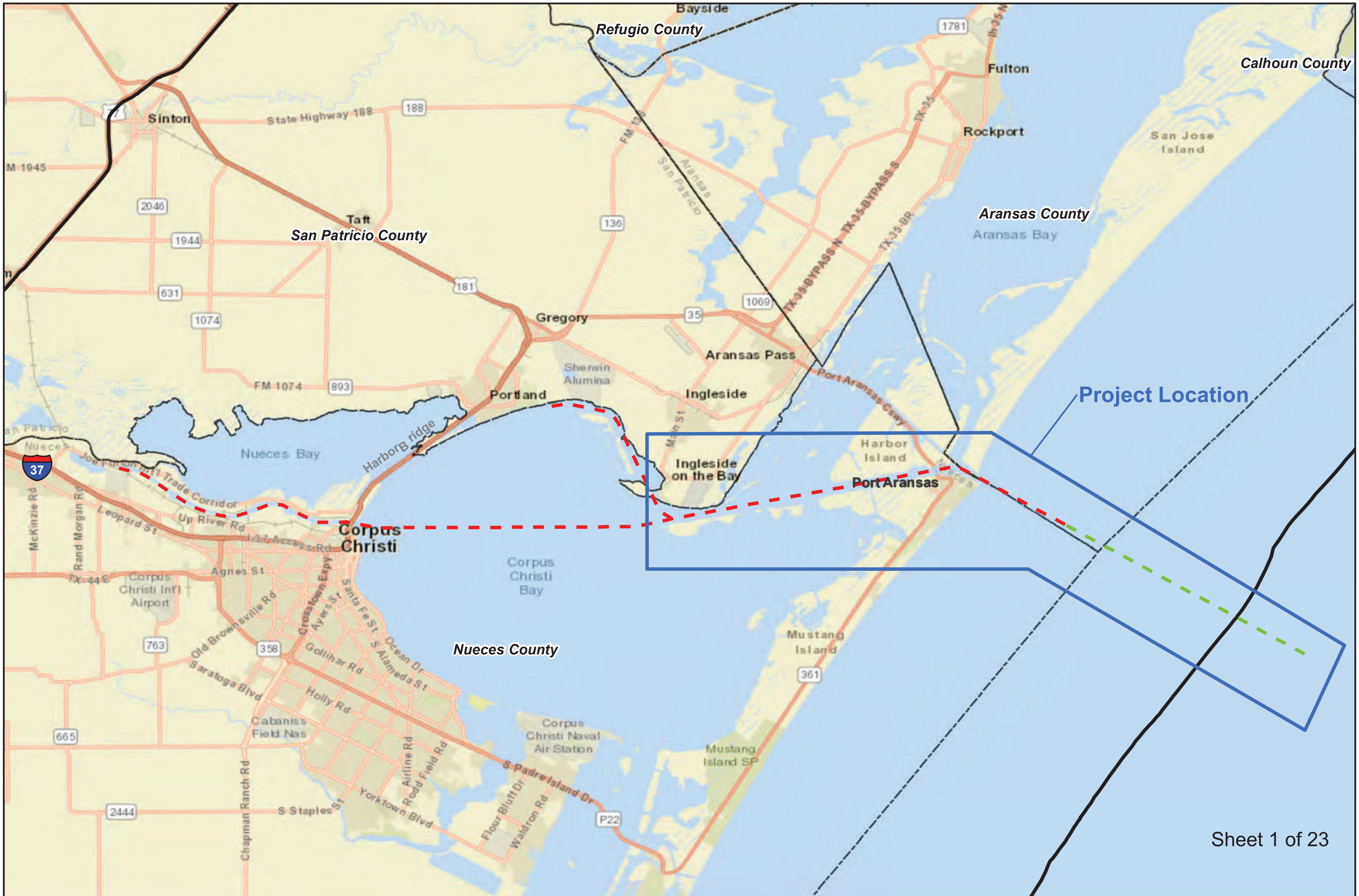
Located in the Gulf of Mexico on the south-central portion of the Texas coast as shown in Figure 1, the Corpus Christi Ship Channel (CCSC) is approximately 200 miles southwest of Galveston and 150 miles north of the mouth of the Rio Grande River, and provides deep water access from the Gulf of Mexico to the PCCA, via Port Aransas, through Redfish Bay and Corpus Christi Bay. The CCSC is currently authorized by the U.S. Army Corps of Engineers (USACE) to –54 feet and –56 feet mean lower low water (MLLW) from Station 110+00 to Station –330+00 as part of the Corpus Christi Ship Channel Improvement Project (CCSCIP). The current authorized width of the CCSC is 600 feet inside the Port Aransas Jetties and 700 feet along the entrance channel in the Gulf of Mexico.

The PCCA Channel Deepening Project (CDP) would deepen the channel from Station 110+00 to Station –72+50 to a maximum depth of –79 feet MLLW (–75 feet MLLW plus two feet of advanced maintenance and two feet of allowable overdredge), and from Station –72+50 to Station –330+00, the channel would be deepened to a maximum depth of –81 MLLW –77 feet MLLW plus two feet of advanced maintenance and two foot of allowable overdredge (Figure 2). The proposed project includes a 29,000-foot extension of the CCSC from Station –330+00 to Station 620+00 to a maximum depth of –81 MLLW (–77 feet MLLW plus two feet of advanced maintenance and two foot of allowable overdredge) to reach the –80-foot MLLW bathymetric contour in the Gulf of Mexico. The proposed project is needed to accommodate transit of fully laden very large crude carriers (VLCCs) that draft approximately 70 feet.

The purpose of this proposed sampling is to determine if the new work material sediments proposed to be dredged are acceptable for disposal in the Corpus Christi Ocean Dredge Material Disposal Site (ODMDS). This Sampling and Analysis Plan (SAP) was developed in compliance with the regulations outlined below.

1.2 BACKGROUND

Channel Deepening Project: Per Marine Protection, Research, and Sanctuaries Act (MPRSA) Section 103 guidelines, PCCA is requesting to place 38.4 million cubic yards (MCY) of new work material generated from the deepening of the Outer Channel Reach offshore in the Corpus Christi New Work ODMDS. Material in the Outer Channel Reach (Stations –620+00 to –330+00) is new work material, and therefore, no maintenance material is anticipated. In all other reaches, navigational maintenance dredging



N

Miles

0 2.5 5

Legend

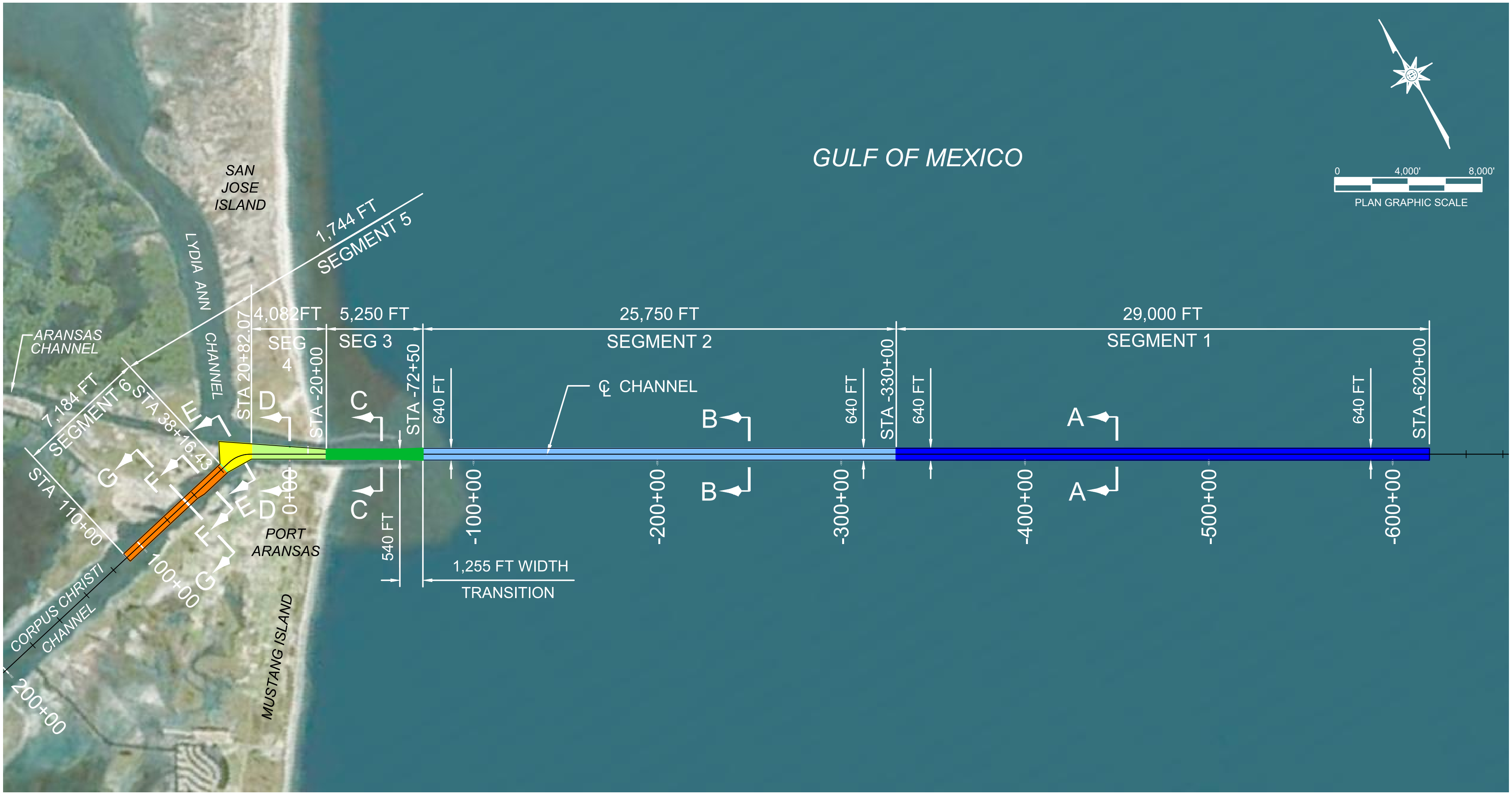
- Corpus Christi Ship Channel
- CCSC Deepening Extension
- Project Location
- Texas Coastal Boundary
- County Boundary

Title: **Vicinity Map**

Project: **Corpus Christi Ship Channel Deepening Project**

Client: **Port of Corpus Christi Authority**

Drawn By:	Date:	Project No.:
DS	5/28/2019	60578532



DREDGING PLAN

SCALE: 1" = 8000'

SEGMENT	STATIONING (@ CHANNEL CL) FROM	TO	*DEPTH (FT BELOW MLLW)	DESCRIPTION	PLAN VIEW LEGEND
1	STA -620+00	STA -330+00	-77.0	*Outer Channel*	(dark blue)
2	STA -330+00	STA -72+50	-77.0	*Approach Channel*	(light blue)
3	STA -72+50	STA -20+00	-75.0	*Jetties to Harbor Island Transition Flare*	(green)
4	STA -20+00	STA 20+82.07	-75.0	*Harbor Island Transition Flare*	(light green)
5	STA 20+82.07	STA 38+16.43	-75.0	*Harbor Island Junction*	(yellow)
6	STA 38+16.43	STA 110+00	-75.0	*Corpus Christi Channel*	(orange)

* DESIGN DEPTH SHOWN. DOES NOT INCLUDE 2.0 FT ADVANCED MAINTENANCE DREDGING OR 2.0 FT ALLOWABLE OVER DREDGE.

Corpus Christi Ship Channel Deepening Project
Individual Permit Application SWG-2019-00067

Preferred Channel Alternative

County: Aransas and Nueces
Application By: Port of Corpus Christi Authority
State: Texas
Date: April 2020

occurs at regular intervals and therefore, any shoaling will be negligible. A capacity analysis for expanding the Corpus Christi New Work ODMDS was performed on behalf of U.S. Environmental Protection Agency (EPA) Region 6 and the USACE Galveston District by a PCCA contract to Freese and Nichols, Inc. (2021). This analysis was accomplished using the MDFATE model and the coupled MPFATE/Delft3D models. The analysis concluded that an expanded New Work ODMDS could accommodate approximately 47.0 MCY of in-situ new work dredged material.

Assumptions: The proposed project includes a 29,000-foot extension of the CCSC from Station –330+00 to Station 620+00 to a maximum depth of –81 feet MLLW (–77 feet MLLW plus two feet of advanced maintenance and two feet of allowable overdredge) to reach the channel depth limits at the –80-foot MLLW bathymetric contour in the Gulf of Mexico.

Description: The CDP would deepen the channel from Station 110+00 to Station –72+50 to a maximum depth of –79 feet MLLW (–75 feet MLLW plus two feet of advanced maintenance and two feet of allowable overdredge), and from Station –72+50 to Station –620+00, the channel would be deepened to a maximum depth of –81 MLLW (–77 feet MLLW plus two feet of advanced maintenance and two feet of allowable overdredge). The project will generate approximately 46.0 MCY from channel stations 110+00 to –620+00. A total of 38.4 MCY from CDP is proposed for placement in the expanded New Work ODMDS.

New Work ODMDS Quantity Summary:

Design Volume	Advanced Maintenance	Paid Allowable Overdredge	Unpaid Allowable Overdredge
38.4 MCY	(2 feet)	(2 feet)	Zero

Location: The proposed CDP is located within the existing channel bottom of the CCSC stating at Station 110+00 near the southeast side of Harbor Island, traversing easterly through Aransas Pass, and extending beyond the currently authorized terminus Station –330+00 an additional 29,000 feet terminating out into the Gulf of Mexico at the proposed new Terminus Station –620+00, an approximate distance of 13.8 miles, in Port Aransas, Nueces County, Texas. The project can be located on the U.S. Geological Survey quadrangle map entitled: Port Aransas, Texas.

Type of Facility Involved: New Work ODMDS, formerly the U.S. Navy Homeport ODMDS, which is located approximately 15,300 feet southeast of the Aransas Pass South Jetty (see Figure 1).

Type of Activity Supported: The activity involves dredging of a portion of the CCSC.

Purpose of the Proposed Dredging: Deepening of the CCSC to accommodate safe navigation and transit of fully laden VLCCs.

Areas, Depths, Volume:

- Area: Approximately 1,150 acres
- Depth: The CCSC Outer Channel Reach (Stations –620+00 to –330+00) would be deepened to –77 feet required (–81 feet allowable) to accommodate safe navigation of VLCCs.
- Allowable Paid Overdredge: 2 feet
- Allowable Non-Paid Overdredge: N/A

Existing Conditions and Depth(s): Depths currently range from –54 feet and –56 feet MLLW between Station 110+00 to Station –330+00 and the Outer Channel Reach (Stations –620+00 to –330+00) is currently undredged with existing Gulf of Mexico sea bottom. Dredged material from the open water in this segment is expected to be new work material, consisting solely of undisturbed base layer geological formations free of impacts from industrial sources or transport mechanisms. The sediment in the area is expected to be similar to nearby areas of the channel for which testing has taken place.

Proposed Dredging Method: The project will be dredged by Cutter Suction Dredges, Trailing Hopper Dredges (Hopper), or by a combination of both.

Proposed Disposal Site/Zone: Corpus Christi Expanded New Work ODMDS

1.3 OBJECTIVES

The purpose of this MPRSA Section 103 sediment characterization testing program is to obtain concurrence from EPA for ocean disposal and Federal permits from USACE in support of new work and future maintenance dredging in the Outer Channel Reach.

The objectives of this Section 103 Testing Program are as follows:

- Provide a SAP for approval before sampling and testing work begins.
- Provide an effective Quality Assurance (QA) program which ensures that laboratory test data are defensible and of sufficiently high quality to support the final decisions regarding the suitability of the dredged materials sampled for ocean disposal.
- Collect a sufficient volume of sediment and site water for required tests and analyses from locations specified in this SAP.
- Collect reference sediment from a site offshore for use in test comparisons.
- Conduct sediment testing in accordance with requirements set forth in Ocean Dumping Regulations, guidance testing including the Regional Implementation Agreement (RIA) (EPA and USACE, 2003) and this scope of work. Provide sufficient information to determine if the proposed discharge of dredged materials will meet or exceed the Limiting Permissible Concentration (LPC) (40 Code of Federal Regulations [CFR] 227.27). Determine if the proposed dredged materials are acceptable for ocean disposal.

- Provide a MPRSA Section 103 sediment testing report and supporting documentation that describes all aspects of the study and presents the results of field sampling and the physical/chemical analyses of sediment. The report should provide the basis for a scientific recommendation regarding the management of dredged sediment.

1.4 PROJECT AUTHORITY AND NEW WORK REQUIREMENTS

The Corpus Christi New Work ODMDS was approved in 1989 and includes two areas, one for maintenance and the other for new work material. Material for this project would fall under the new work category.

On September 15, 2015, EPA modified 40 CRF Part 228 to allow other entities besides the USACE to seek permit approval by EPA to dispose of dredged material into ocean waters pursuant to the Marine Protection Research and Sanctuaries Act (Ocean Dumping Regulations). It is under this regulation that the PCCA is requesting the new work material dredged from the proposed CDP dredge footprint be approved for disposal at the Corpus Christi New Work ODMDS.

Additionally, in 2020, EPA Region 6 proposed to expand the New Work ODMDS to accommodate the placement of additional volumes of construction dredged material. In 2021, a capacity analysis for expanding the Corpus Christi New Work ODMDS was conducted by Freese and Nichols, Inc. (2021) and concluded that an expanded New Work ODMDS could accommodate approximately 47.0 MCY of in-situ new work dredged material.

The proposed CDP dredge area is approximately 1,150 acres. The CDP would deepen the channel from Station 110+00 to Station –72+50 to a maximum depth of –79 feet MLLW (–75 feet MLLW plus two feet of advanced maintenance and two feet of allowable overdredge), and from Station –72+50 to Station –620+00, the channel would be deepened to a maximum depth of –81 MLLW (–77 feet MLLW plus two feet of advanced maintenance and two feet of allowable overdredge). Approximately 46.0 MCY of material would be dredged by Cutter Suction Dredges, Trailing Hopper Dredges, or a combination of both. Of this, a total of 38.4 MCY from the CDP is proposed for placement in the expanded New Work ODMDS.

1.5 TIER I EVALUATION – POTENTIAL SOURCES OF CONTAMINATION

The following sections provide information related to previous material analysis at and adjacent to the proposed CDP as well as background information. This information is included within this SAP as a Tier I evaluation for the proposed CDP.

Historical testing and reporting are summarized in the CCSCIP Environmental Impact Statement (EIS) (USACE, 2003; Appendix A) and the 2018 MPRSA Section 103 Report (USACE, 2018). Findings from the CCSCIP EIS and subsequent sampling reviewed for the 2018 MPRSA Section 103 Report (USACE, 2018) are summarized below by test type and reach.

1.5.1 Corpus Christi Ship Channel Environmental Impact Statement (2003)

The CCSCIP EIS examined water, elutriate, and sediment samples from 1984, 1990, and 1999, and bioassay data from 1980, 1985, and 1995 for the Entrance Channel reach (Station –38+00 to 310+00). For the Lower Bay Channel reach (Station 12+55 to 54+00), data from 1986, 1988, and 1991 for water, elutriate, and sediment samples were examined, with bioassay data from 1981. These are summarized below.

1.5.1.1 Water and Elutriate Chemistry

Entrance Channel. Of the metals, arsenic and copper were found above detection limits in 1984. In 1999, arsenic, barium, cadmium, and zinc concentrations were found above detection limits for water and elutriate samples; nickel was detected in water samples; and chromium and copper were found only in elutriate samples. Elutriate concentrations in 1999 were consistently higher than ambient water concentrations, including Reference samples for barium and cadmium, but the opposite was true for zinc. All samples were well below the Texas Water Quality Standards except for copper in elutriate samples taken from the Harbor Island Transition Flair, however it was thought that the value may be an error since no trends for copper could be determined. Oil and grease were detected in 1984 for water and elutriate samples. No organics were detected in the 1990 or 1999 data for any medium, except for total organic carbon (TOC) and total petroleum hydrocarbons.

Elutriate bioassays were conducted on samples collected form the Entrance Channel in 1981. It was concluded that no acute toxicity to water column organisms could be expected from dredging the Entrance Channel or placement of Entrance Channel sediments.

There was no indication of water or elutriate problems in the Entrance Channel.

Lower Bay Channel. TOC was above detection limits in water and elutriate samples for two stations in 1991, at roughly the same range for both media. No other organics were detected in 1991 and no organics were reported in 1988 for water or elutriate samples. In the 1988, no Texas Water Quality Standards were exceeded in the water or elutriate samples. An increase in oil and grease and TOC in the elutriate samples was noticeable, although not high relative to other reaches, but elutriate concentrations in water samples were much lower than other reaches and the TOC values much higher comparable to the other reaches.

Toxicity testing was conducted on elutriate samples from maintenance material. It was concluded that no acute toxicity to water column organisms could be expected from dredging the Lower Bay Channel or placement of Lower Bay Channel sediments.

1.5.1.2 Sediment Chemistry

Entrance Channel. Arsenic was the only metal above detection limits in 1984; zinc was detected at all stations, chromium, and nickel at three stations, and copper at one station in 1990, all below the Effects Range Low (ERLs). Of the metals, only mercury (three stations), silver (one station), and selenium (no stations) were not found at all stations in 1999 samples. Aside from one sample in 1999 that exceeded the ERL for mercury, there was no indication of a cause for concern relative to maintenance material quality.

Solid Phase bioassays were conducted, it was concluded that no significant undesirable impacts would occur from ocean placement of maintenance material dredged from the Entrance Channel.

Lower Bay Channel. In 1988, chromium, copper, lead, and nickel were all above detection limits for one station and zinc was detected at all stations. In 1991, cadmium, chromium, copper, nickel, and zinc were found at most stations. The values for chromium, copper, nickel, and zinc for 1988 and 1991 were similar. No organics were detected sediments, and no ERLs were exceeded. There was no indication of a cause for concern relative to maintenance material quality.

Solid Phase bioassays were conducted, it was concluded that no significant undesirable impacts would occur from ocean placement of maintenance material dredged from the lower Bay Channel.

1.5.2 Corpus Christi Ship Channel Pre-Dredge Testing (2018)

The majority of the proposed CDP reach was recently tested for offshore disposal under MPRSA Section 103 as part of the CCSCIP. The results were documented in Sampling, Chemical Analysis, and Bioassessment in Accordance with MPSRA Section 103 (USACE, 2018). Based on the results of the sampling, testing, and evaluation of the CCSC Entrance Channel and Extension sediment completed in 2018, site water, and elutriate, as well as toxicity and bioaccumulation testing, a Lines-of-Evidence analysis concluded that no adverse environmental effects would be expected from dredging or placement of the sediment from the project area into the New Work ODMDS. The sediments from the six reaches of the project area met the LPC were deemed suitable for open water ocean placement.

In general, there are no chemicals of concern present in the CCSC Entrance Channel (Jetties to Harbor Island Transition Flare), Entrance Channel Extension (Approach Channel), and Lower Bay (Harbor Island Transition Flare, Harbor Island Junction, and Corpus Christi Channel) (Stations –330+00 to +70+00). Therefore, this SAP focuses on the Outer Channel from Station –330+00 to Station –620+00. However, due to the Harbor Island site history (see Section 1.5.3), this SAP also includes additional DMU sampling points in the vicinity of Harbor Island within the Harbor Island Junction and CCSC.

Based on the 2018 results of the sampling, testing and evaluation of the CCSC Entrance Channel and Extension sediment, site water, and elutriate, as well as toxicity and bioaccumulation testing, a LOE analysis concluded that no adverse environmental effects would be expected from dredging or placement of the sediment from the project area into the New Work ODMDS. The sediments from the project area met the LPC and were suitable for open water ocean placement in the New Work ODMDS.

The following summarizes the sampling conducted, and the conclusion from the results:

1.5.2.1 Particle Size Analysis

All sample locations and the Reference Area, except Dredge Material Management Unit (DMMU)-03, were dominated by sand ranging from 58 to 84%, with the remainder of particles silt and clay. DMMU-03 was classified as having a high percentage of sand but low fines and varied significantly from the sediment analyzed at the other channel DMMUs. The material at DMMU-03 met the exclusion criteria as defined in the RIA and is compliant with the regulations.

1.5.2.2 Site Water Chemistry

Site water was analyzed for semi-volatile volatile organic compounds (SVOCs), polyaromatic hydrocarbons (PAH), and pesticides all samples were below the Target Detection Limit (TDL) and published screening criteria, although for toxaphene (pesticide) the Laboratory Reporting Limit (LRL) is greater than the screening criteria, but at a non-detect concentration. with the exception of toxaphene (pesticides). Since all samples were non-detect and reported below TDL, no additional evaluations were considered.

Silver and cadmium were the only metals below Method Detection Limits (MDLs) at all stations, therefore non-detects. The remaining (arsenic, copper, lead, mercury, nickel, selenium, zinc) were above the MDL in one or more site water samples, but all were below LRL. Arsenic, cadmium, copper, nickel, silver, and zinc concentrations exceeded the TDLs. Silver exceeded the published screening criteria, but concentrations were below non-detect and MDL, therefore silver was reported at LRL.

Ammonia concentrations exceeded the TDL for all site water samples, with concentrations ranging from 98.2 micrograms per liter (ug/L) to 110 ug/L. Total organic carbon for all samples were below TDL. Total suspended solids concentrations ranged between 1,930 ug/L to 5,250 ug/L, and exceeded the TDL for all samples, but the actual MDL achieved was well below the TDL.

1.5.2.3 Sediment Chemistry

Sediment samples were analyzed for volatile organic compounds (VOCs) and SVOCs, all samples were below the MDL and TDL, and reported as LRLs. Additionally, 17 PAHs were tested 11 PAHs were above the MDL including: benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k) fluoranthene, chrysene, fluoranthene, indeno(1,2,3-cd)pyrene, naphthalene, phenanthrene, and pyrene. Of these, chrysene, fluoranthene, and pyrene were detected above the LRL in sample DMMU CCNEW-02 (Entrance Channel), the rest were reported as non-detects. All analytes in all samples were below the TDL and published screening criteria where applicable. Polychlorinated biphenyls (PCBs) were below MDL and TDL in all samples.

All pesticides samples were below MDLs, laboratory detection limits, and screening criteria except for dieldrin. Although dieldrin was below the TDL for all samples, concentrations were greater than minimum screening criteria.

All metals analyzed were detected above the MDL in each sample, with the exception of cadmium in sample DMMU CCNEW-05 (Inner Basin to La Quinta) which was below the MDL. Arsenic, cadmium, total chromium, copper, lead, nickel, zinc) exceeded the TDLs; however, none exceeded the published screening criteria where available. As metals were detected in sediments, further evaluation of all 12 metals (antimony, arsenic, beryllium, cadmium, total chromium, copper, lead, mercury, nickel, selenium, silver, zinc) was required.

All samples exceeded TDLs for ammonia. TOC results were all below the TDL.

1.5.2.4 Elutriate Chemistry

Elutriate samples analyzed for SVOCs were below the MDL, TDL, and published screening criteria. PAHs were below the MDL and TDL for all samples. All pesticides samples were below the MDL and equal to the LRL, with the exception of alpha-BHC and beta-BHC. All samples were below TDLs with the exception of toxaphene.

For metals, arsenic, cadmium, copper, lead, mercury, nickel, selenium, silver, and zinc were detected above the MDL in at least one elutriate sample, all were greater than the MDL but below the LRL. Result concentrations for all but lead exceeded the TDLs, and of these, only silver exceeded the screening criteria. Silver concentrations were below the MDL and the LRL exceeded both applicable screening criteria and as a result was evaluated in the STFATE model.

All samples exceeded TDLs for ammonia and ranged from 1,520 ug/L to 5,610 ug/L. All samples were below the TDL for dissolved organic carbon and TOC. Total suspended solid concentrations exceeded the TDL.

1.5.2.5 Elutriate Bioassay

Three bioassay methods were used to assess the sediment elutriates, *Americamysis bahia* (48-hour method), *Americamysis bahia* (96-hour method), and *Menidia beryllina*. No significant toxicity was observed for any of the elutriate toxicity tests.

1.5.2.6 Whole Sediment Toxicity Bioassay

Two whole sediment toxicity bioassays were conducted, *Leptocheirus plumulosus* (10-day toxicity test) and *Americamysis bahia* (10-day toxicity test). Tests indicate no acute toxicity and the sediments from all the DMMUs met the limiting permissible concentration (LPC) for open water dredged sediment placement.

1.5.2.7 Whole Sediment Bioaccumulation

Whole sediment bioaccumulation tests for *Nereis virens* (28-day bioaccumulation) and *Macoma nasuta* (28-day bioaccumulation) were conducted. The results of testing and lines-of-evidence analysis indicate no significant contaminant bioaccumulation and the sediments from all DMMUs meet the LPC for open water dredged sediment placement.

1.5.3 Harbor Island Site History

Settled as early as 1833 as Sand Point, Port Aransas served as a point of commerce along the Texas coast. In the 1850s, regular steamship service ran between Port Aransas and the City of New Orleans in Louisiana. The City of Port Aransas was incorporated in 1911 with its original boundaries including only the tip of Harbor Island. Several ordinances were passed between 1970 and 1980 to incorporate more of Harbor Island into Port Aransas. Port Aransas now encompasses over 900 acres on Harbor Island. Port Aransas has developed since that time with a varied combination of residential, retail, light commercial and public land uses as well as some interspersed heavy commercial land uses (i.e., welding shops, lumber yards, nurseries, boat repair and storage facilities, construction companies, and construction yards) (City of Port Aransas, 2006). Port Aransas has largely continued its growth as a tourism center.

Harbor Island has been developed since as early as 1857 when Aransas Pass had become popular enough to warrant a lighthouse on the island. In the early 1900s, the USACE deepened Aransas Pass and dredged a deepwater port at Harbor Island. Since 1912, the port has seen the following significant industrial and maritime uses (Guthrie, 1986):

- Cotton compress and shipping from 1912 to 1926
- Shipyard from 1918 to 1919
- Oil terminals from 1912 to 1993
- Offshore rig fabrication from 1976 to 2003
- Offshore services from 1993 to today
- Transshipment of Eagle Ford Shale crude oil

Industrial operators on Harbor Island over the past 100 years have included Aransas Pass Channel and Dock Co. (port services), Aransas Harbor Terminal Railway Inc. (rail terminal), Magnolia Oil (terminal storage), Humble Oil (terminal storage), Atlantic Richfield (terminal storage), American Petrofina (terminal storage), France & Canada Transportation Co. (ferry operations), Brown & Root (fabrication), J. Ray McDermott (fabrication), Haliburton (offshore services), and Martin Midstream (offshore services) (Ford, 2013).

Harbor Island is zoned "HI" which is special use district that allows industrial uses not zoned in other developed areas of Port Aransas. A former shipyard and offshore services facility are present on Harbor Island today.

The Port of Corpus Christi is the third largest U.S. port and includes cargo shipping and receiving facilities for offshore drilling, wind turbine production, steel and steel pipe production, and heavy machinery. In addition, several facilities in and around the port contribute to increasing volumes of chemicals, crude oil, and petroleum products (PCCA, 2016).

The industrial land uses in the project area since as early as the 1910s has the potential to impact the chemical composition of deposited sediments. Specifically, petroleum hydrocarbons and VOCs used and/or stored in terminal storage facilities, shipyards, and other industries in the project area are potential contaminants in the deposited sediment. In addition, over 7,165 emergency response records were identified since 2001 for unauthorized releases/spills of oil and hazardous substances that were reported to the National Response Center.

1.5.4 Chemical Releases

The CDP is composed of six reaches as shown in Figure 2 and the anticipated dredged material by reach is described below:

1. Outer Channel (Gulf of Mexico) (Stations –620+00 to –330+00) – Dredged material from the open water in this segment is expected to be new work material, consisting solely of undisturbed base layer geological formations less likely to be impacted by industrial sources or transport mechanisms.
2. Approach Channel (Stations –72+50 to –330+00) – Dredged material in this reach from the open water is expected to be new work material, consisting solely of undisturbed base layer geological formations less likely to be impacted by industrial sources or transport mechanisms.
3. Jetties to Harbor Island Transition Flare (Stations –72+50 to –15+08.24) – Dredged material in this reach is regularly maintenance dredged. While previous studies and regulated uses in the surrounding area, including 102 reported releases or spills since 2001, 13 past or current leaking petroleum storage tank sites, and four registered hazardous waste generators, indicate that a limited quantity of the dredged material may potentially be impacted by industrial sources in the area, dredged material in this reach is expected to be new work material, consisting solely of undisturbed base layer geological formations less likely to be impacted by industrial sources or transport mechanisms due to the high energetics of this reach and extensive scouring.
4. Harbor Island Transition Flare (Stations –15+08.24 to Station 19+48.10) – Dredged material in this reach is regularly maintenance dredged. While previous studies and regulated uses in the surrounding area, including 142 reported releases or spills since 2001, 14 past or current leaking petroleum storage tank sites, 23 registered aboveground petroleum storage tank sites, and five registered hazardous waste generators, indicate that a limited quantity of the dredged material may potentially be impacted by industrial sources in the area, dredged material in this reach is expected to be new work material, consisting solely of undisturbed base layer geological formations less likely to be impacted by industrial sources or transport mechanisms due to the high energetics of this reach and extensive scouring.
5. Harbor Island Junction (Stations 19+48.10 to Station 38+16.42) – Dredged material in this reach is regularly maintenance dredged. While previous studies and regulated uses in the surrounding

area, including 102 reported releases or spills since 2001, 13 past or current leaking petroleum storage tank sites, and four registered hazardous waste generators, indicate that a limited quantity of the dredged material may potentially be impacted by industrial sources in the area. Although, dredged material in this reach is expected to be new work material, consisting mostly of undisturbed base layer geological formations, the close proximity of this reach to Harbor Island increases the risk that this area may have been exposed to contaminant transport mechanisms from industrial sources.

6. Corpus Christi Channel (Stations 38+16.42 to Station 110+00) – Dredged material in this reach is regularly maintenance dredged. While previous studies and regulated uses in the surrounding area, including 147 reported releases or spills since 2001, four closed landfills or dump sites, one active citizens collection station, 16 past or current leaking petroleum storage tank sites, 25 registered aboveground petroleum storage tank sites, and six registered hazardous waste generators, indicate that a limited quantity of the dredged material may potentially be impacted by industrial sources in the area. Although, dredged material in this reach is expected to be new work material, consisting mostly of undisturbed base layer geological formations, the close proximity of this reach to Harbor Island increases the risk that this area may have been exposed to contaminant transport mechanisms from industrial sources.

2.0 SCOPE OF WORK

2.1 GENERAL

Sediment, water, and elutriate samples, plus one duplicate of each will be collected from dredging units located within the proposed PCCA CDP footprint as outlined in this SAP, and all collected sample material will be delivered to the analytical laboratories. The laboratories will be accredited through the National Environmental Laboratory Accreditation Program (NELAP) for the analytes/analyte groups and matrices to be analyzed. All samples will be collected within a schedule suitable to meet analytical hold-time requirements. The evaluation of samples will include chemical and physical analysis of sediment, water and standard elutriate samples, and bioassays. Procedures for sample collection, required volume, handling, preservation and storage, and shipment to the laboratory are outlined in the proceeding sections.

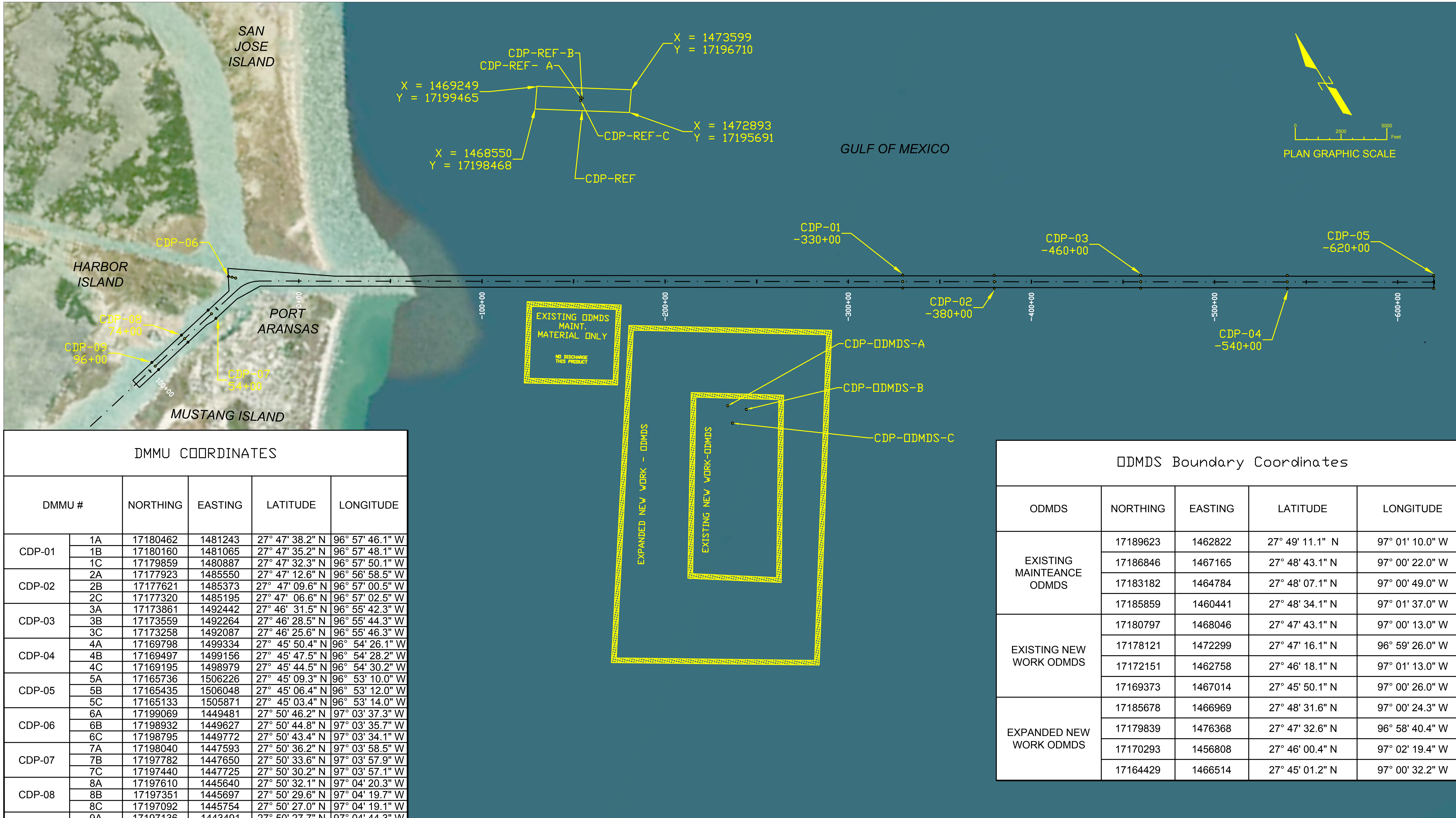
2.2 PROJECT AREA

Samples will be collected from the proposed PCCA CDP footprint, existing New Work ODMDS, and Reference Area (Figure 3).

2.3 SAMPLE LOCATIONS AND TYPE

Samples will evaluate site surface water, sediment, elutriates, Suspended Particulate Phase (SPP) bioassay, direct toxicity bioassay and the bioaccumulation bioassays for new work sediments within the Outer Channel Reach, Harbor Island Junction, and Corpus Christi Channel adjacent to Harbor Island. Surficial samples will be required at the Reference Area. Dredged material sampling locations have been selected to be spatially representative of the dredging prism materials and, for inshore channel samples proximity to Harbor Island. Sampling to refusal addresses the vertical component of the dredging prism. Water and sediment samples are to be collected from the dredge prism within each Dredge Material Management Unit (DMMU) for the purpose of conducting testing to characterize the material that will be excavated. Table 1 gives a summary of the proposed sample collection locations and sample testing. The location and number of samples are described in the following sections.

Sample locations and types are specified in Table 1. Sample coordinates have been selected based upon bathymetry surveys from 2018 (offshore) and 2021 (inshore). Exact sample coordinates for the DMMU stations will be determined in the field at the time of sampling. Each sample will be a composite of three samples from within each DMMU. If a sample cannot be acquired at a designated location, the location will be moved the least distance possible within the DMMU, while remaining within the dredge prism, it must be coordinated with the EPA beforehand.



DMMU COORDINATES

DMMU #		NORTHING	EASTING	LATITUDE	LONGITUDE
CDP-01	1A	17180462	1481243	27° 47' 38.2" N	96° 57' 46.1" W
	1B	17180160	1481065	27° 47' 35.2" N	96° 57' 48.1" W
	1C	17179859	1480887	27° 47' 32.3" N	96° 57' 50.1" W
CDP-02	2A	17177923	1485550	27° 47' 12.6" N	96° 56' 58.5" W
	2B	17177621	1485373	27° 47' 09.6" N	96° 57' 00.5" W
	2C	17177320	1485195	27° 47' 06.6" N	96° 57' 02.5" W
CDP-03	3A	17173861	1492442	27° 46' 31.5" N	96° 55' 42.3" W
	3B	17173559	1492264	27° 46' 28.5" N	96° 55' 44.3" W
	3C	17173258	1492087	27° 46' 25.6" N	96° 55' 46.3" W
CDP-04	4A	17169798	1499334	27° 45' 50.4" N	96° 54' 26.1" W
	4B	17169497	1499156	27° 45' 47.5" N	96° 54' 28.2" W
	4C	17169195	1498979	27° 45' 44.5" N	96° 54' 30.2" W
CDP-05	5A	17165736	1506226	27° 45' 09.3" N	96° 53' 10.0" W
	5B	17165435	1506048	27° 45' 06.4" N	96° 53' 12.0" W
	5C	17165133	1505871	27° 45' 03.4" N	96° 53' 14.0" W
CDP-06	6A	17199069	1449481	27° 50' 46.2" N	97° 03' 37.3" W
	6B	17198932	1449627	27° 50' 44.8" N	97° 03' 35.7" W
	6C	17198795	1449772	27° 50' 43.4" N	97° 03' 34.1" W
CDP-07	7A	17198040	1447593	27° 50' 36.2" N	97° 03' 58.5" W
	7B	17197782	1447650	27° 50' 33.6" N	97° 03' 57.9" W
	7C	17197440	1447725	27° 50' 30.2" N	97° 03' 57.1" W
CDP-08	8A	17197610	1445640	27° 50' 32.1" N	97° 04' 20.3" W
	8B	17197351	1445697	27° 50' 29.6" N	97° 04' 19.7" W
	8C	17197092	1445754	27° 50' 27.0" N	97° 04' 19.1" W
CDP-09	9A	17197136	1443491	27° 50' 27.7" N	97° 04' 44.3" W
	9B	17196877	1443548	27° 50' 25.1" N	97° 04' 43.7" W
	9C	17196618	1443605	27° 50' 22.5" N	97° 04' 43.1" W
CDP-REF	REF A	17197759	1471021	27° 50' 30.7" N	96° 59' 37.6" W
	REF B	17197676	1471064	27° 50' 29.9" N	96° 59' 37.1" W
	REF C	17197591	1470920	27° 50' 29.0" N	96° 59' 38.7" W
CDP-ODMDS	ODMDS-A	17179158	1469397	27° 47' 26.7" N	96° 59' 58.1" W
	ODMDS-B	17178470	1470167	27° 47' 19.8" N	96° 59' 49.6" W
	ODMDS-C	17178211	1469136	27° 47' 17.4" N	97° 00' 01.2" W

ODMDS Boundary Coordinates

ODMDS	NORTHING	EASTING	LATITUDE	LONGITUDE
EXISTING MAINTENANCE ODMDS	17189623	1462822	27° 49' 11.1" N	97° 01' 10.0" W
	17186846	1467165	27° 48' 43.1" N	97° 00' 22.0" W
	17183182	1464784	27° 48' 07.1" N	97° 00' 49.0" W
	17185859	1460441	27° 48' 34.1" N	97° 01' 37.0" W
EXISTING NEW WORK ODMDS	17180797	1468046	27° 47' 43.1" N	97° 00' 13.0" W
	17178121	1472299	27° 47' 16.1" N	96° 59' 26.0" W
	17172151	1462758	27° 46' 18.1" N	97° 01' 13.0" W
	17169373	1467014	27° 45' 50.1" N	97° 00' 26.0" W
EXPANDED NEW WORK ODMDS	17185678	1466969	27° 48' 31.6" N	97° 00' 24.3" W
	17179839	1476368	27° 47' 32.6" N	96° 58' 40.4" W
	17170293	1456808	27° 46' 00.4" N	97° 02' 19.4" W
	17164429	1466514	27° 45' 01.2" N	97° 00' 32.2" W

GENERAL NOTES

1. HORIZONTAL COORDINATE SYSTEM IS NAD83 TEXAS STATE PLANE, SOUTH ZONE, US FOOT.
2. VERTICAL DATUM IS REFERENCED TO NORTH AMERICAN VERTICAL DATUM OF 1958 (NAVD88)

Corpus Christi Ship Channel Deepening Project
FIGURE 3
SAMPLING LOCATIONS

Application By: Port of Corpus Christi Authority

State: Texas

SAP Date: September 2021

Table 1
Summary of Sample Collection and Testing

DMMU Number		Station	Distance from Channel Center Line (feet)	Coordinates*		Sample Matrix		
				X	Y	Sediment	Surface Water	Elutriate
CDP-01	1A	–330+00	350	1481243	17180462	X	X	X
	1B		0	1481065	17180160			
	1C		–350	1480887	17179859			
CDP-02	2A	–380+00	350	1485550	17177923	X	X	X
	2B		0	1485373	17177621			
	2C		–350	1485195	17177320			
CDP-03	3A	–460+00	350	1492442	17173861	X	X	X
	3B		0	1492264	17173559			
	3C		–350	1492087	17173258			
CDP-04	4A	–540+00	350	1499334	17169798	X	X	X
	4B		0	1499156	17169497			
	4C		–350	1498979	17169195			
CDP-05	5A	–620+00	350	1506226	17165736	X	X	X
	5B		0	1506048	17165435			
	5C		–350	1505871	17165133			
CDP-06	6A	31+93	558	1449481	17199069	X	X	X
	6B	32+90	708	1449627	17198932			
	6C	33+75	865	1449772	17198795			
CDP-07	7A	54+00	265	1447593	17198040	X	X	X
	7B		0	1447650	17197782			
	7C		–350	1447725	17197440			
CDP-08	8A	74+00	265	1445640	17197610	X	X	X
	8B		0	1445697	17197351			
	8C		–265	1445754	17197092			
CDP-09	9A	96+00	265	1443491	17197136	X	X	X
	9B		0	1443548	17196877			
	9C		–265	1443605	17196618			
CDP-REF	REF A	N/A	N/A	1471021	17197759	X	X	
	REF B			1471064	17197676			
	REF C			1470920	17197591			
CDP-ODMDS	ODMDS-A	N/A	N/A	1469397	17179158	X	X	
	ODMDS-B			1470167	17178470			
	ODMDS-C			1469136	17178211			

* NAD83 Texas State Plane, South Zone

A total of 11 water and 30 sediment samples will be collected: 27 new work material sediment samples, plus three sediment samples from the Reference Area. Only three water samples will be collected from the New Work ODMDS. One water sample will be collected from the central location at each station from approximately mid-column depth. Bioassay site water will also be collected from each DMMU. Water depths are expected to be about –50 to –80 feet within the DMMUs; –46 to –53 feet at the New Work ODMDS; and –46 to –53 feet at the Reference Area.

Eleven DMMUs will be sampled: nine in the new work improvement area, one at the Reference Area and one at the ODMDS. Each sample is a composite of material representative of the DMMU at that station. The three proposed sampling locations within each DMMU are selected to transect the channel. The location of these sampling points is based upon geotechnical boring information from the CCSC Plans (Appendix B) and hydrographic surveys:

- DMMU CDP-01 (Station –330+00) – This DMMU is located between BH-14 and BH-15 which show materials in this area to be predominantly silty sands with alternative layers of clays. One composited sample is proposed for this reach.
- DMMU CDP-02 (Station –380+00) – This DMMU is located between BH-12 and BH-13 which show materials in this area to be predominantly clays with pockets of clayey sands. One composited sample is proposed for this reach.
- DMMU CDP-03 (Station –460+00) – This DMMU is located between BH-9 and BH- 10 which show materials in this area to be predominantly lean and fat clays. One composited sample is proposed for this reach.
- DMMU CDP-04 (Station –540+00) – BH-6 is located in proximity to this DMMU with materials consisting predominantly of lean and fat clays. One composited sample is proposed for this reach.
- DMMU CDP-05 (Station –620+00) – BH-3 is located in proximity to this DMMU with materials consisting predominantly of lean and fat clays. One composited sample is proposed for this reach.
- DMMU CDP-06 (Station 32+90) – CDP-06 is within the Harbor Island Junction located within an area of shoaling (USACE, 2021) that is immediately east of the southeast corner of Harbor Island. BH-37 is the nearest boring to this DMMU, which consists of clayey sand with an overlay of lean clay. Sediment chemistry must be conducted prior to compositing. One composited sample is proposed for this station for bioassay and bioaccumulation testing.
- DMMU CDP-07 (Station 54+00) – CDP-07 is within the Corpus Christi Channel with BH-38 as the nearest boring to this DMMU with materials consisting predominantly of clayey sand and fat clay, with slightly shallower bathymetry at the channel toes (USACE, 2021). Sediment chemistry must be conducted prior to compositing. One composited sample is proposed for this station for bioassay and bioaccumulation testing.
- DMMU CDP-08 (Station 74+00) – CDP08- is within the Corpus Christi Channel with BH-38 and CB-2 as the nearest borings to this DMMU with materials consisting of a mix of clayey sand, lean clay, and fat clay, with slightly shallower bathymetry at the channel toes (USACE, 2021). Sediment chemistry must be conducted prior to compositing. One composited sample is proposed for this station for bioassay and bioaccumulation testing.

- DMMU CDP-09 (Station 96+00) – CDP-09 is within the Corpus Christi Channel with CB-3 as the nearest boring to this DMMU with materials consisting of predominantly silty sand, with slightly shallower bathymetry at the channel toes (USACE, 2021). Sediment chemistry must be conducted prior to compositing. One composited sample is proposed for this station for bioassay and bioaccumulation testing.
- DMMU CDP-REF (Reference Area) – Sediment samples will be acquired from three locations within the Reference Area and composited to form one Reference Area sample. The water sample will be collected from REF B.
- DMMU CDP-ODMDS (Placement Area [New Work ODMDS]) – Sediment samples will be acquired from three locations within the ODMDS and composited to form one ODMDS sample. The water sample will be collected from ODMDS B.

Numbers and types of samples are detailed in Table 1 and summarized in Table 2 as follows:

Table 2
Summary of Samples to be Collected

DMMU	Segment	Station	Media	Tests
CDP-01	open bay, channel extension	–330+00	SW, SD	physical, chemical, elutriate, bioassays
CDP-02	open bay, channel extension	–380+00	SW, SD	physical, chemical, elutriate, bioassays
CDP-03	open bay, channel extension	–460+00	SW, SD	physical, chemical, elutriate, bioassays
CDP-04	open bay, channel extension	–540+00	SW, SD	physical, chemical, elutriate, bioassays
CDP-05	open bay, channel extension	–620+00	SW, SD	physical, chemical, elutriate, bioassays
CPD-06	Harbor Island Junction, channel deepening	32+90	SW, SD	physical, chemical, elutriate, bioassays
CDP-07	Corpus Christi, Channel, channel deepening	54+00	SW, SD	physical, chemical, elutriate, bioassays
CPD-08	Corpus Christi Channel, channel deepening	74+00	SW, SD	physical, chemical, elutriate, bioassays
CDP-09	Corpus Christi Channel, channel deepening	96+00	SW, SD	physical, chemical, elutriate, bioassays
CDP-Ref	Reference Area	N/A	SW, SD	physical, chemical, elutriate, bioassays
CDP-ODMDS	ODMDS	N/A	SW, SD	physical, chemical, elutriate, bioassays

SW = surface water

SD = sediment

For sediment collection, dredge material sampling will be collected as transects at any given station, however, recent bathymetry (Appendix B) indicates scouring in some locations that may make transects impossible in some sections of the ship channel. In such instances, sampling may shift to be longitudinal to one side of the channel within the DMMU where new work material within the dredge prism is evident. If a sample cannot be acquired at a designated location, the location will be moved the least distance possible, while remaining within the dredge prism and within the DMMU, it must be coordinated with the EPA beforehand. Due to the minimal sampling plan, samples must be collected from all DMMUs, so depth readings will be used to select alternate locations if necessary. Accuracy of the sampling locations is critical in that they must be within the dredge prism. All field conditions and decisions made will be documented in the field notes, the contractors report, and the final project report. For the Reference Area, three samples will be collected from the central portion of the area (Figure 3).

2.4 GENERAL INSTRUCTIONS FOR SAMPLE COLLECTION

All samples will be collected as specified in Table 3. All sediment and water sample collection, handling, preservation, storage and tracking will be conducted in accordance with this Statement of Work (SOW)/SAP and the protocols outlined in Chapter 8 of the Green Book (EPA and USACE, 1998). Specific instructions on water and sediment are provided below. All samples must be collected within a 3- or 4-day window to meet analytical hold-time requirements. Specific instructions on water and sediment are provided below.

2.4.1 Station Positioning

Easting and northing (NAD83 Texas State Plane, South Zone) coordinates for all proposed sample locations are provided in Table 1. Exact sample coordinates for the DMMU stations will be determined in the field at the time of sample acquisition. The location of each sampling station shall be determined and recorded in the field at the time of sampling using a Differential Global Positioning System with ±6-foot horizontal accuracy. Three sample locations will be selected prior to going to the field for the Reference Area sampling locations such that three locations are approximately distributed over the central area of both areas. One central sampling location for the collection of surface water at the New Work ODMDS will be selected prior to starting field activities.

The station coordinates will be entered into a Garmin GPS (or equivalent) receiver capable of less than 10-meter accuracy, as well as a backup GPS unit. Coordinates entered into all GPS units will be double-checked, and target sampling stations will be plotted on a map prior to field sampling to make sure they are within the correct sampling areas and within dredge prism boundaries. Using the vessel's GPS, the captain will navigate as closely as possible to the target sampling location (typically within 100 feet of the target). GPS coordinates will be collected each time the sampler is deployed. Any sample that is not within 100 feet of the target location will be rejected and discarded or the reasons for not collecting a sample within 100 feet of the target location will be documented. The actual sampling points will be plotted on a map and provided in the report to document the accuracy of target sampling stations. Sediment surface and water elevations at each station will be determined in feet MLLW using a Spectra Precision SP80 Global Navigation Satellite System (accurate to ±2 centimeters) interfaced with the RTKNet network. Real-time water levels from the National Oceanic and Atmospheric Administration

Table 3

Summary of Recommended Procedures for Sample Collection Preservation and Storage[a]

Analyses/Test (per sample basis, 10 samples total)	Collection Method[b]	Volume Required[c]	Container[d]	Preservation Technique	Storage Conditions	Holding Times[e]
SEDIMENT (Volume per Sampling Point)						
Chemical/Physical Analyses, Elutriate Prep for Chemical Analyses and Bioassays						
Elutriate Prep for Chemical Analysis and Bioassay Volume of Sediment Required	Core/Grab	Standard Sample 34.6 gallons/QC Sample 39.4 gallons	5 gallon bucket	Completely fill and refrigerate	4°C/dark/ airtight	8 weeks
PAH and PCP	Core/Grab	250 grams	Solvent-rinsed amber glass jar with Teflon lid[f]	Dry ice[f] or freezer storage for extended storages; otherwise refrigerate	4°C[f]/dark[g]	14 days (extraction)[h]
Total Polychlorinated Biphenyl (PCBs) and Chlorinated Pesticides	Core/Grab	250 grams	Solvent-rinsed amber glass jar with Teflon lid[f]	Dry ice[f] or freezer storage for extended storages; otherwise refrigerate	4°C[f]/dark[g]	14 days (extraction)[h]
Metals	Core/Grab	100 grams	Amber glass jar	Dry ice[f] or freezer storage for extended storages; otherwise refrigerate	4°C	Mercury - 28 days Others - 180 days
Grain Size	Core/Grab	1,000 grams	Whirl-pac bag[f]	Refrigerate	<4°C	Undetermined
Total Organic Carbon	Core/Grab	50 grams	Heat treated amber glass jar	Dry ice[f] or freezer storage for extended storages; otherwise refrigerate	4°C[f]	14 days
Ammonia	Core/Grab	40 grams	Glass jar	Refrigerate	<4°C	7 days
pH	Core/Grab	50 grams	Glass jar	Refrigerate	<4°C	Immediate
Total solids	Core/Grab	50 grams	Whirl-pac bag	Refrigerate	<4°C	Undetermined
Miscellaneous	Core/Grab	50 grams	Whirl-pac bag	Refrigerate	<4°C	Undetermined
Volume of Sediment Required per DMMU	1 gallon total for chemical analysis (media) + 34 gallons for elutriates/bioassays; each duplicate requires 35 gallons					
Total Volume Sediment Required for 9-DMMUs + Reference	350 gallons total for chemical analysis (media), elutriates/bioassays; duplicate samples require 35 gallons each					

Analyses/Test (per sample basis, 10 samples total)	Collection Method[b]	Volume Required[c]	Container[d]	Preservation Technique	Storage Conditions	Holding Times[e]
SURFACE WATER						
Chemical/Physical Analyses, Elutriate Prep for Chemical Analyses and Bioassays						
Elutriate Prep for Chemical Analyses and Bioassay Volume of site Water Required	Discrete sampler or pump	30 gallons	5 gallon cubitainer	Completely fill and refrigerate	4°C/dark/ airtight	14 days
PAHs and PCP	Discrete sampler or pump	2 liters	Amber glass bottle with Teflon-lined lid[k]	pH <2, $Na_2S_2O_3$; airtight seal; refrigerate	4°C[k]	7 days for extraction; 40 days for extract analysis[k]
Total PCBs and Chlorinated Pesticides	Core	4 liters	Solvent-rinsed amber glass jar with Teflon lid[f]	Dry ice[f] or freezer storage for extended storages; otherwise refrigerate	4°C[f]/dark[g]	14 days (extraction)[h]
Metals	Discrete sampler or pump	250 milliliters	Acid-rinsed polyethylene or glass jar[k]	PH <2 with HNO_3[k]; refrigerate	4°C - 2°C[k]	Mercury - 14 days Others – 180 days
Ammonia	Discrete sampler or pump	500 milliliters	Plastic	H_2SO_4 to pH <2; refrigerate	4°C	7 days
Total Suspended Solids	Discrete sampler or pump	1,000 milliliters	Plastic or glass	Fill completely and refrigerate	4°C	7 Days
Total organic carbon	Discrete sampler or pump	100 milliliters	Amber glass VOA vials	H_2SO_4 to pH <2; refrigerate	4°C[l]	28 days[l]
Volume of Site Water per DMMU	2 gallons for chemical analysis (media) + 38 gallons for elutriate/bioassays					
Total Volume Surface Water Required for 9-DMMUs + Reference + New Work ODMDS	22 gallons for chemical analysis (media) + 418 gallons elutriate/bioassay[q]					

Analyses/Test (per sample basis, 10 samples total)	Collection Method[b]	Volume Required[c]	Container[d]	Preservation Technique	Storage Conditions	Holding Times[e]
			BIOASSAY (Tissue Analyses)[o]			
			Chemical Analysis			
Mass of Tissue from Bioassays[p] per DMMU	30 – 35 grams per replicate for each chemical analyses + 55 – 65 grams for QC					
Total Mass of Tissue for 9-DMMUs + Reference	1,800 – 2,100 grams for all chemical analyses + 220 – 260 grams for QC					

°C = degrees Centigrade; QC = quality control

Footnotes:

a (i) primary reference EPA and USACE (2003) revised for a project and site-specificity
(ii) This table contains only a summary of collection, preservation, and storage procedures for samples. Consultation with the selected analytical provider will be completed to confirm or modify for site-specific sampling and analyses. Table based upon the Inland Testing Manual (ITM), EPA-823-B-98-004

b Collection method should include appropriate liners

c Amount of sample required by the laboratory to perform the analysis (wet weight or volume provided, as appropriate). THESE QUANTITIES WILL BE CONFIRMED WITH THE ANALYTICAL PROVIDER PRIOR TO SAMPLE COLLECTION. Miscellaneous sample size for sediment will be increased if auxiliary analytes that cannot be included as part of the organic or metal analyses are added to the list. The amounts shown are not intended as firm values; more or less tissue may be required depending on the analytes, matrices, detection limits, and particular analytical laboratory

d All containers should be certified as clean according to EPA and USACE (1990)

e These holding times are for sediment, water, and tissue based on guidance that is sometimes administrative rather than technical in nature
There are no promulgated, scientifically based holding time criteria for sediments, tissues, or elutriates. References should be consulted if holding times for sample extracts are desired. Holding times are from the time of sample collection

f NOAA (1989)

g Tetra Tech (1986a)

h Sample may be held for up to one year if at –20°C

i Phthalates are not being analyzed for; therefore, polypropylene does not need to be used

j Two weeks is recommended; sediments must not be held for longer than eight weeks prior to biological testing

k EPA (1987); 40 CFR Part 136, Table III

l Plumb (1981)

m If samples are not preserved to pH<2, then aromatic compounds must be analyzed within 7 days

n Tetra Tech (1986b)

o Analyses categories for tissue will be determined from the initial chemical screening. Chemical analytical list is inclusive and conservative for the purposes of writing the SAP. For % lipids, if the micro method is use, lipid samples can be as low as 0.150 milligrams

p Total tissue mass (conservative estimate) reported

q Elutriate/bioassay water not collected at ODMDS

(NOAA) station (#8775237 Port Aransas, Texas) will be used as a backup. In addition, the latest available bathymetric survey information will be on board each sampling vessel to be used as a reference in the field to confirm depths.

All sediment samples will be collected within the DMMU boundary as close as possible to the proposed sampling location. If the total volume required cannot be collected at a particular station, the vessel will be relocated to a site as close as possible to the initial sampling location. If a suitable location cannot be found within the DMMU, the field team leader will contact PCCA and USACE to determine the appropriate corrective action.

2.4.2 Conventional Water Quality

Conventional water quality parameters at mid-water column depth will be measured and recorded from the central location within each DMMU, including water temperature, salinity, pH, conductivity, Oxidation Reduction Potential, turbidity, and dissolved oxygen. Water depth, adjusted to MLLW, at each station will be noted along with general site observations (air temperature, wind speed, sea-state, etc.).

2.4.3 Sample Numbering

A sample numbering system that will provide a unique and unambiguous label for each sample will be decided upon and documented prior to going into the field. Labels will be preprinted with as much project information as possible prior to going into the field. Surplus labels should be available should the need arise to utilize them.

2.4.4 Decontamination Procedures

All equipment contacting sediment or water samples will be cleaned and decontaminated as described below. Work surfaces on the sampling vessel will be cleaned before the sampling day begins and before leaving each station. All equipment contacting sediment or water samples, gloves, and any protective clothing will be changed and/or cleaned between sampling stations to prevent cross-contamination. Decontamination procedures include:

- Wash and scrub using site water or tap water to remove gross contamination
- Wash/scrub with Liquinox®
- Rinse with site water
- Rinse with DI water
- Air dry

Any derived waste will be contained and disposed of in accordance with Federal, state, and local laws.

2.4.5 Sample Preservation and Storage

A suitable method for preservation and shipment of all sediment and water samples will be used, as indicated in Table 3 and according to sample handling instructions coordinated with the testing laboratory. Such instructions must be obtained no later than the week preceding field work. The testing laboratory shall furnish clean, appropriately sized glass and/or plastic containers for sediment and water samples, labeled accordingly and containing preservatives, as appropriate. PCCA's subconsultant shall instruct the field contractor as to the nature, size, and precleaning of containers for the collection of bulk media.

All samples will be iced or refrigerated immediately after collection and must be stored at 4 ± 1°C, never frozen, within 24 hours after collection. Samples will be protected from light during storage and transportation and must remain at 4 ± 1°C throughout transport and until received and logged in at the testing laboratory.

2.4.6 Chain of Custody

A dated Chain of Custody document shall be furnished to record all collected samples and must accompany the samples from the field through all shipping to reporting and sample destruction. All Chain of Custody forms must clearly note the sample name, date and time of collection, container type, any special handling (i.e., filtering or acidification), type of analyses required by the laboratories, date relinquished, and signature of all individuals involved in the stages of sample collection, handling, and shipping.

Additional guidance on appropriate Chain of Custody protocols can be found reference guidance documents (EPA, 1986; EPA and USACE, 1995; 1998; Plumb, 1981).

Shipping and sample distribution to the testing facilities will be managed by PCCA's subconsultant and the field contractor.

2.5 SPECIFIC INSTRUCTIONS FOR SEDIMENT SAMPLING

Sediment samples will be collected from each of the nine channel DMMUs, the Reference Area, and the New Work ODMDS (see Table 1 and Figure 3). Since the DMMUs are selected to be representative of reaches, shifts in position will be allowed. If circumstances require, the sampling location will be shifted as minimally as possible while remaining within the dredge prism and within the DMMU to facilitate acquisition of sufficient sample volume. Any deviations will be noted in the field notes and documented in the final report.

For the 27 channel DMMU stations, sediment samples will be collected to project depth or refusal, whichever is encountered first. The sampling is expected to require a vibracore sampler with the stainless steel core tubes, however, if sampling depths are short, other equipment may be utilized. Rationalization for the type of equipment used must be written in the field logs and documented in the final report. Regardless of the equipment used, the material must be representative of the dredge prism and any debris within the sample will be discarded in such a manner as to not compromise the representativeness of the sample.

Prior to collection at each station, the core sampler will be washed with an Alconox solution, flushed with ambient water to remove all remnant sample material, and then rinsed with de-ionized water to avoid cross-contamination among sample sites. At each DMMU, as well as within the Reference Area and the ODMDS, each core/grab collected within the correlated area will, in its entirety, be placed in appropriately labeled pre-cleaned containers, 5-gallon buckets or other suitable containers (Table 3). Sediment cores will be taken to project depth or refusal, whichever is encountered first, using a sampling method capable of accomplishing such a task. Eastings and northings will be recorded for each of the three sampling point replicates (replicates ‘A’, ‘B’, and ‘C’) for DMMUs CDP-01 through CDP-09, as well as from the Reference Area (Table 1). Samples between or from more than one DMMU will not be composited.

It is expected that multiple cores/grabs will be required to obtain the required volume for both chemical and physical analyses as well as bioassays. All containers, regardless of size, will be filled completely to avoid head space. The lids will then be tightly secured, and the containers will be placed into an ice chest or refrigerating unit with sufficient cushioning material to prevent leakage and breakage during shipment.

The Reference Area sediment volume need only be surficial sediment and may be collected as surficial grab samples.

See Table 3 for a summary of sediment sampling parameters including sample volume, container type, handling, storage etc.

Field Data: Field data from all sampling stations shall be described at the time of sampling and will include but not limited to date, time, water depth adjusted to MLLW, sample appearance, odor, horizons, total length of core and horizons, stratifications, texture, plasticity measurements (hand rolled method), GPS coordinates, and photos.

2.6 SPECIFIC INSTRUCTIONS FOR WATER SAMPLING

Water samples will be collected from the central channel location for each of the nine channel DMMUs (see Table 1 and Figure 3). Prior to sample collection, conventional water quality parameters will be measured and recorded at mid-depth in the water column at the center (i.e., location “B”) of each channel DMMU and at one central location from the three selected at the Reference Area and the New Work ODMDS (see Figure 3). These parameters will include water temperature, salinity, pH, conductivity, Oxidation Reduction Potential, turbidity and dissolved oxygen.

At each sample station, the water depth to the top of sediment will be determined. Sediment surface and water elevations at each station will be determined in feet MLLW using a Spectra Precision SP80 Global Navigation Satellite System (accurate to ±2 centimeters) interfaced with the RTKNet network. Real-time water levels from the NOAA station (#8775237 Port Aransas, Texas) will be used as a backup. General site observations will be recorded including, at a minimum, air temperature, wind speed, and sea-state.

The depth of the water sample shall be mid-depth in the water column, but under no circumstances will the water intake hose end be any closer than three feet from the sediment surface.

Special care should be taken to avoid the introduction of contaminants from the sampling device and the containers. PCCA's subconsultant and field contractor shall collect water samples with a non-contaminating stainless steel and Teflon® pump and Teflon®-lined tubing. Prior to sample collection, an initial volume of water equaling at least 10 times the hose volume will be pumped through the sampling device and discarded. If cubitainers are used, they must be made of non-contaminating material and rinsed 10 times prior to filling.

See Table 3 for a summary of surface water sampling parameters including sample volume, container type, handling, preservation, storage, etc.

All water samples that will be submitted for any type of chemical analyses will be field filtered and placed into suitable pre-cleaned laboratory supplied polyethylene bottles or amber glass bottles with appropriate acid or base preservatives (see Table 3). Water samples to be analyzed for metals, with the exception of mercury and selenium, will be field filtered through a clean 0.45 micrometer filter prior to dispensing into containers with acid preservatives as needed. All containers are to be filled completely, avoiding the presence of any head space in the sample bottles. The lids will then be tightly secured, and the containers will be placed into an ice chest with sufficient cushioning material to prevent breakage during shipment. Exact sampling position will be recorded for each sub-sample/sample collected. Water volumes collected for non-chemical testing need not be field filtered.

Water samples from separate DMMUs will not be composited to create a single site sample. Each location will be sampled, analyzed, and reported as a distinct data point collocated with the sediment sample(s) for that point. All water samples are to be filtered with the following exceptions: 1) VOC analyses; 2) metals for mercury and selenium ONLY; and 3) water intended for elutriate testing. A determination as to whether water samples are field filtered or filtered in the laboratory will be made prior to sample collection.

2.7 SPECIFIC INSTRUCTIONS FOR BIOASSAY/ BIOACCUMULATION ANALYSIS

Sufficient sample volume of sediment will be collected so that the laboratory is able to complete all bioassay/bioaccumulation tests for each DMMU. Approximate volumes are noted in Table 3; however, sample volumes will be confirmed with the testing laboratory prior to field collection commencing.

- **SPP (elutriate)** toxicity tests using three species: Zooplankton (*Americamysis bahia*), ≤1 day old; Crustacean (*Americamysis bahia*), 1-5 days old (average); Fish (*Menidia beryllina*), 9 – 14 days old (If water quality conditions are outside the tolerance range of Menidia species (e.g., salinity < 20%), then permission will be sought to test the sheepshead minnow (*Cyprinodon variegatus*), which is more tolerant to wider water quality ranges). The zooplankton test will be conducted for 48-hr while the crustacean and fish tests will be conducted for 96 hours.
- **Solid Phase (direct whole sediment toxicity)** tests two species: Amphipod (*Leptocheirus plumulosus* or *Ampelisca abdita* based on compatibility with the physical attributes of the test sediment) and epibenthic shrimp (*Americamysis bahia*). Tests will be conducted for 10-days.
- **Bioaccumulation (whole sediment)** tests two species: clam (*Macoma nasuta*) and polychaete worm (*Nereis virens*). Tests will be conducted for 28-days.

Bulk samples will be collected in the field in precleaned pails and not homogenized. Bulk samples will be shipped to the testing laboratory where compositing, homogenization, subsampling, and other sample processing logistics will occur.

2.8 SAMPLE SHIPMENT

All sediment and water samples will be delivered to the testing laboratory in the first stage of SOW/SAP execution. Shipping containers and packaging must be capable of protecting the sample containers from breakage and holding sample temperatures 4 ± 2°C through the collection, to the delivery of samples at the testing laboratory. See Table 3 for a summary of procedures for sample collection, preservation, and storage. Final study samples will be shipped within 1-day of completion of all sampling activities.

For the second stage of the SOW/SAP execution, where elutriate and tissue samples for chemical analyses are generated at the testing laboratory, the testing laboratory is responsible for ensuring that analytical holding times for all sample media for the second stage of distribution are not exceeded, and to coordinate a collection and delivery schedule for all samples with the testing laboratory contact identified below.

Alternatively, shipments may be made by refrigerator truck capable of maintaining temperatures 4 ± 2°C. The completed Chain of Custody must be included with sample delivery regardless of the selected shipment alternative.

2.9 SCHEDULE FOR WORK PERFORMED

Table 4 describes the schedule of work for the sampling and analysis. Since the timing of the commencement of field sampling is not known at this time, the schedule is presented in number of days after field work is completed. It is anticipated that the sampling will be performed in mid to late 2021.

Table 4
Schedule of Work Performed

Estimated Deliverable from Award Date (days)	Responsibility	Task	Duration
0		Receive Notice to Proceed	0
7	Contractor	Prepare a draft Field Sampling Plan (FSP) and Health and Safety Plan (HSP)	7
37	PCCA/USACE/Contractor	Review Field Sampling and Safety Plan, send finalized version to EPA	30
40	PCCA/USACE/Contractor	Hold a pre-field coordination call to review FSP	1
45	Contractor	Mobilize to perform field work	45
50	Contractor	Collect sediment and water samples	5
52	Contractor	Transport sample material to shore and deliver to labs	2
66	Contractor	Submit a post-sampling field report	14
97	Contractor / Laboratory	Sediment Chemical and Bioassay Analysis, Site Water and Elutriate Analysis	45
127	Contractor / Laboratory	Sediment Bioaccumulation Analysis	30
157	Contractor / Laboratory	Bioaccumulation Tissue Analysis	30
217	Contractor	Perform data analysis, modeling and complete draft report	60
247	PCCA/USACE	Regulatory agencies review report	30
277	Contractor	Address comments and finalize report	30

2.10 DELIVERABLES

The following reports must be submitted:

1. Draft Field Sampling and Safety Plan submitted for review and comment. Final report should be sent to EPA for final approval.
2. Field Sampling Plan.
3. Post-Sampling Field Report submitted for review and comment. Final report will be provided for PCCA and USACE.

The following documents/deliverables will be prepared:

1. Draft SAP/FSP/HSP submitted to USACE and EPA review and comment.
2. Final SAP/FSP/HSP submitted to USACE and EPA for signature.
3. Sediment chemistry data and recommendations for tissue chemistry. The contractor will summarize sediment chemistry results and prepare a technical memo with tissue chemistry recommendations for USACE and EPA review and approval.

4. Sediment testing report to include all elements and required formats specified by USACE and EPA Region 6, including:
   - A report narrative addressing all aspects of field sampling and laboratory analysis, a discussion of laboratory results, a review of all laboratory quality of control, and Automated Dredging and Disposal Alternative Modeling System model results
   - Copies of all field paperwork including sediment field logs, water quality logs, calibration log, composite logs, temperature logs, chains of custody forms, and daily QC reports
   - Laboratory results provided in condensed data tables
   - Maps of the sampling sites
   - Photographs of the samples as collected

3.0 PROJECT DESIGN

3.1 DESIGN ASSUMPTIONS

The field contractor will collect sediment and water samples from the CCSC Outer Approach Channel, Corpus Christi Channel, and the Harbor Island Junction as outlined in this SOW/SAP and ensure delivery of all collected samples to the analytical provider, as appropriate, within the specified holding times. Procedures for sample collection, required volume, handling, preservation and storage, and shipment are outlined in Section 2.0.

Close coordination by the field contractors, subconsultant, and testing laboratory with PCCA and USACE personnel is an essential component of this SOW/SAP.

If, at the time of sampling and analyzing, conditions require major deviation from the approach outlined in this SOW/SAP, the Contractor must discuss the deviation with the PCCA, with USACE and EPA coordination. USACE will be in contact with the EPA prior to application/implementation.

Should there be a lack of material present at a sampling location, the field contractor, PCCA, EPA, and the USACE will jointly decide how to shift the sample locations. All details of the steps taken to arrive at a decision as to when/how to shift a sampling point will be noted in the field logs and documented in the final report.

3.2 SAMPLE SITES

This SAP will evaluate site surface water, sediment, elutriates, SPP bioassay, direct toxicity bioassay and the bioaccumulation bioassays for new work sediments within the Outer Channel Reach, Harbor Island Junction, and Corpus Christi Channel adjacent to Harbor Island. Surficial samples will be required at the Reference Area.

- DMMUs (CDP-01 through CDP-05): Given that the material will be dredged from the open water in this segment and is expected to be new work material consisting solely of undisturbed base layer geological formations free of impacts from industrial sources or transport mechanisms, samples will be collected to refusal with exact sampling positions recorded for each sample collection.
- DMMUs (CDP-06 through CDP-09): Sample locations for these DMMUs are within the vicinity of Harbor Island, which historically has accommodated oil storage and fabrication facilities, and may be susceptible to contaminant transport mechanisms. As such, samples will be collected to depth with exact positions recorded for each sample location.
- Reference Area (CDP-REF): Surficial samples only are required at the Reference Area.
- New Work ODMDS (CDP-ODMDS): Surficial samples only are required at the New Work ODMDS.

Table 3 provides a summary of the proposed sample collection locations and sample testing. Initial contaminants of concern were selected based upon the 2003 RIA and then refined to be site-specific and project specific.

3.3 SAMPLE VOLUMES AND CONTAINERS

Sample volumes and containers are outlined in Table 3 and Section 2.0.

3.4 CHAIN OF CUSTODY

Appropriate Chain of Custody protocols will be followed. Guidance on appropriate Chain of Custody protocols can be found in EPA (1986), EPA and USACE (1995 and 1998), and Plumb (1981). Shipping and sample distribution to the testing facilities will be managed by PCCA's subconsultant and the field contractor.

4.0 ANALYTICAL AND REPORTING REQUIREMENTS

4.1 CHEMICAL ANALYSES

The analyses of samples will be as specified in Table 5 for water, elutriate, sediment, and tissue samples, along with required target detection limits (TDLs). Testing and analysis for organotin are required for DMMUs CDP-06 to CDP-09. All analyses will be performed by a laboratory accredited by an accrediting authority recognized by the NELAP for the analytes/analyte groups and matrices to be analyzed. All analyses will be performed within the holding period described in the referenced guidance documents.

Table 5
Target Detection Levels for Analysis by Sample Type

Chemical	Water/Elutriate (ug/L)	Sediment (ug/kg)	Tissue (ug/kg)
METALS[a] AND CYANIDE			
Antimony	3.0 (0.02)[e]	2.5	0.1
Arsenic	1.0 (0.005)[e]	0.3	0.1
Beryllium	0.2	1.0	0.1
Cadmium	1.0	0.1	0.1
Chromium (total)	1.0	1.0	0.1
Chromium (+3)	1.0	1.0	50.0
Chromium (+6)	1.0	1.0	50.0
Copper	1.0	1.0	0.1
Lead	1.0	0.3	0.1
Mercury	0.2	0.2	0.0
Nickel	1.0	0.5	0.1
Selenium	2.0	0.5	0.2
Silver	1.0	0.2	0.1
Thallium	1.0 (0.02)[e]	0.2	0.1
Zinc	1.0	2.0	0.1
Cyanide	0.1	0.1	–
CONVENTIONAL PARAMETERS			
Grain Size	–	1.00%	–
Total Organic Carbon	0.10%	0.10%	–
Total Petroleum Hydrocarbons	0.1 mg/L	5	–
Ammonia	30.0 ug/L	0.1	–
Total Solids/Dry Weight	–	0.10%	–
Total Suspended Solids	1,000 ug/L	–	–
ORGANIC COMPOUNDS			
Phenols/Substituted Phenols			
2-Chlorophenol	0.9	110	–
2,4-Dichlorophenol	0.8	120	–
2,4-Dimethylphenol	10	20	20
4,6-Dinitro-o-Cresol	10	600	20
2,4-Dinitrophenol	10	20	20

Chemical	Water/Elutriate (ug/L)	Sediment (ug/kg)	Tissue (ug/kg)
2-Nitrophenol	2.0	200	–
4-Nitrophenol	5.0	500	–
p-Chloro-m-Cresol	0.7	140	–
Pentachlorophenol	50	100	100
Phenol	10	100	20
2,4,6-Trichlorophenol	0.9	140	–
L Polycyclic Aromatic Hydrocarbons			
Acenapthene	0.8	20	20
Acenapthylene	1.0	20	20
Anthracene	0.6	20	20
Fluorene	0.6	20	20
Naphthalene	0.8	20	20
Phenanthrene	0.5	20	20
H Polycyclic Aromatic Hydrocarbons			
Benzo(a)anthracene	0.4	20	20
Benzo(a)pyrene	0.3	20	20
Benzo(b&k)fluoranthene	0.6	20	20
Benzo[g,h,i]perylene	1.2	20	20
Chrysene	0.3	20	20
Dibenzo[a,h]anthracene	1.3	20	20
Fluoranthene	0.9	20	20
Indeno[1,2,3-c,d]pyrene	1.2	20	20
Pyrene	1.5	20	20
Chlorianted Hydrocarbons			
1,2-Dichlorobenzene	0.9	20	20
1,3-Dichlorobenzene	0.9	20	20
1,4-Dichlorobenzene	0.8	20	20
2-Chloronapthalene	0.8	160	–
Hexachlorobenzene	0.4	10	20
Hexachlorobutadiene	0.9	20	40
Hexachlorocyclopentadiene	3.0	300	–
Hexachloroethane	0.9	100	40
1,2,4-Trichlorobenzene	0.9	10	20
Phthalate Esters			
Bis(2-ethylhexyl) phthalate	2.0	50	20
Butyl benzyl phthalate	4.0	50	20
Diethyl Phthalate	1.0	50	20
Dimethyl Phthalate	1.0	50	20
Di-n-butyl Phthalate	1.0	50	20
Di-n-octyl Phthalate	3.0	50	20
Halogenated Esters			
Bis(2-chloroethoxy) methane	1.0	130	–
Bis(2-chloroethyl) ether	0.9	130	–
Bis(2-chloroisopropyl) ether	0.7	140	–
4-Bromophenyl phenyl ether	0.6	160	–
4-Chlorophenyl phenyl ether	0.4	170	–
PESTICIDES			
4,4’-DDD	0.1	5	10

Chemical	Water/Elutriate (ug/L)	Sediment (ug/kg)	Tissue (ug/kg)
4,4'-DDE	0.1	5	10
4,4'-DDT	0.1	5	10
Aldrin	0.03	3	6
Alpha-BHC	0.03	3	6
Beta-BHC	0.03	3	6
Gamma-BHC (Lindane)	0.1	3	6
Delta-BHC	0.03	3	6
Chlordane and Derivatives	0.03	3	6
Dieldrin	0.02	5	10
Endosulfan and Derivatives	0.1	5	10
Endrin and Derivatives	0.1	5	10
Heptachlor and Derivatives	0.1	3	6
Hexachlorocyclohexane (Lindane) and Derivatives	0.1	3	6
Methoxychlor	0.5	5	10
Toxaphene	0.5	50	50
PCBs			
Total PCBs	0.01	1.0	2.0
Organonitrogen Comounds			
Benzidine	1.0	5	5
3,3-Dichlorobenzidine	3.0	300	–
2,4-Dinitrotoluene	2.0	200	–
2,6-Dinitrotoluene	2.0	200	–
1,2-Diphenylhydrazine	1.0	10	100
Nitrobenzene	0.9	160	–
N-nitrosodimethylamine	0.9	–	–
N-nitrosodi-n-propylamine	0.9	160	–
N-nitrosodiphenylamine	2.1	20	20
ORGANOTIN[b]			
Dibutyltin[c]	0.01[d]	10	10
Monobutyltin[c]	0.01[d]	10	10
Tributyltin[c]	0.01[d]	10	10
MISCELLANEOUS		**mg/kg**	
% Lipids	–	–	0.01%
pH	–	0.1	–
Isophorone	1.0	10	100

[a] Metals shall be expressed as Dissolved values in water samples, except for mercury and selenium, which shall be reported as Total Recoverable.

[b] Organotin TDLs are reported from the EPA and USACE Southeast Regional Implementation Manual (2008). For example, sites with historic sandblasting, shipbreaking, maintenance, and repair would warrant analysis of organotin.

[c] Additional Requirement for DMMUs CDP-06 to CDP-09.

[d] TDL value taken from the EPA and USACE Southeast Regional Implementation Manual (2008).

[e] The values in parentheses are based on EPA "clean techniques", (EPA 1600 series methods) which are applicable in instances where other TDLs are inadequate to assess EPA water quality criteria.

4.2 LABORATORY QUALITY CONTROL FOR CHEMICAL ANALYSIS

All chemical and physical analyses must include laboratory QC samples; details of the numbers and types of laboratory QC samples can be found below. Documentation of all QC activities performed specifically in conjunction with this project will be furnished along with sample results. Copies of all raw data, lab notes, chromatograms, standard curves, etc. will be furnished upon request. The laboratory will provide a case narrative of the analyses and any deviations or out of specification events that took place during the analyses with each laboratory deliverable.

Documentation of all QC activities performed specifically in conjunction with this project will be furnished along with sample results. Copies of all raw data, lab notes, chromatograms, standard curves, etc. shall be furnished upon request. The laboratory will provide a case narrative of the analyses and any deviations or out of specification events that took place during the analyses.

a. Method Blanks: Shall be performed at a frequency of one per batch of samples, per matrix type, per sample extraction or preparation method.

b. Laboratory Control Samples (Ongoing Precision and Recovery): Shall be analyzed at a minimum of one per batch of 20 or less samples per matrix type, per sample extraction or preparation method, except for analytes for which spiking solutions are not available.

c. Matrix Spike/Matrix Spike Duplicates: Will be performed ***ON PROJECT MATERIAL AND NOT LABORATORY SAMPLES UNRELATED TO THE SITE*** at a frequency of one in 20 samples per matrix type, per sample extraction or preparation method, except for analytes for which spiking solutions are not available.

d. Surrogates: Surrogate compounds must be added to all samples, standards, and blanks for all organic chromatography methods except when the matrix precludes its use or when a surrogate is not available

e. Instrument Performance: Calibration of instrumentation and performance of periodic instrument checks according to the manufacturer and EPA recommendations, and appropriate Standard Operating Procedures (SOPs)

f. Laboratory Performance Evaluation: Participation in performance evaluation and method studies available from EPA, American Society for Testing and Materials, or other agency. Performance evaluation under such a program is to be conducted, at least, on a semiannual basis

g. Laboratory Contamination: Each new shipment or lot of solvent, reagent or adsorbent will be evaluated for purity in accordance with appropriate SOPs

h. Laboratory Standards: Laboratory standards will be prepared and verified in accordance with appropriate SOPs

i. QC Limits: Calculation of QC limits and preparation of control charts will be performed in accordance with appropriate SOPs

j. Deviations: Out of control events, or outlier data will be noted, and corrective action will be taken in accordance with appropriate SOPs

Chemical analysis of water and elutriate samples will be performed according to analytical methods in:

- USACE (1995). QA/QC Guidance for Sampling and Analysis of Sediments, Water and Tissues for Dredged Material Evaluations (Chemical Evaluations). EPA-823-B-95-001;
- EPA and USACE (1998). Evaluation of Dredged Material Proposed for Discharge in Waters of the U.S. – Testing Manual. ITM;
- EPA and USACE (1991). Evaluation of Dredged Material Proposed for Ocean Disposal. Testing Manual. ("Green Book"). EPA 503/8-91/001; and
- EPA and USACE (2003). RIA for the Ocean Dredged Material Disposal Program. EPA Region 6 and USACE, Galveston District. July 2003.

Sediment results will be compared to published sediment screening values where appropriate. These levels are the Threshold Effects Level and the ERL. The Threshold Effects Level represents the concentration below which adverse effects are expected to occur only rarely, and the ERL is the value at which toxicity may begin to be observed in sensitive species (Buchman, 2008). Comparisons will be used for reference only, not for any regulatory decisions. In addition, the results will be evaluated for samples which exceed the laboratory reporting limit, and the corresponding tissue samples will be analyzed for the compounds where the sediment exceedances occurred.

Elutriate and site water results will be compared to the EPA National Recommended Water Quality Criteria Critical Maximum Concentration and the acute Texas State Water Quality Standards. The Critical Maximum Concentration is an estimate of the highest concentration of a pollutant in saltwater to which an aquatic community can be exposed briefly without resulting in an unacceptable effect (EPA, 2002a). The Texas State Water Quality Standards provides a similar comparison for contaminants within Texas, specifically.

Tissue chemistry results will be compared to reference values and U.S. Food and Drug Administration (FDA) action levels (FDA, 2020). For tissue results above reference, ecological effects threshold and North Gulf of Mexico background concentrations will be used for comparison.

Results will be evaluated for the following:

- All results and information presented in the data tables will be compared to the electronic reports from the laboratories and original field sheets.
- All chemical results will be compared to the target detection or reporting limits shown in tables 4, 5, and 6 to ensure that the limits were met. If the laboratory's detection limits do not meet the TDLs, the affected data will be flagged in the table and discussed in the QA/QC section of the

report. All chemical laboratory QCs will be compared to the criteria specified in the Galveston Chemical Quality Assurance Report.

- All toxicological results will be compared to the criteria specified below and the Chemical Quality Assurance Report. Any failures to meet the specified criteria can usually be evaluated sufficiently early in the project to allow re-analysis within holding time. These comparisons will include the following:
  - Evaluation of control sediment against acceptance limits.
  - Comparison of project sediment to reference material.
  - Review of statistical calculations including 50% mortality, 50% development, and student t-test summaries.
  - Review of supplemental information, including daily hydrographic measurements as well as ammonia and sulfide concentrations, to meet project and regulatory guidelines.
  - If required, the Automated Dredging and Disposal Alternative Modeling System model will be run, and results will be compared to the sample's limiting permissible concentration (LPC) to determine if the material will meet offshore disposal criteria.
- All calculations, including statistical comparisons of project tissues to reference tissues, will undergo an independent review to ensure that the correct values are presented.

4.3 WATER COLUMN BIOASSAY, SOLID PHASE BIOASSAY/BIOACCUMULATION

All tests described below shall be performed by the analytical provider with documented QA/QC to validate the bioassay testing. Procedures for performing these tests can be found in the resources listed below. Project specific details are summarized in Table 6.

- RIA (EPA and USACE, 2003);
- The "Green Book" (EPA and USACE, 1998);
- Methods for Measuring the Acute Toxicity of Effluents and Receiving Waters to Freshwater and Marine Organisms (EPA, 2002b); and
- Methods for Assessing the Toxicity of Sediment-Associated Contaminants with Estuarine and Marine Amphipods (EPA, 1994).

Table 6
Summary of Marine Bioassay Testing and Evaluation Criteria[1]

Parameter	Suspended Particulate Phase (Elutriate) Toxicity *Americamysis bahia* (zooplankton, invertebrate), *Menidia beryllina* or *Cyprinodon variegatus*[2]	Solid Phase Bioassay *Americamysis bahia* and amphipod *Leptocheirus plumulosus* or *Ampelisca abdita*	Bioaccumulation *Macoma nasuta* and *Nereis virens*
Test Procedures	OTM, ITM (EPA and USACE, 1991; 1998; RIA, 2003)	OTM, ITM (EPA and USACE, 1991; 1998; RIA, 2003)	OTM, ITM (EPA and USACE, 1991; 1998; RIA, 2003)
Test Type/Duration	static/48 or 96 hours	static/10 days	static renewal/28 days
Replicates/Treatment	5	5	5
Organisms/Replicate	10	20	1 gram wet tissue per 200 grams wet sediment (target: 65 grams)
SPP Concentrations	100, 50, 10%	N/A	N/A
Water Type	reconstituted seawater	reconstituted seawater	reconstituted seawater
Water Renewal	none	none	3 times weekly
Test Temperature	20 ± 1°C	*L. plumulosus*: 25 ± 1°C; *A. bahia* and *A. abdita*: 20 ± 1°C	*M. nasuta*: 15 ± 1°C; *N. virens*: 20 ± 1°C
Test Photoperiod	16L:8D	amphipods: continuous light *A. bahia*: 16L:8D	16L:8D
Endpoint	survival	survival	tissue residues
Acceptability Criteria	≥ 90% survival in control	≥ 90% survival in control	residue analysis
Feeding Requirements	*A. bahia*: twice daily; *M. beryllina*: at 48-hours	*L. plumulosus*/*A. abdita*: none; *A. bahia*: daily	none
Salinity	30 ppt ± 2 ppt	*L. plumulosus*/*A. abdita*: 20 ppt ± 2 ppt; *A. bahia*: 30 ppt ± 2 ppt	30 ppt ± 2 ppt
Dissolved Oxygen	≥ 40% saturation	≥ 40% saturation	≥ 40% saturation

°C = degrees Centigrade; OTM = Ocean Testing Manual; ppt = parts per thousand

4.3.1 Suspended Particulate Phase (Elutriate) Toxicity Data Analysis

Survival in each of the undiluted (100%) dredged material elutriate treatment will be compared to survival in the dilution water treatment(s). If survival is greater than or equal to survival in the dilution water treatment, the SPP will meet the guidelines for placement under the water column evaluation. If survival in the dredged material treatments is less than survival in the dilution water treatment, but the difference does not exceed 10%, the SPP will meet the guidelines for placement under the water column evaluation.

However, if the difference in survival between the sediment elutriate and the dilution water exceeds 10% then survival in the 100% dredged material elutriate treatment will be statistically compared to survival in the dilution water. Statistical analyses will be performed as described in the OTM and ITM (EPA and USACE, 1991; 1998). If the 100% dredged material elutriate treatment is not statistically different from the dilution water, the SPP is not predicted to be acutely toxic and will meet the guidelines for placement under the water column evaluation.

If mortality is greater than 10% in the control treatment or in the dilution water treatment for a particular test species (30% mortality/abnormality for zooplankton), the test should be rejected, and the bioassay repeated.

If survival in the 100% dredged material elutriate treatment is statistically lower than the dilution water, the LPC will be calculated. If survival is >50%, then the LPC will be calculated as the 100% elutriate multiplied by an appropriate application factor. If survival is <50%, then a Lethal Concentration (LC50) value will be calculated and the LPC will be determined as the LC50 multiplied by an appropriate application factor. While the default application factor is 0.01, regulations state that alternative factors may be used when there is reasonable scientific evidence on a specific material to justify the use of an alternative application factor to calculate the LPC (MPRSA 103, 40 CFR 227.27(a)(3), NAS (1972)). If an alternative factor is used, justification will need to be provided to the USACE and EPA prior to its application to the study data.

The numerical model, STFATE, will then be required to determine compliance with the LPC (EPA and USACE, 1991). The modeled concentrations of the dredged material in the water column outside the boundary of the disposal site during the 4-hour initial mixing period and the maximum concentration in the water column in the marine environment after the 4-hour mixing period will be compared with the LPC to determine compliance. If both modeled concentrations are less than the LPC, compliance for the SPP will have been met. If either of the modeled concentrations exceeds the LPC, compliance for the SPP will not have been met and placement of the dredged sediment cannot be conducted without appropriate management.

4.3.2 Solid Phase (Sediment) Bioassay Data Interpretation

Two conditions are required to designate sediment as potentially toxic based on survival in whole sediment toxicity (solid phase) testing:

1. Mortality that is more than 10% greater for the mysid shrimp or 20% greater for the amphipod than mortality in the reference; and
2. A statistically significant reduction in survival compared to survival in the reference sediment (EPA and USACE, 1991; 1998).

If dredged material mortality exceeds reference mortality by the magnitude describe in condition 1 above, dredging sediment toxicity data will be statistically compared to data from reference sediments as described in the OTM and ITM (EPA and USACE, 1991; 1998). If both conditions are met, the sediment fails to meet the LPC and the dredged material will be deemed unsuitable for open water placement. If one or both of these conditions are not met, the sediment will have met the LPC for whole sediment toxicity (solid phase).

If greater than 10% mean mortality occurs in the control sediment, the test should be repeated.

4.3.3 Bioaccumulation Test Data Interpretation

For bioaccumulation tests, tissue residues will be conservatively compared to the FDA action levels (where available and appropriate) using the 95th UCL of the mean of the data distribution. If concentrations of one or more contaminants statistically exceed the FDA action level, then the sediment does not meet the LPC for open water placement.

If tissue concentrations do not exceed the FDA action levels, then the tissue residue levels will be statistically compared to tissue concentrations of organisms exposed to reference sediment. In cases where tissue residues are less than detection limits, half the detection limit will be applied to statistical comparisons as recommended by Clark (1998). If tissue concentrations in organisms exposed to sediment from the dredging site do not statistically exceed the contaminant concentrations in tissues exposed to the reference sediment, adverse effects are not likely, and the sediment will have met the LPC for bioaccumulation.

If tissue concentrations are statistically greater in organisms exposed to sediment from the dredging site than in organisms exposed to the reference sediment, further evaluation will be required by assessing the eight factors described in the 2003 RIA. The factors are assessed in a weight of evidence approach for determination of LPC compliance.

If a compliance decision still cannot be reached following evaluation of these eight factors, further actions will be developed and agreed upon by both the EPA and the USACE.

Further details on bioassay protocols for each test type can be found in Appendix C.

4.4 DATA SUBMITTAL

A report compliant with this SAP will be submitted by USACE to PCCA at completion of the dredge material characterization and evaluation. The report will synoptically summarize the key points as appropriate from the SOW/SAP, cross reference to study documents and at a minimum, include:

1. Sample collection: sampling sites and locations (water and sediment); tabulated and plotted on figure showing locations and the dredging prism; summarized and cross referenced to study documents as needed

2. Field procedures: synoptic summaries and cross referenced to provided project documents; including compositing, physical observations (e.g. odor, stratification, etc.) and other field procedures, observations, deviations as appropriate
3. QC (field): described and cross referenced to project documents, as needed
4. Analyses: description of what was analyzed, methodologies etc.
5. Results and discussion: discuss data and proceed by environmental medium and within each medium, by analyte category. Similarly, discuss and proceed through each bioassay and within each bioassay by test organism. Prior to issuance of the final report, the report will also discuss any of the applicable subparts and sections of 40 CFR Parts 227 and 228 listed in the RIA.

A report containing the finding of the toxicity and bioaccumulation studies will be provided. The report will include an executive summary, introduction, methods and results section. The report will include test endpoint tables providing means, standard deviations for survival, tissue mass, etc. Water quality analysis tables will include mean, standard deviation, N, and range of values for each endpoint measured.

One (1) hard copy and an electronic PDF version of the report will be provided. Experimental data will be provided in an Excel Electronic Data Deliverable.

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Appendix A

Corpus Christi Ship Channel, Texas
Channel Improvement Project (2003)

U.S. Army Corps
of Engineers

Galveston District
Southwestern Division

Corpus Christi Ship Channel, Texas
Channel Improvement Project

Volume I

Final Feasibility Report
and
Final Environmental Impact Statement

April 2003

CORPUS CHRISTI SHIP CHANNEL
CHANNEL IMPROVEMENTS PROJECT
CORPUS CHRISTI AND NUECES BAYS
NUECES AND SAN PATRICIO COUNTIES, TEXAS

FINAL
ENVIRONMENTAL IMPACT STATEMENT

U.S. Army Corps of Engineers
Galveston District

April 2003

ABSTRACT

FINAL
ENVIRONMENTAL IMPACT STATEMENT

Corpus Christi Ship Channel Channel Improvements Project
Corpus Christi and Nueces Bays
Nueces and San Patricio Counties, Texas

The responsible lead agency is the U.S. Army Engineer District, Galveston. The responsible cooperating agency is the U.S. Environmental Protection Agency.

Abstract: The Galveston District has reviewed the Port Aransas-Corpus Christi Ship Channel (45-Foot Project) and other reports to determine the feasibility of modifying the Corpus Christi Ship Channel (CCSC) to improve commercial navigation. The plan of improvements is described in the accompanying Feasibility Report and Final Environmental Impact Statement (FEIS). The CCSC and La Quinta Channel are navigation channels that connect the harbor facilities in Corpus Christi and Ingleside-On-The-Bay, San Patricio and Nueces Counties, Texas with the Gulf of Mexico. Ship sizes have increased resulting in the need for light loaded vessels to traverse the present waterway. The current channel depth requires that large crude carriers remain offshore and transfer cargo into smaller crude tankers for the remainder of the voyage. Ship delays are experienced as well due to the 400-foot channel width versus the needed 530-foot channel width and from the lack of barge lanes. Crude petroleum imports and petroleum product imports are expected to increase 50% and 500% by 2056, respectively. Twenty-three alternatives were evaluated. Based on the environmental impacts, engineering feasibility, and economic considerations, the recommended plan consists of deepening the CCSC to 52 feet and widening to 530 feet with modifications to turning basins; addition of 12-foot-deep, 200-foot-wide barge lanes on either side of the 530-foot channel for 9.6 miles in the upper Corpus Christi Bay; extension of La Quinta Channel for 1.4 miles at a depth of 39 feet and width of 300 feet; and a dredged material management/beneficial use plan.

THE OFFICIAL CLOSING DATE FOR THE RECEIPT OF COMMENTS IS 30 DAYS FROM THE DATE ON WHICH THE NOTICE OF AVAILABILITY OF THIS FINAL EIS APPEARS IN THE *FEDERAL REGISTER*.

If you would like further information on this statement, please contact:

Ms. Carolyn Murphy
U.S. Army Engineer District, Galveston
2000 Fort Point Road
Galveston, Texas 77550
Commercial telephone: 409/766-3044

NOTE: Information, displays, maps, etc., discussed in the Feasibility Report and Appendices are incorporated by reference in the FEIS.

April 2003

SUMMARY

Major Conclusions and Findings

Major factors affecting formulation of the Corpus Christi Ship Channel – Channel Improvements Project, Texas, were effects on water quality, sediment quality, bay system hydrology, estuarine resources, socioeconomic, and cumulative impacts. Contaminant studies demonstrated that new work and maintenance dredged material from all sections of the channel, with the exception of the Inner Harbor, is acceptable for offshore disposal, beneficial uses in the bay or ocean, or upland disposal. Because there have been contaminant problems with sediments in the Inner Harbor in the past, this material will be placed in existing, nearby upland sites to remove it from the system. The Hydrodynamic and Salinity Model demonstrated that minimal impacts on water exchange, inflow, and salinity would occur. Tidal amplitude may increase up to 0.06 feet and changes in salinity may seasonally and locally decrease by up to 4 parts per thousand (ppt). Shoreline erosion was studied without the beneficial use sites and it was concluded that neither the existing or proposed conditions had consistently positive or negative impacts on shoreline erosion. Several of the beneficial use sites are located to provide erosion protection to areas of concern for erosion.

The Beneficial Uses Workgroup of the Regulatory Agency Coordination Team developed a dredged material management/beneficial use plan that utilizes dredged material in an environmentally sound and economically acceptable manner and that incorporates other public benefits into its design. Beneficial uses of dredged material investigations identified a plan that will result in the following: creation of 935 acres of shallow water habitat, creation of 15 acres of submerged aquatic vegetation (as mitigation), creation of 26 acres of marsh, construction of 26,400 linear feet of rock breakwater, creation of 1,590 acres of offshore topographic relief, construction of 120 acres of upland buffer zone, construction of 7,500 linear feet of rock revetment, protection of 45 acres of submerged aquatic vegetation, protection of an existing bird island, and protection of 400+ acres of wetlands. Channel enlargement will result in direct permanent and temporary losses to 5 acres of patchy submerged aquatic vegetation, which will be mitigated through creation of 15 acres of submerged aquatic vegetation. The cumulative impact assessment showed that the proposed navigation improvements with the beneficial use plan will result in a net positive environmental effect to the Corpus Christi Bay ecosystem relative to the without project condition.

Recommended Plan

The Corpus Christi Ship Channel – Channel Improvements Project provides navigation safety and efficiency enhancements and environmental restoration via beneficial uses of dredged material. The recommended plan consists of deepening and selective widening of the existing –45 foot MLT deep, 400-ft-wide authorized channel from the Entrance Channel to a point about ½ mile east of the Harbor Bridge. Deepening of the channel will occur along its entire 34 mile length to –52 feet MLT. The existing Entrance Channel will be lengthened 10,000 feet and deepened from its present authorized depth of –47 feet MLT to an authorized depth of –54 feet MLT. The channel will be widened from its present

400-foot width to 530 feet through Upper Corpus Christi Bay. The Lower Corpus Christi Bay reach will be widened from its present 500-foot width to 530 feet. Barge shelves, which will each be 200 feet wide as measured from the toe of the widened channel, will occur along both sides of the channel through Upper Bay. The recommended plan includes the extension of La Quinta Channel approximately 7,400 feet at a width of 300 feet and to a depth of –39 feet MLT.

The Dredged Material Management/Beneficial Uses Plan outlines the placement of dredged material from construction of the project improvements. Eight existing confined upland sites, an existing offshore placement site, and eight existing, unconfined bay sites will be utilized to confine both new work and maintenance dredging material. An additional upland placement site for the La Quinta Channel Extension and seven new open-water beneficial use sites will be established; two offshore, and the remainder in Lower Corpus Christi Bay. Additional beneficial use project features for erosion protection that will benefit the coastal environment will be constructed without the use of dredged material.

Other Major Conclusions and Findings

This Environmental Impact Statement has been prepared to satisfy the requirements of all applicable laws and regulations using the Council of Environmental Quality's National Environmental Policy Act regulations (40 CFR Part 1500) and the Corps of Engineers regulation ER 200-2-2 (33 CFR 230). The following is a brief summary of the effects of the recommended plan on the significant environmental resources of Corpus Christi Bay.

Water Quality

A Hydrodynamic and Salinity Model for Corpus Christi Bay, developed by the Texas Water Development Board, evaluated water exchange and salinity impacts. The model results concluded that changes in tidal amplitude of 0.06 feet or less are expected in the project area, and that changes in salinity may seasonally and locally decrease by up to 4 ppt or increase up to 0.38 ppt. Testing of maintenance material elutriates with chemical analyses and water column bioassays has indicated no cause for concern. No significant increase or decrease in ballast water introductions is expected. As a result, no net adverse direct or indirect impacts from water quality are expected as a result of the recommended plan.

Sediment Quality

The results of sediment analyses demonstrated that new work and maintenance dredged material are acceptable for beneficial uses with two exceptions. Sediments from the Inner Harbor will be placed in several upland confined placement areas, and the fine material from the Upper Bay will continue to go into open-bay, unconfined placement areas.

Community Types

Five acres of submerged aquatic vegetation will be directly impacted by the recommended plan. This loss will be mitigated by planting 15 acres of seagrass within a 200-acre shallow water beneficial use site. The beneficial use plan will protect and create submerged aquatic vegetation habitat areas, wetlands, and coastal shore areas.

Fish and Wildlife Resources

No significant adverse impacts to finfish, shellfish, recreational and commercial species, aquatic communities, essential fish habitat, and wildlife resources are expected to occur from the recommended plan. Temporary impacts to fish and wildlife resources may be experienced from dredging and resulting suspended solids (turbidity). However, the beneficial use plan will create new habitat to be used by these species.

Threatened and Endangered Species

Identification of all Federally listed threatened or endangered species in the project area and any impacts the project may have on these species has been completed. A Biological Assessment of impacts on threatened, endangered, and candidate species in the area has been prepared and coordinated with the U.S. Fish and Wildlife Service and National Marine Fisheries Service. The Galveston District has determined that the recommended plan will not have any significant adverse effect on the listed species and the FWS has concurred (Appendix C). The NMFS's Biological Opinion is also included in Appendix C.

Hazardous, Toxic, and Radioactive Waste

A review of a regulatory agency database information search, an aerial photographic review, interviews with regulatory officials, and a site reconnaissance were conducted to determine the impacts of the recommended plan on or from existing hazardous, toxic, and radioactive waste. Areas identified in the Inner Harbor will not cause an impact because dredged materials will go to upland confined placement areas. Petroleum pipelines occur within the channel and will be relocated. No impacts to oil and gas wells are expected.

Historic Resources

All project impact areas have been evaluated for potential effects to historic properties including multiple marine remote-sensing surveys and diver assessments. The recommended plan will impact one significant historic property, the wreck of the SS *Mary* (41NU252) and mitigation will be done in coordination with the State Historic Preservation Officer. No terrestrial cultural resources will be impacted.

Air Quality

Minor, temporary impacts on air quality from the recommended plan would result during construction dredging activities while air quality from maintenance dredging and ship operations should be similar to those now occurring. Changes in air quality may occur due to the increase in traffic in the La Quinta Channel extension because of the proposed La Quinta Gateway Container Facility. This impact is not a result of the recommended plan and is expected to occur regardless of the deepening and widening of the main channel.

Noise

Minor, temporary impacts to the noise environment from the recommended plan would result during construction while maintenance dredging activities should be similar to those now occurring. Noise is not expected to increase significantly.

Socioeconomic Resources

Implan Professional, a computer-based modeling program, was used to predict indirect and induced effects from the recommended plan. Industry and employment data from the Nueces and San Patricio counties was used in the analyses. No adverse effects to socioeconomic resources are expected to occur from the recommended plan but beneficial economic impacts are expected.

Cumulative Impacts

Nine past, present, and reasonably foreseeable future projects and their impacts upon the project area were evaluated. The cumulative impact assessment concluded that the recommended plan has a net positive environmental effect on the project area relative to the without project (existing CCSC).

Areas of Controversy and Unresolved Issues

A draft Fish and Wildlife Coordination Act Report (CAR) is under revision by the FWS and will not be ready for inclusion in this document. The Final CAR for this project is included with the FEIS. Other resource agencies submitted comments on the recommended plan and the beneficial uses sites discussed in the 50-year disposal plan.

Relationship to Environmental Requirements

The recommended plan is in full compliance with the environmental requirements applicable to this stage of the planning process. A discussion of the applicable laws can be found in Section 7.0 of the FEIS.

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1.0 NEED FOR AND OBJECTIVES OF ACTION

1.1 STUDY AUTHORITY AND LOCATION

A congressional resolution was adopted 1 August 1990 by the committee on Public Works and Transportation, U.S. House of Representatives, which authorized the U.S. Army Corps of Engineers (USACE) to review the reports on the Port Aransas-Corpus Christi Ship Channel, Texas (45-foot project), published as House Document 99, 90th Congress, Second Session, and other pertinent reports to determine the feasibility of modifying the Corpus Christi Ship Channel (CCSC) system from the current depth of 45 to 50 feet to accommodate large vessels, increase shipping efficiency, and enhance navigation safety. The Port of Corpus Christi Authority (PCCA), non-Federal sponsor of the existing channel system, began consideration of additional channel improvements upon the 1989 completion of the 45-foot deepening project. The USACE completed the reconnaissance study in 1994 concluding that the benefits of channel improvements would be 2.5 times greater than the project cost. Thus began a Feasibility Study (FS), Corpus Christi Ship Channel – Channel Improvement Project (CCSCCIP), to determine whether the Federal navigation project is justified and to provide documentation needed to request Congressional authorization and funding for construction of the project. In 1999, the USACE and PCCA signed an agreement to conduct an FS, including an Environmental Impact Statement (EIS). The project is being led by the USACE, but cost is shared with PCCA, with the U.S. Environmental Protection Agency (EPA) as a cooperating agency.

The study area for the CCSCCIP encompasses Corpus Christi Bay, including the southern section of Redfish Bay and the northernmost section of the Laguna Madre, Nueces Bay, the lower Nueces River (12 miles), Inner Harbor, Viola Channel, La Quinta Channel, and the watershed surrounding these water bodies up to roughly ½ mile inland from all shorelines (Figure 1-1). The coastline of this area extends across Nueces and San Patricio counties and is adjacent to the cities of Corpus Christi, Portland, Ingleside-On-The-Bay, and Port Aransas.

The CCSC is located in Corpus Christi Bay on the south-central portion of the Texas coast, 200 miles southwest of Galveston and 150 miles north of the mouth of the Rio Grande River. This channel ranks seventh in the nation for tonnage shipped on oceangoing vessels, and, in Texas, only the Houston Ship Channel handles more tonnage.

1.2 PURPOSE AND NEED

The purpose of the project includes improvement in the efficiency and safety of the deep-draft navigation system, and protection of the quality of the area's coastal and estuarine resources. Safety improvements would address problems identified below and contribute to economic efficiency. Economic efficiency would result from the passage of large ships through the CCSC that previously had to remain offshore and transfer cargo into smaller crude tankers for the remainder of the voyage. Vessel delays and the potential for accidents would also be reduced. Protection of the area's coastal and estuarine resources would be associated with reduced potential for accidents and oil spills.

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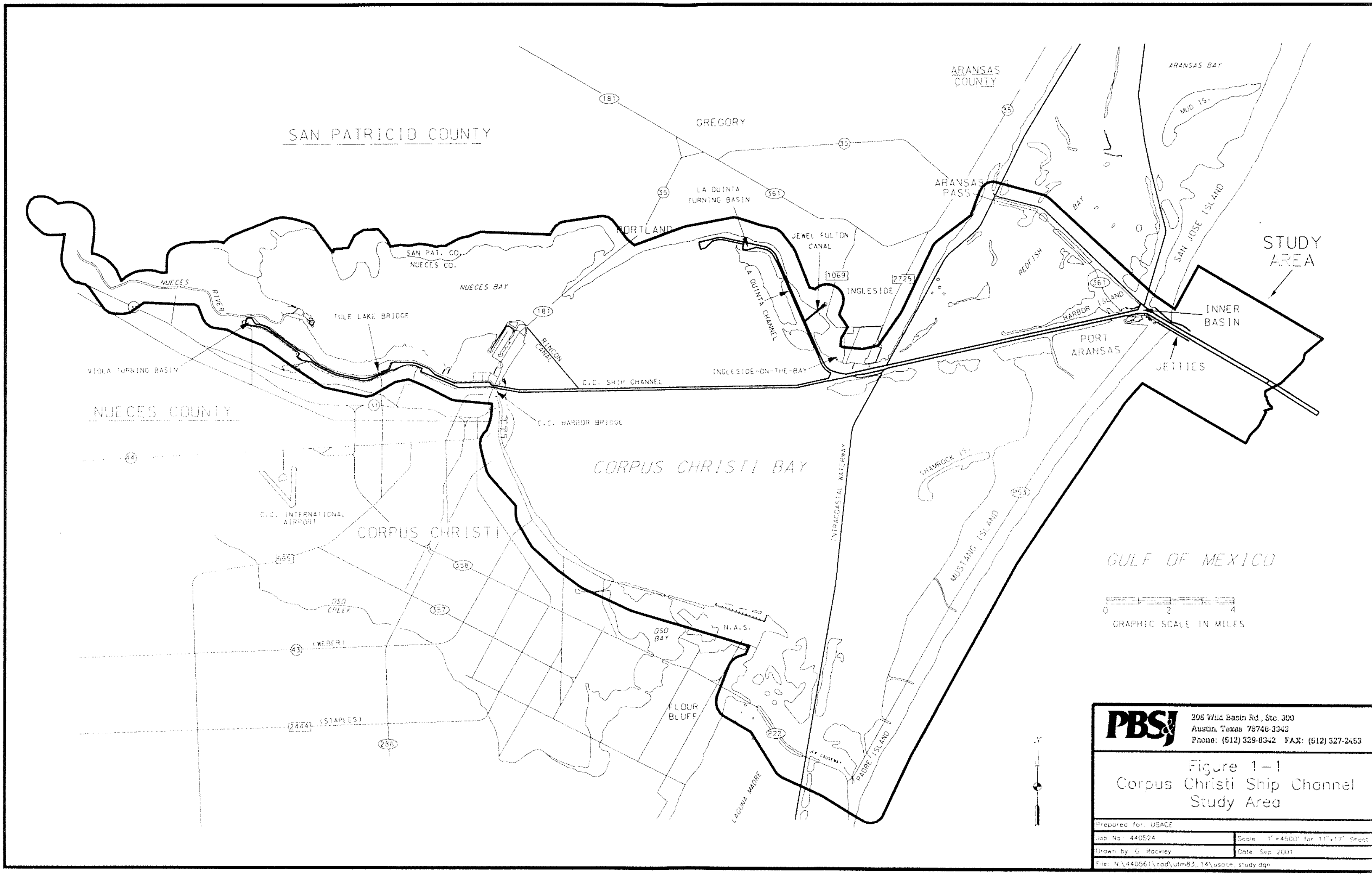

Figure 1-1
Corpus Christi Ship Channel
Study Area

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The channel reach between the Corpus Christi Harbor Bridge and the La Quinta Channel is only 400 feet wide and, since it is in an open-bay area, is subject to strong crosswinds and currents. At present, ships wait offshore and time their entrance into the CCSC to pass in the 500-foot reach since they cannot pass in the 400-foot reach, rather than incur the expense to obtain tug assistance to moor and wait with a pilot on board as well as tugs standing by to release them from the moorings. Widening the 400-foot reach is needed to increase the safety factor for this area and to reduce shipping delays, especially since shipping trends indicate a movement toward use of larger vessels.

Presently, few crude oil vessels are loaded to more than 41 feet because general policy requires vessels to have 3 feet of underkeel clearance. Therefore, the current channel depth requires that large crude carriers remain offshore and transfer their cargo into smaller crude tankers for the remainder of its voyage. Lightering also increases the potential of a collision, oil spill, or fire, leading to adverse environmental consequences. Channel deepening is needed to avoid both inefficiency and risk of adverse impacts from lightering.

Channel widening and deepening are also needed since several of the major petrochemical industries are currently undergoing major expansions, which will result in an increase in crude oil imports. As these imports increase, the number of lightering vessels and product carriers will also increase, adding to shipping delays and congestion. Since the most frequent shipping accidents result from collisions between ships and inland tows, the towing industry and channel industries are concerned that restrictions may be placed on the tows to limit these costly and environmentally damaging events. The proposed project would reduce delays, and the inclusion of barge shelves will reduce the risk of ship-tow collisions.

1.3 EXISTING PROJECT

The CCSC, formerly known as the Port Aransas – Corpus Christi Waterway, is a consolidation of past improvements of Port Aransas and the channel from Aransas Pass to Corpus Christi. The CCSC project channel system also includes La Quinta Channel, Jewel Fulton Canal, and Rincon Canal. The history of Federal Involvement in navigation improvements in the Corpus Christi Bay area began with the Rivers and Harbors Act of June 18, 1878. In August 1968, authorization of major improvements to the CCSC included increasing existing channels and basins to a 45-foot depth, a deep-draft turning area, a deep-draft mooring area and mooring facilities, and widening of the channels and basins at certain locations. The undredged northward extension of the Inner Basin at Harbor Island and the undredged west turnout between the La Quinta Channel and the main channel of the waterway was deauthorized. The 45-foot project was completed in 1989.

The existing authorized Federal navigation project consists of channels and turning basins suitable for oceangoing vessels and rubble-stone jetties. The channel begins at deep water in the Gulf of Mexico about 4.3 miles offshore, passes through the jettied inlet, and extends about 21 miles westward to Corpus Christi. Continuing west, the channel extends about 8.5 miles through the harbor area before terminating at the Viola Turning Basin. The north and south jetties are 11,190 and 8,610 feet long and extend into the Gulf from San Jose (formerly St. Joseph's) and Mustang islands, respectively, and stabilize the natural inlet of Aransas Pass. The stone dike on San Jose Island connects with the north jetty and extends 20,991 feet up the island. The La Quinta Channel extends off of the CCSC near Ingleside, Texas, and runs parallel to the eastern shoreline of Corpus Christi Bay for 5.5 miles to the La Quinta Turning Basin.

1.4 PROBLEMS, NEEDS, AND PUBLIC CONCERNS

Existing water resource problems and needs in Corpus Christi Bay were identified through coordination with Federal and State agencies, area residents, waterway users, and the USACE and PCCA. Most of the identified problems are not unique to Corpus Christi Bay but are common to many of the bays and estuaries in Texas. It should be noted that the following include all of the problems and concerns raised at a series of public meetings. Some have no relevance to this project and are general concerns raised by the citizens of the area. Many are concerns that cannot or will not be addressed in a project-specific EIS. However, all of the concerns raised by agencies and persons at those meetings are discussed in this section. As a consequence of the way the questions, comments, and concerns were collected, some are vague. However, they were reproduced as nearly as possible in this document, without embellishment. Concerns pertinent to the proposed project are addressed in this FEIS.

1.4.1 Navigation/Commerce

The CCSC was the first waterway in Texas to be completed to a 45-foot depth. Since the completion of the 45-foot project, the size of ships using the waterway has steadily increased, and vessels currently have to be light-loaded to traverse the waterway.

The channel reach between the Corpus Christi Harbor Bridge and Ingleside is only 400 feet wide and is subject to strong crosswinds and currents, while the reach between Ingleside and the jetties is 500 feet wide and is semi-protected by emergent Dredged Material Placement Areas (PAs) (Figure 1-2). As part of the 45-foot project, a mooring area was constructed near Ingleside. This facility consists of six mooring dolphins and ten mooring anchors. It was designed to hold inbound ships at Ingleside while other large ships were crossing the open water area from the Harbor Bridge to Ingleside. This facility has not functioned as designed, is in poor repair, and will soon be removed. Shippers prefer to wait offshore and time their entrance to pass in the 500-foot reach rather than incur the expense to obtain tug assistance to moor and wait with a pilot on board and tugs standing by to release them from the moorings. Widening the upper bay reach would increase the safety factor for this area and would reduce shipping delays, especially since shipping trends indicate a movement toward use of larger vessels. The ultimate size of vessels using the channel is restricted by the 138-foot vertical clearance of both the Harbor Bridge and the Tule Lake Lift Bridge. However, the clearance is sufficient to accommodate the present fleet of vessels using the project.

The 45-foot channel deepening project became operational in the late eighties and, at that time, crude oil tankers with loaded drafts up to 45 feet mean low tide (MLT) were not uncommon. MLT is 1 foot lower than National Geodetic Vertical Datum 29 (NGVD 29) (i.e., 0 feet MLT is equivalent to –1 NGVD 29) as used by the Galveston District of the USACE. Presently, few crude oil vessels are loaded to more than 41 feet. Examination of vessel records shows that some petroleum coke vessels are

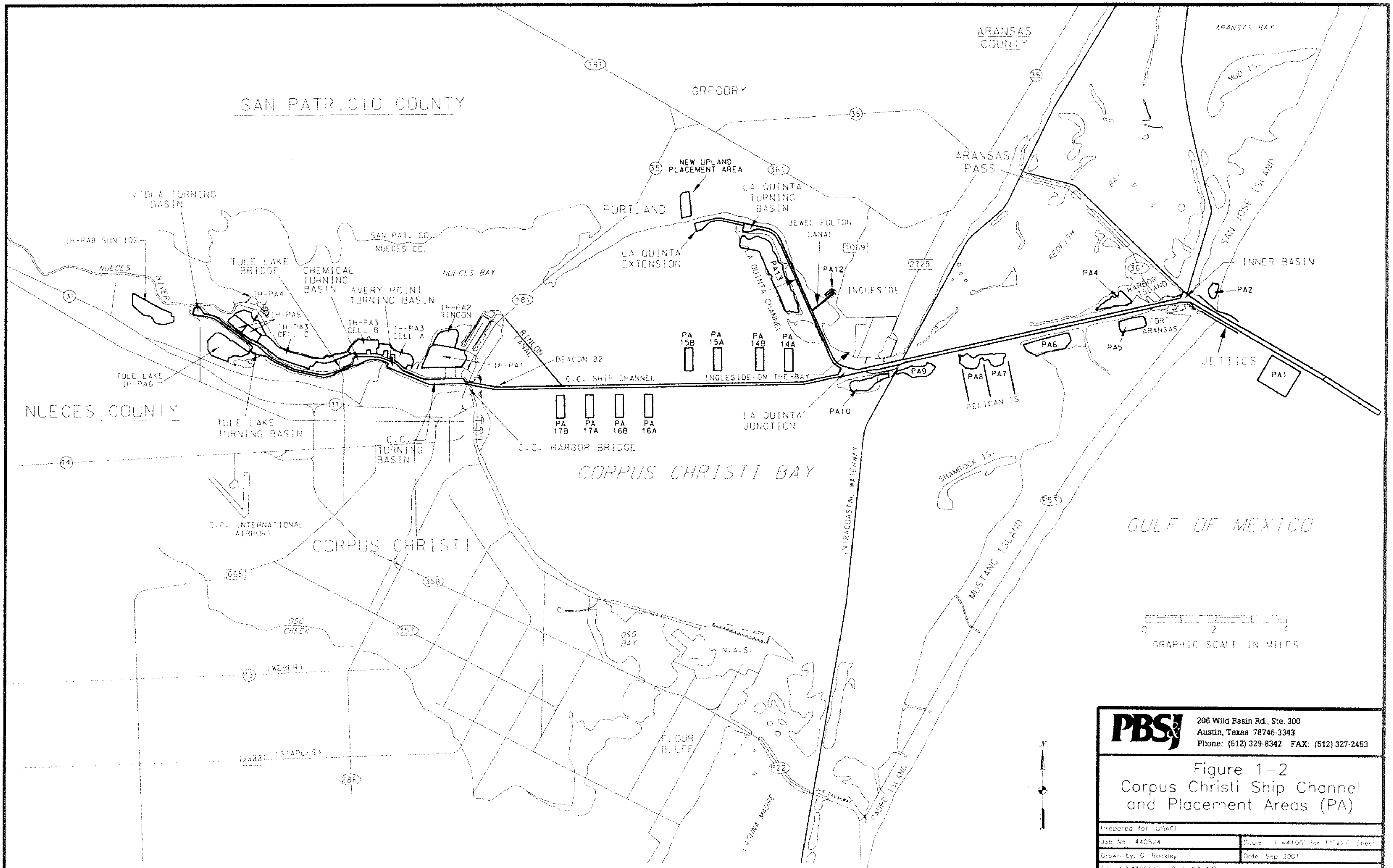

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Figure 1-2
Corpus Christi Ship Channel and Placement Areas (PA)

Prepared for USACE
Job No: 440524
Scale: 1"=4100' for 11"x17" Sheet
Drawn by: G. Rackley
Date: Sep 2001
File: N:\440561\cad\utm83_14\usace_ccsc.dgn

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presently loaded to depths of up to 45 feet MLT. Some pilots have allowed dry cargo, such as petroleum coke, to be loaded to deeper depths than liquid cargo. The general policy requires vessels to have 3 feet of underkeel clearance. Examination of 1996-1999 transit records shows that loaded drafts over 41 feet are infrequent, particularly for liquid cargo. In comparison, 1990 traffic data compiled for the 1994 reconnaissance report reveals that 1 foot of underkeel or less was not uncommon for liquid cargoes during the early 1990s.

The current channel depth requires that large crude carriers remain offshore and transfer their cargo into smaller crude tankers for the remainder of its voyage. This lightering operation takes place in the Gulf where the two ships, the mother ship and the lightering ship, come together to transfer the cargo. Although this operation has been occurring for years, the possibility for a collision, oil spill, fire, or other adverse environmental consequence is always present.

Several of the major petrochemical industries are currently undergoing major expansions which will result in an increase in crude oil imports. As these imports increase, the number of lightering vessels and product carriers will also increase, adding to shipping delays and congestion. Since the most frequent shipping accidents result from collisions between ships and inland tows, the towing industry and channel industries are concerned that without the proposed project, restrictions may be placed on the tows to reduce the potential for these costly and environmentally damaging events occurring.

Other issues of concern associated with navigation include those related to erosion and siltation. Shoreline erosion is occurring along the ship channel in the Port Aransas area. Ship wakes may be contributing to this problem, and an evaluation of the erosion problem was requested for inclusion in this study. The channel area in Corpus Christi Bay near the Harbor Bridge has a high siltation rate.

The remaining capacity of existing upland placement sites as well as the continued suitability of bay placement areas was suggested as requiring further study. It was suggested that a bay-wide plan which encourages the use of dredged materials for beneficial uses (BU) should be developed in the future.

1.4.2 Environmental

Many of the problems, such as pollution, are caused by human activities around the bay system and in the contributing watershed, while others, such as shoreline erosion, are a result of both human activities and natural processes, including normal wind-generated waves and hurricanes. The environmental concerns identified during meetings with the public and resource agencies in the reconnaissance study included the following items:

The increasing potential for environmental harm resulting from shipping accidents is a major concern. In the absence of adequate channel widening, one-way traffic will increase as a means to reduce this threat. One-way traffic has already been imposed when combined beam widths of meeting vessels would exceed 251 feet in the existing 400-foot-wide channel.

Oil spill recovery and definition of the liabilities associated with the clean-up are important to both the environmental community and the oil shipping industry. This understanding is necessary to ensure that cleanup activities are started immediately and are completed as quickly as possible to minimize damages.

Sediment quality in the Inner Harbor has been questioned by members of the RACT and environmental groups. See sections 3.2.3.5, 3.3.1, 3.3.2.5, 4.1.3, and 4.2 for an explanation of how these sediments will be handled.

The ship channel and open-bay placement areas could impact circulation and salinity levels within the bay. In addition, open-bay placement may present problems for the benthic community, circulation, and recreational and commercial fisheries, and may produce a need for future maintenance dredging.

During public scoping meetings and resource agency workshops, several areas of concern were raised that could possibly receive some type of action as a result of channel modifications or mitigation of the unavoidable impacts. It was suggested that water interchange between Corpus Christi Bay and the Laguna Madre could be improved, specifically in the vicinity of the John F. Kennedy (JFK) Causeway and the Gulf Intracoastal Waterway (GIWW). Impacts to wetlands, submerged aquatic vegetation (SAV), and shallow water were a concern as well. Suggested beneficial actions include construction of oyster reefs in and around the Corpus Christi area, enhancement of Redfish Bay, creation of wetlands, SAV, and unvegetated shallow water, and development of bird rookery islands in Nueces Bay.

1.5 PLANNING OBJECTIVES

The planning objectives of the Federal navigation project include improvement in the efficiency and safety of the deep-draft navigation system, and maintenance or enhancement of the quality of the area's coastal and estuarine resources. Safety improvements would address problems identified and contribute to economic efficiency. Economic efficiency would result from the passage of large ships through the CCSC that previously had to remain offshore and transfer cargo into smaller crude tankers for the remainder of the voyage. Economic benefits could also be realized from the proposed container terminal adjacent to the La Quinta Channel extension. Vessel delays and the potential for accidents would also be reduced.

Maintenance and enhancement of the area's coastal and estuarine resources would be associated with reduced potential for accidents and oil spills; beneficial uses of dredged material; minimization of effects to oyster beds, seagrasses, and other valuable habitats; and avoidance of areas with known cultural resource sites.

1.6 NON-FEDERAL SPONSOR AND COORDINATION

The Galveston District, USACE, is responsible for the general management of this FEIS. The PCCA is the non-Federal sponsor and has been an active participant during the reconnaissance phase and FS. As non-Federal sponsor for the waterway, the PCCA has the overall responsibility of acquiring PAs. Generally, the feasibility phase is cost-shared equally between the non-Federal sponsor and the Federal government through the General Treasury. Management has been coordinated between the USACE and the non-Federal sponsor.

EPA is a cooperating agency (40 CFR Part 1501.6) in the EIS process pursuant to its specific programs and responsibilities, including: 1) Section 309 of the Clean Air Act in review of the EIS in compliance with NEPA; 2) the Marine Protection, Research, and Sanctuaries Act in the designation of feasible and environmentally acceptable ocean dredged material disposal sites; and 3) Section 404 of the Clean Water Act in consideration and evaluation of impacts on wetlands and waters of the United States in coordination with the USACE and FWS.

The FS involves multidisciplinary studies to determine the specific improvements needed and the benefit-cost ratios of various alternatives. The Regulatory Agency Coordination Team (RACT), established by the PCCA and the USACE, provides guidance and wise counsel on matters relating to the evaluation of environmental impacts of this project. Members include PCCA, USACE, National Marine Fisheries Service (NMFS), U.S. Fish and Wildlife Service (FWS), Texas Parks and Wildlife (TPWD), U.S. Environmental Protection Agency (USEPA), Texas Natural Resource Conservation Commission (TNRCC), Railroad Commission (RRC), Texas Water Development Board (TWDB), Texas Department of Transportation (TxDOT), and Texas General Land Office (GLO).

Several technical work groups composed of members of the RACT have been established to focus on specific environmentally related areas of the project, with some overlap between workgroups. These groups have helped define the scopes of work for certain studies as well as review study results (Table 1.6-1). Workgroups include Shoreline Erosion Workgroup (SEW), Cumulative Assessment Workgroup (CAW), Hydrodynamic and Salinity Modeling Workgroup (HSMW), Contaminants Workgroup (CW), Mitigation Workgroup (MW), and Beneficial Uses Workgroup (BUW).

The SEW was created to evaluate the relationship and relative contribution of the project on shoreline erosion in the project area and provide information to guide shore stabilization, erosion protection, project impact assessment or mitigation, and beneficial use alternatives analysis.

The CAW was created to collect information from past changes in bay water salinity patterns, bay bottom losses and disturbances, wetland losses, and water and sediment quality changes, and future projections of the cumulative impact based on reasonably foreseeable development within the project area.

The HSMW was created to identify the model scenarios, which should be addressed to evaluate environmental and biological effects potentially associated with the project.

The CW evaluated water and sediment quality associated with the proposed project, including characterization of existing conditions in the project area and the results of any physical, chemical, and biological analysis.

The MW was created to identify methods to assess direct effects of the proposed project and evaluate environmentally compatible design measures to mitigate adverse effects on fish and wildlife resources.

TABLE 1.6-1

CORPUS CHRISTI SHIP CHANNEL – CHANNEL IMPROVEMENTS PROJECT
WORKGROUP PARTICIPANTS
1998 – MAY 14, 2002

U.S. Army Corps of Engineers

Frank Garcia
Bob Bass
Bob Heinly
Terry Roberts
Carolyn Murphy
Rob Hauch
Gary Ray, WES
Doug Clark, WES
Carl Anderson
Wade Williams
Carlos Tate
Jon Plymale
John McManus
Dale Williams
Rick Medina
Rao Vemulakonda, WES
Ed Reindl
Mike Kieslich
George Alcala

U.S. Environmental Protection Agency

Mike Jansky
Monica Young
Tim Landers

U.S. Fish and Wildlife Service

Johnny French
Clare Lee
Tom Schultz
Tom Shearer
Pat Clements
Mary Orms

National Marine Fisheries Service

Bill Jackson
Rusty Swafford

Texas Department of Transportation

Raul Cantu
Amy Link
Melissa Gabriel
Paul Douglas
Scott Sullivan

Texas General Land Office

Ray Newby
Tom Calnan
Kim Halbrook
Heidi Wadzinski

Texas Natural Resource Conservation Commisson

Bruce Moulton
Mark Fisher
Rene Mariscal
Chris Caudle
Robert Burgess

Texas Parks and Wildlife Department

Smiley Nava
Jim Tolan
Mary Ellen Vega
Beau Hardegree
Kay Jenkins

Texas Railroad Commission

Mary McDaniel
Don Gault
Bill Meyer

Texas Water Development Board

Gary Powell
Junji Matsumoto
Barney Austin
Mark Wetzel

Port of Corpus Christi Authority

Greg Brubeck
David Krams
Paul Carangelo
Stacey Bryant
Sandy Escobar

Coastal Bend Bays and Estuary Program

Leo Trevino

PBS&J

Martin Arhelger
Gary Galbraith
Kari Jecker
Kathy Calnan

Pacific International Engineering

Vladimir Shepsis
Hugo Bermudez

Olivarri and Associates

Leah Olivarri
Kelly Billington

The BUW was created to identify potential beneficial uses of dredged materials and to develop a Dredged Materials Management Plan for the use of these materials. A goal of the BUW was to develop a plan that would provide a net environmental benefit (gain) for the ecosystem. One type of in-bay beneficial use site would be developed by using the dredged material to establish a "platform" of varying elevation, which would provide a mosaic of habitat conducive for colonization by seagrass and emergent vegetation. Most BU sites are multiple-use sites and are located to provide, for example, erosion protection for an area and human recreation opportunities. The offshore sites will provide topographic relief to attract marine organisms to the site. The BU sites represent the beneficial use of new work material lending itself to a purpose of a net benefit to the ecosystem. Monitoring of the sites will not occur; however, the BUW would remain organized throughout the life of the project to participate in the design of the BU sites, monitor the sites during and after construction, and provide recommendations to the project sponsors to repair or renourish the sites, as needed, during future maintenance dredging operations so that the sites function as viable habitat for the ecosystem. The maintenance material varies from silt to sand and its use will be determined by each site's purpose as determined by the BUW.

The RACT and workgroups evaluated alternatives and various studies including engineering design, ship simulations, barge shelf studies, hydrodynamic and salinity modeling, ballast water studies, and benefit and cost analysis, as well as many others.

1.7 RESOURCE MANAGEMENT ACTIONS

Resource management actions are primarily, but not limited to, beneficial uses (BUs) of dredged material, as outlined below.

The BUW and RACT developed a dredged material management/beneficial use plan (DMM/BU Plan) that utilizes dredged material in an environmentally sound and economically acceptable manner and that incorporates, to the extent possible, other public benefits into its design. The estimated amount of dredged material generated would be approximately 41 million cubic yards (mcy) of new work material, and approximately 208 mcy of maintenance material over the next 50 years, from the Entrance Channel, Lower Bay, La Quinta Channel and extension, Upper Bay, and Inner Harbor.

While developing the DMM/BU Plan, the PCCA and the BUW have solicited information from the public to identify the BUs. Categories considered included shoreline protection; erosion protection; habitat development, including creation of marshes, bird islands, underwater berms, shallow water unvegetated and vegetated areas, seagrass areas, reef structures and ecological stimulation; beach nourishment; waterfront development; construction materials; seagrass protection; recreation use; maximization of benefits from freshwater inflows; and increasing the capacity of existing PAs. Seventy-seven sites were originally derived from several public meetings and then, in December 2000, consolidated into nine categories that contained similar suggestions (PCCA, 2001a). These ideas were fully considered further by the BUW during development of the DMM/BU Plan, including the beneficial use sites described below. Within the DMM/BU Plan, eleven sites have been proposed for new habitat development and/or protection areas as described below (Figure 1-3). New work material (16.7 mcy) will be utilized to create two offshore sites, one upland site, and five open-water sites (Table 1.7-1). There are no plans to use dredged material from maintenance dredging at this time in the BU sites although, as at

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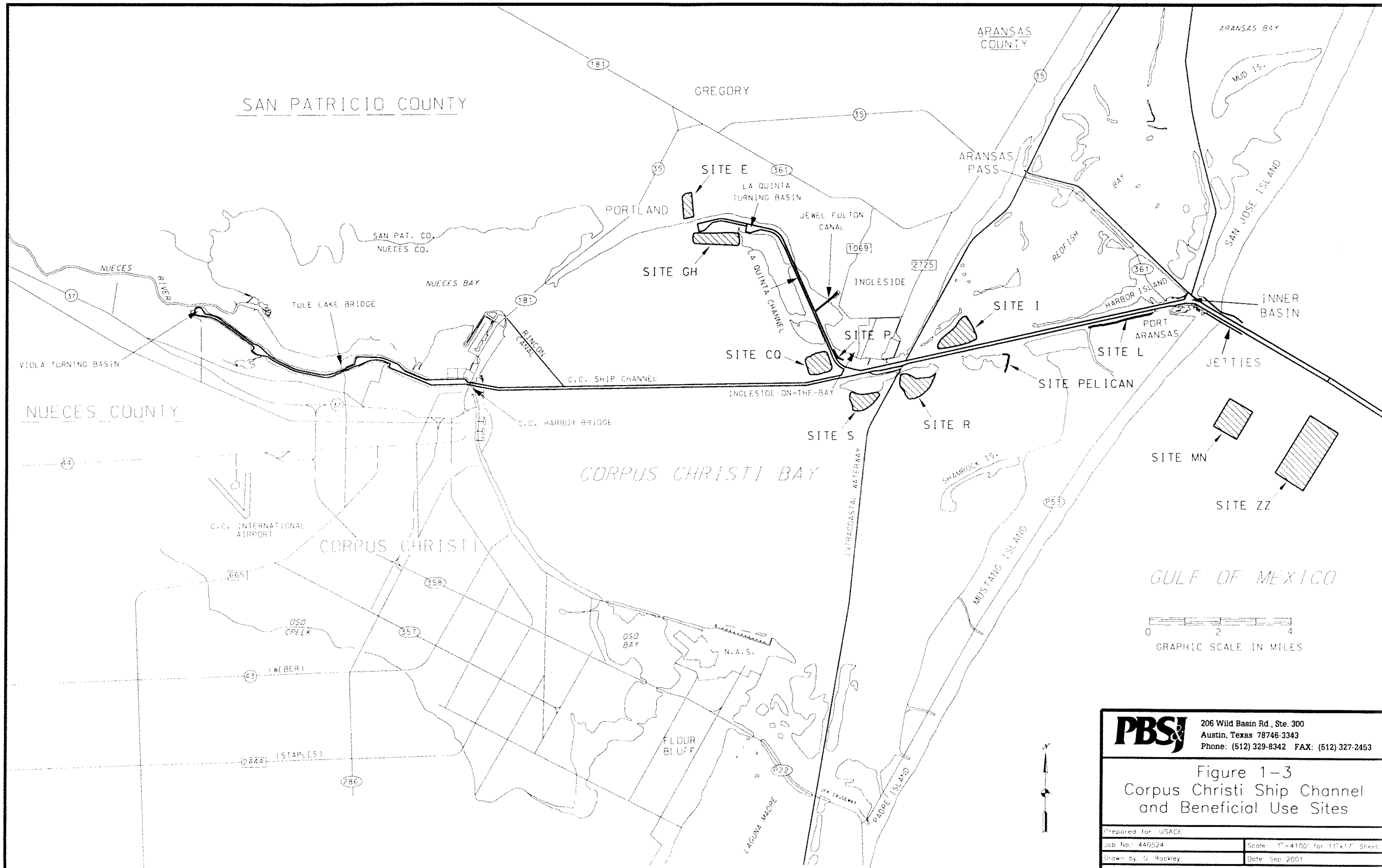

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Figure 1-3
Corpus Christi Ship Channel and Beneficial Use Sites

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Job No.: 440524	Scale: 1"=4100' for 11"x17" Sheet
Drawn by: G. Rackley	Date: Sep 2001
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TABLE 1.7-1
BENEFICIAL USE SITES

Site	New Work Dredge Material Used at Site: Type	New Work Dredge Material Used at Site: Amount	Description of Creation or Protection: Approximate Amount	Description of Creation or Protection: Type
GH	Dense sand and hard clay	2.5 mcy	Creates 200 acres	Shallow water habitat
			Creates 15 acres	SAV
			Creates 7,500 LF	Rock breakwater
			Creates 6 acres	Marsh
CQ	Dense sand	2.9 mcy	Creates 250 acres	Shallow water habitat
			Creates 8,000 LF	Rock breakwater
			Creates 5 acres	Marsh
P	None; imported rock	n/a	Creates 2,400 LF	Rock breakwater
			Protects 45 acres	SAV
I	Dense to very dense sand	2.1 mcy	Creates 163 acres	Shallow water habitat
			Creates 7,000 LF	Rock breakwater
			Creates 15 acres	Marsh
R	Dense to very dense sand	2.4 mcy	Creates 201 acres	Shallow water habitat
S	Dense to very dense sand	1.5 mcy	Creates 121 acres	Shallow water habitat
Pelican	None; existing bird island	n/a	Protects Existing	Rookery habitat
			Creates 1,500 LF	Rock breakwater
L	None; imported rock	n/a	Creates 7,500 LF	Rock revetment
			Protects 400+ acres	Wetlands
E	Hard clay and dense sand	1.0 mcy	Creates 120 acres	Future buffer zone
ZZ	Soft silty and soft sandy clays	2.6 mcy	Creates 1,150 acres	Offshore topographic relief
MN	Soft clays with primarly dense sands	1.7 mcy	Creates 440 acres	Offshore topographic relief
	TOTALS	16.7 mcy of new work dredged material	Creates 935 acres	Shallow water habitat
			Creates 15 acres	SAV
			Creates 26,400 LF	Rock breakwater
			Creates 26 acres	Marsh
			Creates 1,590 acres	Offshore topographic relief
			Creates 120 acres	Future buffer zone
			Creates 7,500 LF	Rock revetment
			Protects 45 acres	SAV
			Protects existing	Bird Island
			Protects 400+ acres	Wetlands

* Maintenance dredged material may also be used to augment BU Sites CQ, R, S, and I, if determined to be needed in the future and maintenance material available at the correct grain size.

present, some maintenance material may be used beneficially, but only after coordination with BUW members.

Proposed BU Site GH is a rectangular site located in open water adjacent to the south side of the La Quinta Channel extension and west of PA 13 at the terminus of the existing La Quinta Channel. After construction, the site will be protected from wave erosion on two sides and contain approximately 200 acres of shallow water high and low marsh aquatic and estuarine habitat. The shallow water would have an approximate mudline from –1 to –2 feet MLT developed from the existing depth of –6 to –12 feet MLT. Approximately 15 acres of submerged aquatic vegetation (SAV) will be planted within this site as mitigation for project impact. BU Site GH will be bordered on the south and west by hydraulically filled embankments protected by geotubes and riprap to elevation +6 feet MLT to protect the shoreline and enhance vegetation colonization. A single row of *Spartina* would be planted along the inside (north side) of the wave-protection levee creating approximately 6 acres of marsh. The area would be ±7,200 to 9,000 feet long running east to west and 1,500 feet wide from north to south. The northern edge of the area would be located approximately 1,500 feet from the existing shoreline. The project provides for deposition of 2.5 mcy of new work dredged material to create the shallow water habitat.

BU Site CQ is located north of the ship channel and west of the La Quinta Channel. Site CQ will be a rectangular open water site, partially enclosing approximately 250 acres of newly created shallow water and emergent island habitat with 6 to 10 mounds of material placed in a northwest to southeast direction to decrease wind fetch inside the site. The new work material would be allowed to flow freely in the deeper eastern half of the site to fill to depths shallow enough to support seagrass. There may be some deeper holes that would not support seagrass, but these areas would provide a mosaic of habitats for marine life. The mounds would be about +3 to +5 feet MLT, and the perimeter of the emergent mounds would be fringed with *Spartina* spaced at 5-foot intervals to hasten vegetation growth and erosion protection, creating 5 acres of marsh. An armored levee for wave protection and to help contain dredged material would be created around the site on the west, south, and east boundaries with geotubes or rock breakwaters to elevation +6 feet MLT, placed over hydraulically filled base. The existing bottom is –3 to –10 feet MLT and would be raised to –1 to –2 feet MLT. This site would be approximately 4,600 feet across. The project provides for the deposition of approximately 2.9 mcy of new work dredged material to create the habitat.

BU Site P is approximately 2,400 feet long and located along the east bank of the La Quinta Channel and Ingleside-On-The-Bay. This site will function as a breakwater to minimize bank erosion and provide protection to about 45 acres of existing seagrass beds. The wave barrier would consist of a rock breakwater to elevation +6 feet MLT. The existing seagrass habitat to be protected at this site is 0 to–3 feet MLT. Dredged material will not be placed at this site.

BU Site I is located adjacent to and north of the ship channel between Dagger Island and Pelican Island, and west of the GIWW. One of the goals of BU Site I formulated by the BUW is to partially protect Dagger Island from ongoing shoreline erosion. Site I is a proposed triangular-shaped open water site, partially enclosing approximately 163 acres of shallow water habitat, including a 10- to 15-acre island in the southeast corner of the site filled to an elevation of +8 to +10 feet MLT and about 20 mounds scattered across Site I filled to an elevation of about +3 feet MLT. The site will be bordered on the south and east sides by a hydraulically filled embankment protected on the exterior slopes by riprap and geotubes to +6 feet. The west and north sides will remain open to provide circulation between the site and the surrounding bay. A mixture of open water, shallow water, and suitable habitat for emergent and high marsh would be created at this site. A fringe of *Spartina* would be planted around the edge of the mounds and the larger island (a single row with 5-foot centers) creating approximately 15 acres of marsh. The existing bottom is at an elevation of –6 to –9 feet MLT. The project provides for the deposition of approximately 2.1 mcy of new work dredged material.

BU Site R is a proposed triangular-shaped open water site, partially enclosing approximately 201 acres of newly created shallow-water habitat. The shallow water would have an approximate mudline from –1 to –2 feet MLT developed from the existing depth of –6 to –10 feet MLT. It is located adjacent to and south of the ship channel, south of PA 9, and east of the GIWW. It will be bordered on the south and west sides by a hydraulically filled embankment, protected by riprap and geotubes on the exterior slopes to an elevation of +5 feet MLT. The project provides for the deposition of approximately 2.4 mcy of new work dredged material to create the shallow water habitat.

BU Site S is a proposed triangular-shaped open water site, partially enclosing approximately 121 acres of newly created shallow-water estuarine habitat. The shallow water would have an approximate mudline from –1 to –2 feet MLT developed from the existing depth of –6 to –10 feet MLT. It is located south of the ship channel, south of PA 10, and west of the GIWW. It will be bordered on the east side by a hydraulically filled embankment, protected by riprap and geotubes to an elevation of +5 feet MLT. The project provides for the deposition of approximately 1.5 mcy of new work dredged material to create the shallow water habitat.

A short stretch of channel(s) may have to be dredged in some of the shallower areas to allow a barge to bring rock and equipment into the area to armor the levee around Sites R and S. The dredged material from the channel(s) would be sidecast along the channel. No plantings are proposed for Sites R and S.

BU Site Pelican is a proposed open water site, located adjacent to and south of the channel, on the east side and south of Pelican Island (PAs 7 and 8). New work material will not be used at this site per se, but approximately 0.3 mcy of suitable quality new work material will be used to fill the geotubes. In the past, maintenance dredged materials have been placed on the south side of the island and allowed to flow out into the open water as a part of the ongoing rookery island enhancement, and this practice will continue. Rock revetment (1,500 feet) on the northeast corner of the island that was constructed previously to protect that part of the island from erosion will be replaced. The armoring has been lost over the years to erosion flanking the rock. Approximately 2,200 linear feet of hydraulically filled embankment, protected by geotube and riprap, will extend bayward from the east end of the island. The purpose of this hydraulically filled embankment is to contain the dredged maintenance material flowing off the south side of the island to maintain an open-water channel between Pelican and Mustang Islands, thereby preventing land bridge access to Pelican Island from Mustang Island by predators. This embankment will also protect the island from shoreline erosion.

BU Site L is located on the south bank of the channel between Piper Channel and the public Fishing Pier just west of Port Aransas. The rock revetment at this site is intended for a marsh/ecosystem protection site and will not use dredged material. The rock revetment will follow the shoreline with 3,400-foot, 500-foot, and 3,600-foot sections from west to east, respectively. A gap will be left between each section to allow for storm tide exchange. The existing ground elevation is +5 feet.

BU Site E is located on PCCA-owned land just north of the turning basin for the La Quinta Channel Extension. New work material at Site E would create a 120-acre upland buffer between lands to the west and the La Quinta Gateway Project. The existing site comprises uplands which include brushland. Approximately 1.0 mcy of new work dredged materials will be placed in this area to serve as a future source of landscaping for a tree-lined greenbelt separating public use lands to the west and industrial sites to the east. Best management practices on site will keep air concerns to a minimum.

Offshore placement of the new work material from the entrance channel extension is being coordinated with EPA for BU Site ZZ, the old U.S. Navy Homeport Ocean Dredged Material Dumping Site (ODMDS), under Section 404 guidelines. In this plan, approximately 2.6 mcy of new work material dredged from the entrance channel extension will be placed in the approximately 1,150-acre site, located approximately 15,300 feet southeast of the Aransas Pass South Jetty. The BUW and the RACT concurred that this Beneficial Use is preferable to general ocean placement. BU Site ZZ will provide topographic relief to the deeper offshore bay bottom, thereby enhancing the marine ecosystem in the area.

BU Site MN is approximately 440 acres and is located just outside the 30-foot contour outside the surf zone 10,000 feet south of the project channel centerline. Approximately 1.7 mcy of new work dredged material will be placed into this area, providing topographic relief to the nearshore Gulf bottom, thereby enhancing the marine ecosystem in the area.

2.0 ALTERNATIVES

2.1 HISTORY AND PROCESS FOR FORMULATING ALTERNATIVES

For the preparation of the CCSCCIP, alternatives were analyzed during the Initial Plan Formulation Phase to identify the alternative that maximized National Economic Development (NED) benefits. Twenty-three alternatives, including combinations, were analyzed during this initial stage. The Feasibility Report, to which this FEIS is attached, provides details of the Alternatives Analysis. Only a brief summary is included below.

The Planning, Environmental, and Regulatory Division of the Galveston District (PER) provided channel depths for analysis. Channel widths were determined by design economic vessels and ship simulations based on information from Aransas-Corpus Christi Pilots and the U.S. Army Engineer Research and Development Center (ERDC). Non-Federal sponsor requests were also evaluated.

An economic evaluation of project modifications to the Corpus Christi and La Quinta channels was conducted by calculating project benefits based on reductions in transportation costs. Benefits were evaluated for the following alternatives: Corpus Christi depths of 48, 50, and 52 feet; deepening the existing Federal portion of the La Quinta Channel; extension of the La Quinta Channel Federal project; and widening the Corpus Christi Bay Channel 400- and 500-foot reaches to 530 feet. In addition to widening of the bay channel, benefits were evaluated for barge shelves in the 400-foot reach. The shelves would extend 200 feet from the toe of the proposed 530-foot-wide channel on either side.

2.2 ALTERNATIVES SCREENING

An initial screening analysis of the plan alternatives was completed in early 2000. The results of the initial screening were presented at the 4 April 2000 Feasibility Scoping Meeting (FSM). The initial screening showed that a Corpus Christi channel depth of 52 feet produced the highest net excess benefits for the deepening plans evaluated for the main channel. The screening analysis suggested that additional studies were necessary to determine whether widening of the bay reach and extension of the La Quinta channel was within Federal interest. An additional recommendation of the FSM was to further investigate deepening of the La Quinta Channel beyond the existing project depth of 45 feet. In regard to channel widening, the non-Federal sponsor and pilots association expressed a strong interest in widening the bay reach due to safety concerns and associated vessel delays and self-imposed vessel meeting restrictions. The recommendation for widening the entire bay reach to 530 feet was based on the USACE Waterways Experiment Station (WES) findings and the safety interest of Aransas-Corpus Christi Pilots. The pilots presently limit vessel meetings to combined beam width up to 251 feet in the 400-foot reach and a combined loaded draft limit of 80 feet.

The USACE conducted the FSM to discuss the twenty-three alternatives with preliminary benefit-cost (BC) ratios providing justification for reducing the alternatives to six. Mitigation was not required to be considered during this initial screening process. Cost factors such as levee construction, dredging, and pipeline relocations were included in the cost analysis. The essence of the initial screening process was to put all the alternatives on an equal basis without the mitigation costs. Costs were developed for all 23 alternatives, but benefits were determined to be needed only on certain alternatives (48-, 50-, and 52-foot depths in the main channel and 400- and 500-foot widths).

The outcome of this initial screening resulted in six alternatives to be analyzed further. The following briefly describes each alternative:

- Deepen to 52 feet from the Gulf of Mexico to Viola Turning Basin and widen across Corpus Christi Bay (maximum net excess benefits)
- Deepen to 50 feet from the Gulf of Mexico to Viola Turning Basin and widen across Corpus Christi Bay
- Widen only across Corpus Christi Bay (Sponsor Request)
- Deepen La Quinta Channel to 50 feet (Sponsor Request)
- Extend La Quinta Channel
- Provide Barge Lanes across the Upper Bay in Corpus Christi Bay

The initial screening indicated that added depth was not needed on La Quinta Channel and channel extension. Reynolds Metals and Oxychem stated that they did not need additional depth in La Quinta Channel. Despite the 0.6 Benefit Cost Ratio, the widening-only alternative was also evaluated further for additional benefits that could change the ratio.

While not part of the initial screening, alternatives also arose for offshore placement of dredged material, including ocean placement pursuant to Marine Protection Research and Sanctuaries Act and beneficial use pursuant to Section 404 of the Clean Water Act. To ensure maximum use of the dredged materials in a beneficial way, the BUW determined that disposal of materials beneficially was the preferred disposal option (BU Site ZZ; see Section 1.6).

2.2.1 Channel Deepening Benefit Summary

Channel deepening benefits were calculated for Corpus Christi crude petroleum, petroleum products, and grain cargoes. The transportation savings benefits were calculated using a Federal discount rate of 6⅝ percent and using fiscal year 2000 hourly operating costs. Transportation costs were calculated for 45- to 52-foot channel depth alternatives (see economic appendix for details).

Projected deepening will result in a decrease in the cost per ton for both the shuttles associated with offshore lightering and for vessels associated with direct shipments. Nearly all crude oil shipped from the Mideast is lightered and will continue to be lightered in the future, and nearly all oil shipped from Mexico and Venezuela is currently shipped direct and will continue to be in the future. Lightering and lightening costs are presently costs slightly less than direct shipment cost for movements from Africa and the North Sea. The deepening project will reduce the differential between direct shipping cost and lightering cost and the reduction in this differential will make direct shipment more likely for movements from Africa and the North Sea. The cost differential reduction is expected to result in a slight increase in direct shipment for Africa and North Sea crude oil imports.

Although lightering would not be eliminated, there would be an overall decrease in the number of vessels needed to transport a given volume of petroleum products. The percentage of tonnage by trade route and method of shipment is displayed in the economic appendix.

The purpose of the spill analysis was to identify accident and spill frequencies for the Corpus Christi Ship Channel project area. The affected area primarily includes the offshore entrance, the bay channel, La Quinta, and the Inner Harbor. Lightering occurs in international waters. A literature search was conducted of national spills. Over one-half of the mother vessels associated with Corpus Christi's offshore transfers operate in the international waters offshore from Galveston. The remainder of crude is transferred in the international waters off of Corpus Christi.

2.2.2 Channel Widening Benefits

Benefits were calculated for widening the Corpus Christi Bay Channel 400- and 500-foot reaches to 530 feet. In addition to widening the bay channel, benefits were evaluated for a barge shelf in the 400-foot reach. The barge shelf would extend 200 feet from the toe of the proposed 530-foot channel.

The benefits associated with widening the bay reach to 530 feet were calculated based on the probability of vessel meetings and potential delays. The Aransas-Corpus Christi Pilots vessel meeting criterion is that vessels with combined beam widths of 251 feet or more cannot meet in the 400-foot reach. An additional criterion is that meetings are not permitted between vessels with combined loaded drafts in excess of 80 feet. The pilots noted that the 80-foot combined draft limit was invoked in the early 1990s.

Benefits for widening the bay reach were calculated based on reductions in delays due to the combined beam width restriction. Benefits were not calculated for easement of the underkeel clearance policy, as the pilots indicated there would be no change in the policy to maintain 3 feet of underkeel clearance.

National data reviewed for the Corpus Christi study showed that for the period 1973–93, there were 38,778 spills in the waters monitored by the USCG and falling in the category of "outer continental shelf and inland regimes." Twenty percent of these spills involved tank ships. The associated volume spilled was 66 million gallons. Two percent of the 66 million gallons was associated with lightering operations. Corpus Christi project data obtained from the USCG for the period 1992-99 was evaluated for the Corpus Christi study. Analysis of the USCG data records showed that pollution incidents, collisions, and allisions most frequently occur in the project area between the Inner Harbor and Viola Turning Basin, where channel widening and barge lanes will reduce the probability of collisions (see economic appendix for details).

2.2.3 Deepening of the Existing La Quinta Federal Project

Examination of the vessel sizes and trade routes associated with tonnage transported through the existing 45-foot channel showed that only a small number of vessels were loaded to drafts in excess of 40 feet. Additional analyses indicated that port depths at shipping and receiving ports were and would continue to remain a constraint. Comparison of the project construction costs for deepening the existing channel to depths over 45 feet with potential reductions in transportation costs associated with more deeply loaded vessels did not produce a BC ratio above unity, which is typically required for a Federal deep-draft navigation project (refer to Feasibility Report – Economic Criteria).

2.2.4 Extension of the Existing La Quinta Federal Project

Determination of the Federal interest in the extension of the existing limits of the La Quinta Channel was evaluated based on the results of a multiport analysis. The purpose of the analysis was to determine whether the La Quinta Channel extension to a proposed container terminal offered a competitive advantage over existing and anticipated container facilities such as the Port of Houston's Barbours Cut and Bayport projects and the Texas City Shoal Point project. It was determined that it would, that the BC ratio was greater than one, and that it would be in the Federal interest.

2.3 RECOMMENDED ALTERNATIVE

The study area has been divided into five reaches for discussion in this document: the Entrance Channel, Lower Bay, La Quinta Channel, Upper Bay, and Inner Harbor (Figure 2-1). Information for the Gulf Intracoastal Waterway (GIWW) across Corpus Christi Bay is also discussed but is not considered a reach since there are no improvements to it associated with this project. The Entrance Channel includes that area from the Gulf of Mexico through the Aransas Pass jetties to the Inner Basin (Station -38+00 to 310+00). The Lower Bay includes the area from the Inner Basin to La Quinta Junction (Station 12+55 to 54+00). La Quinta is the channel from the La Quinta Junction north (Station 309+51 to 382+00). The Upper Bay includes the area between the La Quinta Junction and Beacon 82 (Station 54+00 to 1050+00). Between Beacon 82 and Viola Turning Basin lies the Inner Harbor reach (Station 1050+00 to 1561+00).

2.3.1 No-Action

In the absence of Federal actions to improve the CCSC, the existing Federal project will continue to be maintained at its current dimensions and the dredged materials will be disposed of in a manner very similar to existing practices. It is also expected that industrial expansion in the area will continue and that shipping will likewise increase. The No-Action Alternative is discussed more fully under the various affected resource categories in Section 4, Environmental Consequences.

2.3.2 Preferred Alternative

The following plan is based on the economic, engineering, and environmental factors and is the USACE-recommended and PCCA-preferred alternative for the CCSCCIP. The preferred alternative includes deepening of the CCSC from Viola Basin to the end of the jetties in the Gulf of Mexico to 52 feet, deepening of the remainder of the channel to 54 feet, widening of the Upper Bay and Lower Bay reaches to 530 feet, construction of barge lanes across the Upper Bay portion of the CCSC, and extension of the La Quinta Channel at 39 feet.

The land locked portion of the Entrance Channel will be deepened to 52 feet plus 2 feet of advanced maintenance. The area of the Entrance Channel in the open waters of the Gulf will be dredged to a 54-foot authorized depth with an additional 2 feet of advanced maintenance to insure safe vessel

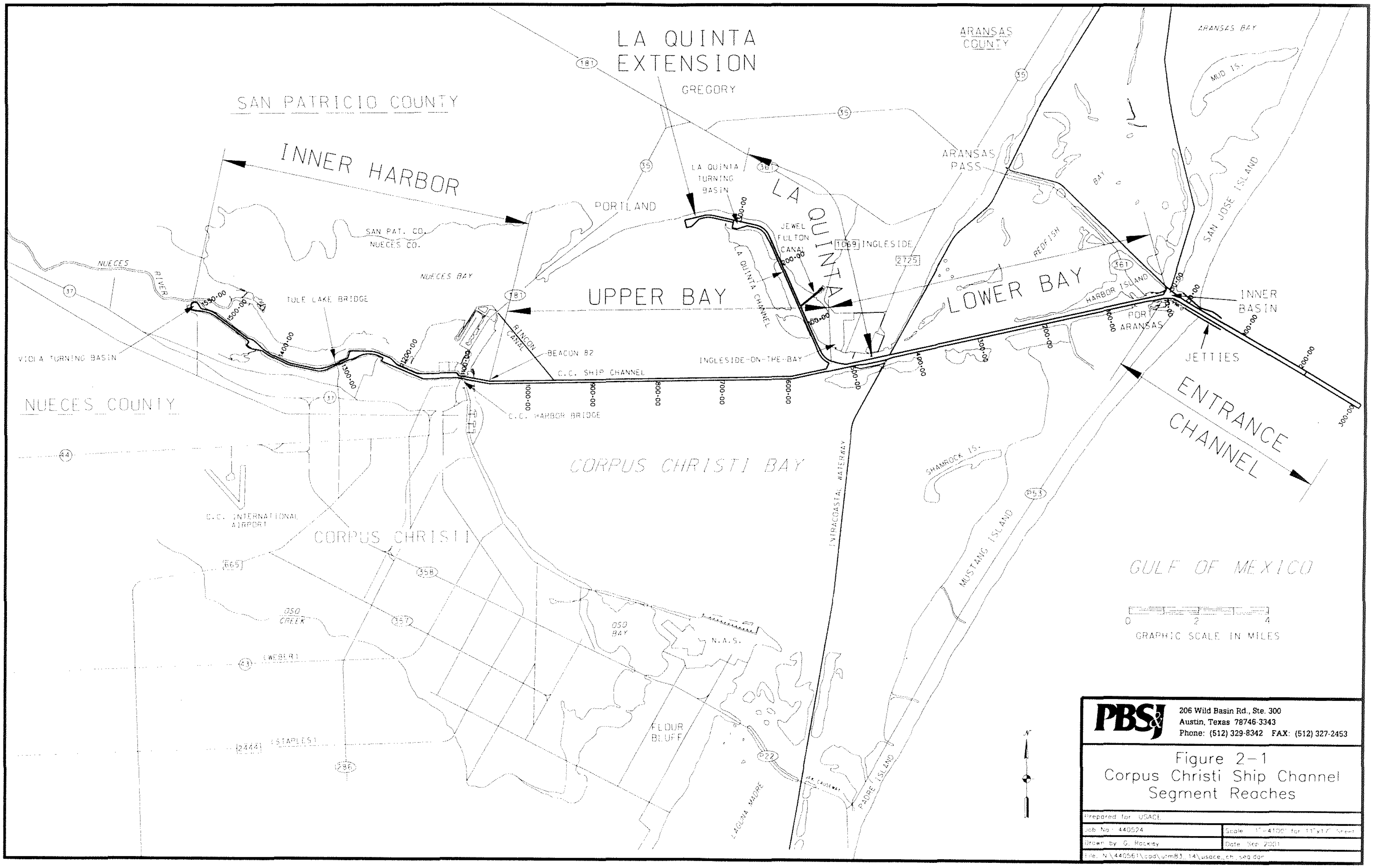

Figure 2-1
Corpus Christi Ship Channel
Segment Reaches

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passage in a high wave energy environment. The existing channel will be extended an additional 10,000 feet into the Gulf in order to reach a 54-foot natural depth. Minor widening is necessary in a 100-foot-wide area on the northern side of the channel from in the Inner Basin to allow for a better turning radius when entering the Gulf or the Lower Bay portion of the channel.

The Lower Bay will be deepened from 45 feet to 52 feet plus 2 feet of advanced maintenance. The eastern portion of this channel segment is currently wider than the selected 530 feet and no widening will be necessary in this reach. The western half is approximately 500 feet in width and will be widened to 530 feet.

The Upper Bay is currently 400 feet wide and 45 feet in depth. This reach will be deepened to 52 feet with 2 feet advanced maintenance and widened to 530 feet. Barge lanes will be constructed on both sides of the channel and will extend 200 feet from the toe of slope of the main channel and will be dredged to a depth of 12 feet with 2 feet of advanced maintenance.

The Inner Harbor will be deepened to 52 feet plus 2 feet of advanced maintenance. The channel width will range between 300 and 400 feet. Several minor modifications will be made to the turning basins to ensure that they meet USACE navigation requirements. One basin, the Avery Point Basin, will not meet USACE width criteria due to the presence of industry on the shoreline of the channel. In the vicinity of the Tule Lake Lift Bridge, because the bridge may be removed and/or replaced, the channel width in this area will be authorized at 400 feet. This width is consistent with the remainder of the Inner Harbor channel segment. Making the channel width consistent in this area, should the bridge be removed, will allow safer passage through the channel for all ship traffic. Should the bridge remain at the time of project construction, construction will be limited to 200 feet to ensure no impacts to the bridge supports. This 200-foot width is sufficient to allow all expected traffic access beyond the bridge and will not prevent the realization of project benefits.

The La Quinta Channel at the current depth of 39 feet will be extended approximately 7,400 feet beyond its current limit. The channel will measure 300 feet wide at the toe and a second turning basin with a 1,200-foot radius will be constructed. No changes will be made to the existing channel.

New work material will be dredged to deepen the channel from the –56-foot isobath in the Gulf to the Inner Harbor. A complete description of the texture and quality of the new work material and the existing maintenance material can be found in Sections 3.3.1 and 3.3.2 of the FEIS, respectively. Table 2.3-1 provides the quantities, by reach, of the new work and maintenance material expected from the preferred alternative. All dredged material will come from widening, deepening, and subsequent maintenance of the CCSC and the La Quinta Channel.

The project has identified eight existing confined upland sites, one existing offshore (open-water) site, and eight existing bay (open-water) sites for meeting the capacity requirements for the placement of both new work and maintenance dredging materials, as described below. However, the project may utilize all existing upland sites as needed during the life of the project to maintain operational flexibility.

TABLE 2.3-1
QUANTITIES OF NEW WORK AND MAINTENANCE DREDGED MATERIAL (mcy)

Reach	New Work Material	Maintenance Material (50 years)
Entrance Channel	4.337	62.0
Lower Bay	8.754	11.7
Upper Bay	14.419	82.2
Inner Harbor	6.916	24.1
La Quinta Channel	6.257	28.0
Barge Lanes	0.271	NA

The existing offshore PA 1, 510 acres in size, is located approximately 2 miles offshore and 1,000 feet south of the channel centerline. This site was designated by the EPA as the Corpus Christi Ship Channel ODMDS pursuant to Section 102(c) of MPRSA in 1989, but USACE terminology is PA 1. The reader should note that these two are the equivalent names for the same site. It is proposed that this site be used to place approximately 62.0 mcy of maintenance dredging materials (over a 50-year period) from the Entrance Channel portion of the project. Modeling was conducted which determined that PA 1 would be able to accommodate the additional volume of maintenance material, included with the proposed project, without exceeding the mounding requirements of the ODMDS Site Management Plan (Appendix A). Designation of the ODMDS by the EPA does not constitute approval by the EPA for placement of materials at the site. Prior to each placement event, the concurrence by the EPA must be given after determination that the materials meet all environmental criteria and regulatory requirements pursuant to MPRSA (40 CFR 220-228). The EPA and USACE, Galveston District, have established a Regional Implementation Agreement (RIA) for testing and reporting requirements for ocean disposal of dredged materials that outlines dredged material characterization and evaluation requirements.

PA 2 is partially confined on the beach and dune area just north of the San Jose Island jetty, which protects the CCSC Entrance Channel near Port Aransas. Effluent flows from the site, over the beach, and into the Gulf of Mexico.

Suntide PA (IH-PA 8) is a 306-acre UCPA located just west of the terminus of the Inner Harbor reach of the project channel in Corpus Christi. It will be used to contain approximately 1.2 mcy of new work dredged materials, and 1.0 mcy of future maintenance dredged materials for the project.

The Inner Harbor PA 1 (IH-PA 1) is a 350-acre upland confined placement area (UCPA) located just north of the inner harbor area in Corpus Christi. IH-PA 1 is subdivided into two cells (A and B), and will be used to contain approximately 800,000 CY of material from new work dredging and 10.6 mcy from maintenance dredging over a period of 50 years.

The Rincon PA (IH-PA 2) is a 230-acre UCPA located adjacent to and just north of PA 1. It will be used to contain approximately 900,000 CY of new work material and 5.2 mcy of future maintenance material.

South Shore (IH-PA 3) is a UCPA located on the south shore of Nueces Bay at Corpus Christi, just west of IH-PA 1 and north of the CCSC. It is divided into 3 cells, A, B, and C. Cell A is 200 acres in size and Cell B is 183 acres. Cell C is not proposed for use to meet capacity requirements under this project, but will continue to be available should it be needed. Cell A of IH-PA 3 will be used to contain approximately 1.0 mcy of new work material and is not planned for any future maintenance material. Cell B will be used to contain approximately 1.0 mcy of new work material and 1.0 mcy of future maintenance material.

IH-PA 6 is a 360-acre upland confined placement area which is south of the ship channel, as shown on Plate F-42 in the Feasibility Report. IH-PA 6 will be used to contain approximately 1.6 mcy of new work material and 1.1 mcy of future maintenance dredged material. Although this placement area is an existing placement area that has been used for material disposal in the past, it is not specifically provided or used under the present authorized 45-foot project. Consequently, IH-PA 6 will have to be acquired for the improved channel to satisfy storage capacity needs.

PA 6 is a 304-acre UCPA, located on the northern point of Mustang Island, south of and adjacent to the CCSC between Port Aransas and the La Quinta junction. It has been used once in the past as a placement area, but currently is in a state of disrepair. Its utilization will require major renovation of the perimeter levees and drop structure. PA 6 will be used to contain approximately 2.7 mcy of new work material from the channel. The project does not include the use of PA 6 for future maintenance dredging of the channel.

PAs 7 and 8 (Pelican Island) form a 360-acre UCPA located to the west of PA 6, south of the CCSC. PAs 7 and 8 will not be used for new work material but will continue to be used periodically to receive 11.7 mcy of future maintenance material over the 50-year life of the project.

PA 10 is a 196-acre UCPA located on the south side of the CCSC across from Port Ingleside. It will not be used for the placement of any new work dredged materials, but will be used to contain approximately 2.8 mcy of future maintenance dredged material over the 50-year life of the project.

PA 13 is a 750-acre UCPA located in the northeast corner of Corpus Christi Bay on the west side of the La Quinta Channel, near Port Ingleside. PA 13 will be used to contain approximately 3.7 mcy of new work dredged materials, and 25.2 mcy of future maintenance dredged materials over the 50-year life of the project.

PAs 14-A, 14-B, 15-A, 15-B, 16-A, 16-B, 17-A, 17-B, open water placement areas, are considered to have unlimited capacity for placement of dredged materials. They are located on either side of the ship channel across Corpus Christi Bay, These areas will be used for containment of approximately 11.8 mcy of new work dredged materials, and 87.4 mcy of future maintenance dredged materials over the 50-year life of the project.

New work material from the outer half of the Entrance Channel will be used beneficially in BU Site ZZ (Appendix A) and maintenance material will be placed in PA 1. New work material from the inner half of the Entrance Channel will be placed in BU Site MN; from the Lower Bay in BU sites I, R, and S and PA 6; from the La Quinta Channel extension in Sites E and GH and a portion stockpiled in PA 13 for future levee renovation at PA 13; from the Upper Bay in BU Sites R, S, CQ, and PAs 14a – 17b; and from the Inner Harbor in a series of UCPAs. Maintenance material from the jetty channel will be placed in offshore PA 1 and/or in PA 2 for beneficial use (only from a section of the Lower Bay), if it is of the correct grain size; from the Lower Bay at Pelican Island for rookery enhancement, BU Sites S and R, and PA 10; from the La Quinta Channel in PA 13; from the Upper Bay in PAs 10 and 14a-17b; and from the Inner Harbor in a series of UCPAs.

The following PAs are designated for placement of dredged maintenance material from the CCSC authorized 45-foot deepening project. While not scheduled for use at this time, these areas are available for the 52-foot project future, if needed.

Inner Harbor PAs 4 and 5 (IH-PA 4 and IH-PA 5) are privately owned, but are potentially available for use through an agreement with the land owner or by navigation servitude. IH-PA 4 and IH-PA 5 were last used 23 years ago during the CCSC 45-foot deepening project.

PA 4 is a confined site located north of the CCSC on Harbor Island. It has not been used since the 45-foot deepening project for the placement of new work dredged material. It is owned by the PCCA and may be available for use by the proposed project.

PA 5 is an upland unconfined site located on the south side of the CCSC west of Port Aransas. It has not been used since before the CCSC was deepened to 45 feet and may be available for use by the proposed project through navigation servitude.

PA 9 is an unconfined emergent placement area located south of the CCSC and east of the GIWW crossing. It has not been used in the past 23 years. It was last used for placement of new work material during the 45-foot deepening project.

PA 18 is an unconfined open-water placement area that is configured as two narrow, parallel placement corridors oriented perpendicular to the CCSC. PA 18 is available for use, but has not been used recently because of concerns that it could accelerate filling of the small-boat channels near the Corpus Christi City Marina.

Creation of all BU sites will cover roughly 935 acres of unvegetated deep bay bottom and 120 acres of upland. The area of the offshore BU Site MN and the topographic relief feature further offshore at BU Site ZZ depends on the exact placement methods and equipment and height of the berms, but will cover approximately 1,590 acres of Gulf of Mexico bottom. Offshore PA 1 is the only site currently in use offshore. It should be noted that the site where BU Site ZZ is located was not originally designated as a BU site, but as the ODMDS for virgin and maintenance material from the U.S. Navy Homeport project (see Section 5.3.3). The physical location of BU Site ZZ and the ODMDS for the Homeport project coincide. Physical examination of the materials proposed for placement in BU Site ZZ indicated that additional testing would be required to determine suitability for placement at the site pursuant to MPRSA (i.e., ocean dumping). However, the BUW determined that beneficial use of these materials is the preferred option and disposal of these materials at the site beneficially is evaluated under Section 404 of the Clean Water Act (Appendix A) and under the Fishery Conservation and Management Act.

All BU sites, except BU sites E, MN, and ZZ, will be located in deep, unvegetated bay bottom. BU Site E will be located upland. BU Site MN will be located in 20 to 40 feet of Gulf water, whereas BU Site ZZ will be located in approximately 50 feet of Gulf water. The maintenance PAs are currently being used to receive maintenance material dredged from the CCSC and La Quinta Channel. The BU sites will be constructed during widening and deepening of the CCSC, creation of the barge lanes, and extension of the La Quinta Channel. Maintenance will be ongoing. Only hydraulic pipeline dredges will be used inshore of the jetties. The entrance channel will be dredged with an oceangoing hopper dredge. The completed elevation of most BU sites will be approximately –1 to –2 feet MLT, to promote the growth of seagrasses. Most BU sites include breakwaters to an elevation of +6 feet MLT and most have fringes around the inside of the breakwaters with a design elevation of around +2 feet MLT for *Spartina* growth. Sites I and CQ include interior islands to an elevation between approximately +3 to +10 feet MLT. Site MN and the offshore topographic relief feature at site ZZ will likely have elevations around 6 feet above the Gulf bottom.

The new work material will range from mostly hard clay in the Inner Harbor and La Quinta Extension to mostly soft clay in the Upper Bay and mostly medium-to-dense sand in the Lower Bay to very dense sand in the jetty channel portion of the entrance channel and soft-to-firm clay in the outer portions of the entrance channel. The maintenance material is silt or sandy silt in the Inner Harbor, Upper Bay, and La Quinta Channel; fine or silty sand and silt in the entrance channel; and a mixture of silt or sandy silt, fine or silty sand, and sand in the Lower Bay.

This project was coordinated with State and Federal resource agencies. Their recommendations have been considered and are expected to be implemented. Any unavoidable resource losses have been identified by the RACT/MW and will be mitigated. The BU sites, including the offshore sites, are designed to lead to an overall increase in the productivity and diversity of habitat in the project area.

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3.0 AFFECTED ENVIRONMENT

3.1 ENVIRONMENTAL SETTING

The study area for the CCSCCIP encompasses Corpus Christi Bay, including the southern section of Redfish Bay and the northern section of the Laguna Madre, Nueces Bay, the lower Nueces River (12.379 miles), Inner Harbor, La Quinta Channel and the watershed surrounding these water bodies up to roughly 0.5 mile inland from all shorelines. The coastline of this area extends across Nueces and San Patricio counties and is adjacent to the cities of Corpus Christi, Portland, Ingleside-On-The-Bay, and Port Aransas.

3.1.1 Physiography

The study area is characterized by interconnected natural waterways, restricted bays, lagoons, estuaries, narrow barrier islands, and dredged intracoastal canals and channels. The surface topography of the study area is mainly flat to gently rolling and slopes to the southeast. The Nueces River drains areas to the west of the study area and discharges into Nueces Bay. A few short, low-gradient streams drain directly into Nueces and Corpus Christi bays. Vegetation is sparse at most places, but there are oak clusters and other vegetation in more sandy areas and in the uplands along streams. Broad areas of coastal prairies, chaparral pastureland and farmland occur inland from the bays. On the Gulf side of Mustang Island, and for a short distance inland, sand dunes break the flatness of the terrain.

The Nueces and Corpus Christi bay systems are relatively low-energy environments protected on the seaward side by barrier islands. Water depths in Corpus Christi Bay range from a maximum of approximately 13 feet in the central part of the bay to less than 6 feet along the bay margins (Brown, et al., 1976). Tidal channels, passes, and dredged channels are greater than average depth. Water exchange between the bay and the Gulf is normally limited to natural and artificial tidal passes through the barrier island. Fresh water is supplied to the bays by the Nueces River and by small streams that drain local areas adjacent to coastal uplands. The bay systems were formed when rising sea levels inundated and flooded the older Nueces River Valley. The arcuate shoreline of Nueces Bay is a relict of meanders of the old river valley.

The primary physiographic environments of the study area include fluvial-deltaic systems, bay-estuary-lagoon systems, barrier island-strandplain systems, locally distributed marsh-swamp systems, and eolian (wind) systems (Brown et al., 1976). The Coastal Zone within the study area is underlain by sedimentary deposits that originated in ancient, but similar, physiographic environments. These ancient sediments were deposited by the same natural processes that are currently active in shaping the present coastline such as long shore drift, beach wash, wind deflation and deposition, tidal currents, wind-generated waves and currents, delta outbuilding, and river point-bar and flood deposition (Brown et al., 1976).

3.1.2 Geology

Pleistocene age fluvial and deltaic sediments of the Beaumont Formation surround much of Nueces and Corpus Christi bays. These sediments were deposited in both marine and nonmarine environments. Recent alluvium present in the western portion of the study area is associated with the Nueces River and deposits in the eastern portion are related to Mustang Island.

The geologic units consist primarily of mixtures of sand, silt, clay, mud and shell deposited within the last one million years. Exposed sediments are composed primarily of interdistributary mud and lesser amounts of distributary and fluvial sands and silts. The majority of the outcropping Beaumont Formation within the study area consists predominantly of stream channel, point bar, natural levee, and back swamp deposits and, to a lesser extent, coastal marsh, mud flat, lagoonal and sand dune deposits. The Beaumont consists of mainly beach and relict barrier island deposits along a north-south trending belt parallel to the Laguna Madre-Redfish Bay system. These deposits are mostly fine-grained sand and shell, and are probably part of the laterally extensive Pleistocene age Ingleside barrier island system.

Sediment distributions within the bay system consist chiefly of terrigenous clastics. Clean quartz sands can be found in some PAs along parts of the mainland shoreline and in the wind-tidal flats areas. Muddy sands occur adjacent to dredged material placement mounds, in the shallow bay margin areas next to the mainland shore and at the edge of the wind-tidal flats. Muddy sand distribution is not depth controlled, rather it is related to hurricane washovers, dredging activities, and reworking of relict sediment (McGowen and Morton, 1979).

3.1.3 Climate

The coastal climate within the study area may be described as subhumid to semiarid. Major climatic influences are temperature, precipitation, evaporation, wind, and tropical storms/hurricanes. This area is subject to extreme variability in precipitation with rainfalls averaging about 29 inches in the Corpus Christi vicinity, with the greatest concentration falling in the spring and fall months. However, there is an average annual deficit of 12 to 16 inches when evapotranspiration is taken into account. The peak rainfall in late summer and fall coincides with the tropical storm/hurricane season. Rainfall totals decrease toward the southern coastline and inland to the west. The temperatures in the area are fairly high with an average in the lower 70s, punctuated with occasional killing freezes.

The persistent wind is from the southeast from March to September and the northeast from October to February. The hurricane season spans June through November with the greatest number occurring in the area in August and September. Wind velocities may be at least 74 miles per hour (mph), with wind gusts exceeding sustained wind speeds by up to 50 percent (Dunn and Miller, 1964). The winds are important agents in eroding and reworking sediments and sands as well as affecting water levels and circulation patterns depending on the velocity and duration of the wind. The direction and intensity of persistent winds control the orientation and size of wave sequences approaching the shoreline, ultimately eroding or depositing sediment along the shoreline (Brown et al., 1976).

3.2 WATER QUALITY

3.2.1 Water Exchange and Inflows

There are two principal types of water exchanges in the Corpus Christi Bay system: one is bidirectional, involving the tidal exchange of the bay system with the Gulf of Mexico and between components of the bay system, and the other is unidirectional, involving freshwater flow into the system and through-flow to the Gulf.

Tidal influence in the Gulf of Mexico is dominated by the 12.4-hour semidiurnal and the 24.8-hour diurnal lunar tides and the 13.6-day cycle in the magnitude of the declination of the moon (Ward 1997). Because of the constriction provided by the Corpus Christi Jetty Channel, the diurnal tide is severely dampened and the semidiurnal tide is dampened even further. Ward (1997) notes that because of its longer period, the "quasi-periodic" semi-annual rise and fall of Gulf waters pass into the bays with almost no attenuation, leading to high water levels in the spring and fall and low water levels in the winter and summer.

Frontal passages can also cause changes in water levels and exchanges between the bays and the Gulf. As the front approaches from the north, onshore airflow increases, forcing water from the Gulf into the bays. With frontal passage, the wind direction shifts, forcing water from one bay to another for short-lived, low energy fronts and from the bays into the Gulf for longer-duration fronts.

Freshwater flow into the bay system is dominated over the long term by the Nueces River and, to a lesser extent, by other freshwater inputs into the system from runoff. The long-term average freshwater replacement time for the Corpus Christi Bay system (bay volume divided by average inflow rate) is around 50 months (Ward 1997). Ward (1997) notes that while on the long term, diversions of freshwater from entering the bay system for human uses have been "non-negligible but minor when compared to natural watershed inflows and evaporative losses."

3.2.2 Salinity

The mean salinity in the upper 1 meter of the various segments of Corpus Christi Bay, for the period of record (1958 – 1993) examined by Ward and Armstrong (1997) ranges from 26.1 parts per thousand (ppt), near the mouth of Nueces Bay, to 31 ppt in the center of the Bay. This compares to an average mean salinity, based on latitudinal sections of Corpus Christi Bay, from 27°44′N to 27°50′N, which ranges from 28.96 to 29.24 ppt (USACE, 1999a). Ward and Armstrong (1997) note that there is little vertical gradient to the salinity profile and no apparent correlation between salinity and the presence of the ship channels; i.e., no salt wedge, as is apparent in, for example, Galveston Bay. Therefore, changes in channel depth will not cause salinity impacts like those that would be expected in a bay system with a strong salt wedge. The gradient that is evident from the data of Ward and Armstrong (1997) and USACE (1999a) is an increase in salinity from north to south from reduced freshwater inflow and increased evaporation to the south. However, both Corpus Christi Bay and Nueces Bay show almost no gradient from west to east, as one moves farther from the source of freshwater inflow.

Ward and Armstrong (1997) do note that there is a long-term increase in salinity in Corpus Christi Bay of about 0.1 ppt per year. They favor the hypothesis that long-term decreases and changes in the timing of fresh water inflow are the cause for this increase in salinity.

3.2.3 Water and Elutriate Chemistry

The CW determined that both Tier I and Tier II evaluations according to EPA and USACE guidance was to be conducted for both water and sediment quality. To this end, contaminants of concern were identified and all current and historic data were compiled and presented to the CW in both graphical and tabular format (Tier I) for both Gulf areas (covered by the Ocean Dumping Manual (EPA/USACE, 1991) or the Green Book) and inland areas (covered by the Inland Testing Manual (EPA/USACE, 1998) or the ITM). Water and elutriate data were compared with Water Quality Standards and past water column toxicity compliance was determined (Tier II). For those areas where the CW felt there were insufficient data (e.g., the BU Site ZZ), additional data were collected and analyzed (Tier II). After analysis of the data, the CW concluded that there would be no adverse impacts to the waters of the U.S. from the project and that additional testing, including toxicity testing, was not required (Tier II). This information is discussed in this section and in Section 3.3.

Ward and Armstrong (1997) noted a general improvement in water quality in the Corpus Christi Bay system over the 25 years preceding their study. Their study area was much broader than the CCSCCIP study area, as was the scope of their determination. For the present document, concerns are with the channel improvements and beneficial uses included in the CCSCCIP. Therefore, the emphasis will be on areas in and near the CCSC. This need is met by an examination of the data collected at regular intervals by the USACE. For a more general discussion of water and sediment quality in the overall Corpus Christi Bay system, the reader is referred to Ward and Armstrong (1997).

The data collected by the USACE since 1981 were analyzed to determine the water quality of Corpus Christi Bay. Also included below is a discussion of the elutriate, which provides information on those constituents that are dissolved into the water column during dredging and placement. Since the elutriate represents the dissolved concentrations that would be expected in the water column, they are compared to the Texas Surface Water Quality Standards (TWQS) provided by the Texas Natural Resource Conservation Commission (TNRCC, 2000) for the protection of aquatic life and EPA water quality discrete criteria. Since the values are from samples, not long-term composites or averages, and are from a marine environment, the acute marine TWQS are used (there are no TWQS for barium, but the Gold Book Criterion (U.S. Environmental Protection Agency (EPA), 1986, as revised) is 1,000 micrograms per liter (µg/L) barium for domestic water supplies. No value exceeded 1,000 µg/L barium). The CW has reviewed selected-screening criteria and concurs with these findings.

3.2.3.1 Entrance Channel

Water quality tables referred to in this section are contained in Appendix B (tables 3.2-1 through 3.2-11). Historical water and elutriate data for detected compounds from 1984, 1990, and 1999 are presented in Table 3.2-1. No constituents were found in 1990, although detection limits were high; in 1984, however, a few constituents were found despite higher detection limits. Some constituents detected in 1999 could not have been detected with either 1984 or 1990 detection limits. Of the metals, arsenic and copper were found above detection limits in 1984. In 1999, arsenic, barium, cadmium, and zinc concentrations were found above detection limits for water and elutriate samples; nickel was detected in water samples; and chromium and copper were found only in elutriate samples. Elutriate concentrations in 1999 were consistently higher than ambient water concentrations, including Reference samples, for barium and cadmium, but the opposite was true for zinc. All samples were well below the TWQS, except for copper in the elutriate samples from station CC-J-84-01 (0+00). Looking at the other 1984 copper data and those from 1999 (which are in the range of 1.3 to 4 µg/L), the elutriate value of 30 µg/L for CC-J-84-01 may be in error. Consequently, there are no apparent temporal trends in the data; since copper was the only compound detected in more than 1 year, trends for compounds other than copper could not be determined.

Oil and grease were detected in 1984 for water and elutriate samples. No organics were detected in the 1990 or 1999 data for any medium, except for total organic carbons (TOC) and total petroleum hydrocarbons (TPH).

Two sets of elutriate bioassays have been conducted on samples collected from the Entrance Channel (Southwest Research Institute (SWRI), 1980 and EH&A, 1985). The results of these tests are presented in Table 3.2-2, an examination of which indicates that in all tests, survival of organisms exposed to the liquid phase (LP, elutriate) and suspended particulate phase (SPP, unfiltered elutriate) of sediments from the Corpus Christi Entrance Channel was greater than 50 percent. Therefore, no 96-hour LC_{50} (that concentration of a substance which is lethal to 50 percent of test organisms after a continuous exposure time of 96 hours) could be calculated. This indicates that no acute toxicity to water column organisms could be expected from dredging the Entrance Channel or placement of Entrance Channel sediments.

There is no indication of water or elutriate problems in the Entrance Channel.

3.2.3.2 Lower Bay

This reach of the CCSC is not dredged often due to scouring and, therefore, very little data have been collected. Historical water and elutriate data for detected compounds from 1988 and 1991 are presented in Table 3.2-3. No metals were detected for the 1988 and 1991 data for water and elutriate. This is not surprising since the material is 72 to 97 percent sand.

TOC was above detection limits in water and elutriate samples for two stations in 1991, at roughly the same range for both media. No other organics were detected in 1991 and no organics were reported in 1988 for water or elutriate samples.

Water and construction sediment samples were collected for the proposed U.S. Navy Homeport project, for which an EIS was prepared in 1988 (U.S. Navy, 1987). The concentrations of detected compounds can be found in Table 3.2-4. No TWQS were exceeded in the water or elutriate samples. Most noticeable about Table 3.2-4 is the increase in oil and grease and TOC in the elutriate samples, relative to the corresponding water sample. The elutriate oil and grease concentrations are not high, relative to other reaches (there are no other oil and grease data for the Lower Bay Reach), but the elutriate concentrations in the water samples are much lower than in other reaches. For TOC, the values for the water samples are comparable to the other reaches but the elutriate values are much higher. U.S. Navy (1987) indicates no water or elutriate quality problems.

Toxicity testing has been conducted on elutriate samples made with maintenance material from this reach of the project area (Tereco, 1981) and is presented in Table 3.2-5. While the survival of mysids (*Mysidopsis almyra*) exposed to the LP from Station IB-1 was low, it was not significantly less than control survival (97 percent) at the 95 percent confidence level. Since the LP is a subset of the SPP, the low survival in the LP versus the high survival of mysids exposed to the SPP from Station IB-1 is enigmatic. Also, survival in no bioassay was less than 50 percent. Therefore, no 96-hour LC_{50} could be calculated. This indicates that no acute toxicity to water column organisms could be expected from dredging the Lower Bay Channel or placement of Lower Bay Channel sediments.

There is no indication of water or elutriate problems in the Inner Basin to La Quinta Junction Reach.

3.2.3.3 La Quinta

Historical water and elutriate data for detected compounds from 1985, 1990, and 2000 are presented in Table 3.2-6. Arsenic was the only metal found above detection limits in 1985, and it was found in all water and elutriate samples. Although arsenic was not detected in 1990, copper was found in all water and elutriate samples, and nickel was detected in all elutriate samples, indicating a release of nickel with dredging and placement. However, all elutriate values were less than TWQS. In 2000, arsenic was found in most water but no elutriate samples; barium and zinc were detected in all water and elutriate samples; cadmium was found in most water and elutriate samples; lead was found in one water sample at the detection limit; and selenium was found in most elutriate and some water samples near the detection limit. No trends indicated whether elutriate or water concentrations were higher. Moreover, TWQS were not exceeded by any metal, and barium concentrations were well below 1,000 µg/L (ppb). No temporal trends could be determined, since there were no detected chemicals common to more than one data set.

Oil and grease were detected in all samples in 1985, and elutriate concentrations were consistently higher than water concentrations. TOC was above detection limits for elutriates for all stations and most water samples, and were consistently higher in elutriate samples in 1990. No organics, including TOC, were detected in 2000 water and elutriate samples.

Toxicity testing has been conducted on elutriate samples made with maintenance material from this reach of the project area (Tereco, 1982); the results are presented in Table 3.2-7. While the survival of silverside minnows (*Menidia beryllina*) exposed to the LP from Station LQ-1 and grass shrimp (*Palaemonetes pugio*) exposed to the SPP from Station LQ-1 was low and significantly less than the respective control survival (97 percent for both) at the 95 percent confidence level, survival in no bioassay was less than 50 percent. Therefore, no 96-hour LC_{50} could be calculated. Tereco (1982) concluded that, with judicious management, no toxicity to water column organisms could be expected from dredging the La Quinta Channel or placement of La Quinta Channel sediments.

Overall, there is no indication of water or elutriate problems in the Channel to La Quinta Reach.

3.2.3.4 Upper Bay

Historical water and elutriate data for detected compounds from 1981, 1983, 1985, 1987, 1988, 1989, 1991, 1994, 1995, 1997, and 1998 are presented in Table 3.2-8. Arsenic was found above detection limits in 1983 and 1985 (water and elutriate samples), 1994 (water only), and from one reference station in 1998 (elutriate only), with the highest concentrations in 1983. Barium, for which analyses were not conducted before 1994, was detected for both water and elutriate in 1994, 1995, 1997, and 1998 (highest concentrations in 1995); chromium in both media in 1994 and for water only in 1997; mercury at only two of 15 stations in the elutriate in 1998; and nickel in both media in 1988. Copper was also detected in 1981, 1985, 1988, 1991, 1994, 1997 (water only), and 1998, with higher concentrations in 1988 and 1994 than in 1998. Zinc was detected in 1985 at one station each for water and elutriate, in 1987, 1988 (water only), 1989, 1991, 1994, 1997, and 1998, and was only high in 1987 when the TWQS was exceeded in 13 of 19 water samples and one elutriate sample. For that one elutriate sample, the concentration in the water was higher than in its corresponding elutriate sample. Barium concentrations are generally higher in elutriate than in water. Concentrations of zinc in the elutriate samples were less than in water samples in 1987 and 1998, but in 1989, the opposite was generally true.

TOC was not measured until 1991 and was above detection limits for water and elutriates for most stations in 1991, 1994, 1995, and 1998 (one station) (Table 3.2-8). Detected concentrations in the historic data for TOC were similar in value for all water and elutriate samples. Oil and grease were detected in 1981, 1983, 1985, 1987, and 1988 for water and elutriate samples. All oil and grease values were similar for water and elutriate; however, there were increased concentrations in 1981 and 1988 when compared with the other historical data.

As noted above, the only metal found above TWQS was zinc in 1987, and no trends indicated increasing concentrations with time.

Toxicity testing has been conducted on elutriate samples made with maintenance material from this reach of the project area (Tereco, 1982); the results are presented in Table 3.2-9. While the survival of mysids exposed to the LP from Station MT-1 was low, it was not significantly less than the control survival (90 percent) at the 95 percent confidence level. Since the LP is a subset of the SPP, the low survival in the LP versus the high survival of mysids exposed to the SPP from Station MT-1 is enigmatic. Also, survival in no bioassay was less than 50 percent. Therefore, no 96-hour LC_{50} could be calculated. This indicates no acute toxicity to water column organisms could be expected from dredging the Lower Bay Channel or placement of Lower Bay Channel sediments.

3.2.3.5 Inner Harbor

All material from this reach will be placed in Upland Confined Placement Areas (UCPA). Elutriates are, thus, of key interest in this reach, since the elutriate most nearly represents discharge from the UCPAs.

Historical water and elutriate data for detected compounds from 1983, 1988, 1991, 1994, 1997, and 2000 are presented in Table 3.2-10. Of the metals, arsenic, barium, cadmium, chromium, copper, nickel, and zinc were found above detection limits in water and elutriate samples. Arsenic was detected in both media at all stations in 1983; not detected in 1988, 1991, 1997, and 2000; and detected in water only at two stations in 1994. Barium was found above detection limits in 1994, 1997, and 2000 (there was no analysis for barium in 1983, 1988, or 1991), as was chromium in 1994 and 1997, nickel in 1988, and zinc in 1988, 1991, 1997, and 2000 for both water and elutriate samples. For 1988, copper was detected in both water and elutriate samples; however, it was only found in water samples for 1994 and 1997. Cadmium was only found in 1997 at two stations in elutriate samples. In 1997, station CC-TB-97-09 (1500+00) had an elevated barium concentration when compared to other stations of the same year and to previous years, but all concentrations were less than 1,000 µg/L. Interestingly, zinc concentrations were lowest (i.e., not detected) in 1994 when sediment concentrations were the highest in the data set, and were similar to other years in 1997 when sediment zinc concentrations were also high. Copper levels were generally lower in 1997 than in 1994; none was detected in 2000. All concentrations for both media and for all years were less than the TWQS.

TOC was above detection limits for water and elutriates for most stations in 1991 and 1994 (it was not determined in 1988) (Table 3.2-10). Oil and grease were detected in 1983 and 1988 for water and elutriate samples. Oil and grease were replaced by TPH after 1988 but TPH was not detected in any water or elutriate samples until 2000, when it was found in all water and elutriate samples from channel stations, PAs, and Reference sites. Concentrations of TPH in water were numerically higher than in the elutriates at all stations.

There is no indication of water or elutriate problems in the Beacon 82 to the Viola Turning Basin Reach.

3.2.3.6 GIWW Across Corpus Christi Bay

Most of the GIWW across Corpus Christi Bay is in water deeper than 12 feet and, therefore, does not require maintenance dredging. However, on the south side of the Bay, where the Upper Laguna Madre begins, the water shoals and maintenance dredging is conducted. This section discusses the data from that portion of the GIWW, roughly USACE channel stations 0+000 to 10+000.

Historical water and elutriate data for detected compounds from 1983, 1990, and 1993 are presented in Table 3.2-11. Of the metals, arsenic was found above detection limits for 1983 for water and elutriate samples, but was not detected in 1990 or 1993. Barium was detected for both water and elutriate at all stations in 1993, but was not included in the analyses in 1983 or 1990. No TWQS were exceeded.

Oil and grease were detected in 1983 at one station in the elutriate. Also in 1983, hexachlorocyclohexane (the gamma isomer of which is lindane) was detected in all water and elutriate samples below or equal to the TWQS (Table 3.2-11). TOC was above detection limits for water and elutriate samples for all stations in 1990 and 1993. No other organics were detected in 1990 or 1993 for either medium.

Since no evidence of hexachlorocyclohexane has been present since 1983 and all other constituents were below TWQS (or the EPA criterion, for barium), there is no indication of water or elutriate problems in the GIWW across Corpus Christi Bay.

3.2.4 Brown Tide

A major water quality concern since the early 1990s has been the phytoplankton, brown tide (*Aureoumbra lagunensis*) (De Yoe et al., 1997). Although brown tide has been and continues to be in general decline throughout the study area, there are sporadic patches of algal blooms throughout the area, generally in canals and near developments (Villareal and Dunton, 2000). However, Dr. Tracy Villareal reported in May 2000 (Villareal, 2000) that brown tide counts at Marker 53, roughly 2 miles south of the JFK Causeway, were similar to those in the long brown tide bloom from 1989 to 1997.

There are several potential impacts of algal blooms to estuarine ecosystems. Buskey et al. (1996) estimates that brown tide has caused a recent loss of 10 square kilometers (2,471 acres) of seagrass coverage in the Upper Laguna Madre and has also contributed to impacts such as decreased abundance, biomass, and diversity of benthic fauna, and reduced larval fish populations. Stockwell (1993) suggests that the persistent brown tide has temporarily changed the phytoplankton/seagrass production ratio and altered nutrient cycles within the Laguna Madre. Barrera et al. (1995) report that under normal conditions, turbidity is minimal and seagrass meadows are extensive in the Laguna Madre, but the persisting brown tide bloom has caused serious problems to the seagrasses of the Laguna Madre.

3.2.5 Ballast Water

The National Invasive Species Act of 1996 (NISA) calls for a variety of measures to reduce the risk of exotic species invasions associated with release of ballast water by ships. Ballast water is carried by ships to provide stability and adjust a vessel's trim for optimal steering and propulsion. The use of ballast water varies among vessel types, among port systems, and according to cargo and sea conditions. Ballast water often originates from ports and other coastal regions which are rich in planktonic organisms. It is variously released at sea, along coastlines, and in port systems. As a result, a diverse mix of organisms is transported and released around the world with ballast water of ships (Smithsonian Environmental Research Center [SERC], 1998).

Today, ballast water appears to be the most important vector for marine species transfer throughout the world. Ballast water transfers have been identified as a potential source of non-indigenous invasive species (NIS) (Carangelo, 2001). Refer to Table 3.2-12 for the Gulf of Mexico Program list on non-indigenous marine species, a list generated in a cooperative program between the EPA's Gulf of Mexico Program and the Gulf Coast Research Laboratory Museum of the University of Southern Mississippi. It has been estimated that as few as 5 to 10 percent of the vessels worldwide represent 80 to 95 percent of the risks on non-native species introductions through ballast water (Carangelo, 2001).

Although the effects of many introductions remain unmeasured, it is clear that some invaders are having significant economic and ecological impacts as well as human-health consequences. These organisms have the potential to become aquatic nuisance species (ANS). ANS may displace native species, degrade native habitats, spread disease, and disrupt human social and economic activities

TABLE 3.2-12

GULF OF MEXICO NON-INDIGENOUS MARINE SPECIES

Common Name	Scientific Name
Shrimp Viruses	
Infectious Hypodermal and Hematopoietic Necrosis Virus (IHHNV)*	
Taura Syndrome Virus	
White Spot Baculovirus complex	
Yellow Head Virus	
Bacteria	
	Mycobacterium marinum (C)
Cholera	*Vibrio cholerae*, serotype Inaba, biotype El Tor*
	Vibrio parahaemolyticus (including O3:K6 strain*)
Tunicates	
A sea squirt	*Botryllus niger* (C)
A sea squirt	*Botryllus schlosseri**
A tunicate	*Diademnium perleucidum**
A sea squirt	*Styela plicate**
Bryozoans	
A bryozoan	*Conopeum* "seurati" (C)
A bryozoan	*Cryptosula pallasiana**
A bryozoan	*Sundanella sibogae**
A bryozoan	*Victorella pavida**
A bryozoan	*Watersipora subovoidea**
A bryozoan	*Zoobotryon verticillatum* (C)
Coelenterates	
A hydroid	*Cordylophora caspia**
Orange-striped anemone	*Diadumene lineata**
A scyphoid jellyfish	*Phyllorhiza punctata**
Flatworms (Phylum Platyhelminthes)	
Eurasian strigeid trematode	*Bolbophorus confusus**
Marine blackspot	*Cryptocotyle lingua**

Common Name	Scientific Name
A flatworm	*Taenioplana teredini*
Roundworms (Phylum Nematoda)	
Eel parasite	*Anguillicola crassus**
Segmented Worms (Phylum Annelida)	
A polychaete worm	*Boccardiella ligerica**
A polychaete worm	*Hydroides elegans**
Mollusks	
Lake Merrit cuthona	*Cuthona perca*
A California nudibranch	*Ercolania fuscovittata*
An Indo-Pacific shipworm	*Lyrodus medilobatus*
European salt-marsh snail	*Ovatella myosotis**
Brown mussel	*Perna perna**
Green mussel	*Perna viridis**
Black-lipped pearl oyster	*Pinctada margaritifera*
Atlantic rangia	*Rangia cuneata*
Striped falselimpet	*Siphonaria pectinata*
Giant clam	*Tridacna crocea**
Giant clam	*Tridacna maxima**
Crustaceans	
Striped barnacle	*Balanus amphitrite**
A barnacle	*Balanus reticulatus**
A barnacle	*Balanus trigonus**
A copepod	*Centropages typicus**
Portunid crab	*Charybdis hellerii**
An amphipod	*Chelura terebrans**
Chinese mitten crab	*Eriocheir sinensis**
Potted bumblebee shrimp	*Gnathophyllum modestum*
An isopod	*Ligia exotica**
An isopod	*Limnoria pfefferi* (C)
An isopod	*Limnoria saseboensis* (C)
Pacific white shrimp	*Litopenaeus vannamei**
Jumbo tiger prawn	*Penaeus monodon**

TABLE 3.2-12 (cont'd)

Common Name	Scientific Name
Serrated swimming crab; Somoan crab	*Scylla serrata**
A wood-boring isopod, gribble	*Sphaeroma terebrans**
An isopod	*Sphaeroma walkeri**
A tanaid	*Zeuxo maledivensis**
Fishes	
Spotted seatrout	*Cynoscion nebulosus*
Spotted seatrout x orangemouth corvina	*Cynoscion nebulosus x C. xanthulus**
Sheepshead minnow	*Cyprinodon variegatus*
Gulf killifish	*Fundulus grandis*
Naked goby	*Gobiosoma bosc*
Spot	*Leiostomus xanthurus*
Atlantic croaker	*Micropogonias undulatus*
White bass	*Morone chrysops*
Wiper	*Morone chrysops x M. saxatilis*
Striped bass	*Morone saxatilis*
Coho salmon	*Oncorhynchus kisutch*
Rainbow trout	*Oncorhynchus mykiss*
Chinook salmon	*Oncorhynchus tshawytscha*
Rainbow smelt	*Osmerus mordax*
Gulf flounder	*Paralichthys albiguttata*
Pacific batfish	*Platax orbicularus**
Amazon molly	*Poecilia formosa*
Sailfin molly	*Poecilia latipinna*
Black drum	*Pogonias cromis*
Blackdrum x red drum	*Pogonias cromis x Sciaenops ocellatus*
Atlantic salmon	*Salmo salar*
Red drum	*Sciaenops ocellatus*
Algae	
A green tropical alga	*Caulerpa taxifolia*
A red alga	*Prionitis* sp.

* Exotic
C Cryptogenic

Source: Gulf of Mexico Program, 2000.

that depend on water resources (U.S. Coast Guard (USCG), 2000). Ballast-mediated introductions, such as the zebra mussel in the U.S. Great Lakes and toxic dinoflagellates in Australia, have had tremendous ecological and economic impacts (SERC, 1998).

The issue of regulating, controlling, or otherwise reducing the risk of ballast mediated introductions is a topic of ongoing national and international debate and investigation. The complexity of the issue led to the development or implementation of various foreign nation, domestic state, port-specific, or species-specific strategies (Carangelo, 2001). The U.S. Coast Guard is responding to these concerns through a comprehensive national ballast water management program.

3.2.5.1 The U.S. Coast Guard Ballast Water Management Program

Purpose of Regulations

The USCG Interim Rule on ballast water management, Implementation of the NISA of 1996, was published in the Federal Register on May 17, 1999. The new regulations amend 33 CFR Part 151, Vessels Carrying Oil, Noxious Liquid Substances, Garbage, Municipal or Commercial Waste, and Ballast Water. These regulations are intended to limit the introduction and spread of aquatic nuisance species into the waters of the United States. Presently, the primary means of preventing this is to replace ballast water taken on in foreign ports with deep ocean water through an at sea ballast water exchange. The new USCG rule establishes voluntary ballast water management guidelines for all waters (except the Great Lakes and sections of the Hudson River) of the U.S. and establishes mandatory reporting and sampling procedures for nearly all vessels entering U.S. waters.

Key Provisions of the USCG Guard Ballast Water Management Program

Voluntary Guidelines & Recommended Practices. These guidelines include suggested practices that should be taken by every vessel to minimize the uptake and release of harmful aquatic organisms, pathogens, or sediments. Additionally, the rule recommends that vessels carrying ballast water into the waters of the U.S. after having operated beyond the Exclusive Economic Zone (EEZ) to employ one of the following ballast water management practices:

- Conduct an exchange of ballast water beyond the EEZ, in an area no less than 200 miles from any shore and where the water depth exceeds 2,000 meters
- Retain the ballast water on board
- Use an alternative method of ballast water management
- Discharge ballast water to an approved reception facility
- Conduct the exchange in an approved Alternative Exchange Zone.

Mandatory Requirements. All vessels calling in a U.S. port must submit a completed Ballast Water Report Form (Appendix to 33 CFR 151, Subpart D) to the Smithsonian Environmental Research Center (SERC). Submission of the International Maritime Organization Ballast Water Reporting Form will also fulfill this reporting requirement. The reports must be kept on board the vessel and available for inspection for 2 years.

3.3 SEDIMENT QUALITY

The data collected by the USACE, on maintenance material, and others since 1981 were analyzed to determine the sediment quality of Corpus Christi Bay. The data presented here are from bulk sediment analyses, which tend to vary, even within duplicates, by a factor of up to five times. The data are compared to one type of Sediment Quality Guidelines (SQG), a co-occurrence type of SQG known as the Effects Range Low (ERL, originated by Long and Morgan, 1990), as given in the National Oceanic and Atmospheric Administration (NOAA) Screening Quick Reference Tables (Buchman, 1999). The CW has reviewed selected parameters of concern and screening criteria for this analysis and have concurred with the findings.

ERLs were developed by assembling a large group of sediment data sets, comprised of samples for which there was both bulk sediment chemistry and exhibition of toxicity. For each chemical in the data set, the concentrations are ranked in ascending order and the ERL is calculated as the lower 10th percentile of the concentrations. However, this approach demonstrates no cause and effect from the chemicals in the data set, since the fact that a chemical was detected does not demonstrate that it was responsible for the toxicity exhibited by the sediment. Not surprisingly, when ERLs derived from sets of data from different areas are compared, the results are inconsistent (WES, 1998). For example, when the ERLs of a number of chemicals were compared using a northern California data set versus a southern California data set, the ERLs differed by a range, from only a factor of three for total polychlorinated biphenyls (PCB) to a factor of 2,689 for p,p'-DDE. Since the ERLs are not based on cause and effect data, one would expect them to exhibit low predictive ability and to give a high number of false positives, both of which are true (WES, 1998). ERLs could only be compared to detected compounds. Although some detection limits were greater than ERLs, primarily for acenapthene, chlordane, and DDT, these were not listed as exceedances since there was no way to determine what the true values were.

In Section 3.2.3, it was noted that water and elutriate samples were compared to TWQS, which are regulatory standards, promulgated by the TNRCC (2000), and tied to effects from empirical data presented in the scientific literature. Because of the reasons noted above, the SQG are guidelines with no regulatory authority, used only to determine a "cause of concern".

3.3.1 Surficial Sediments

Surficial sediments have been examined by several studies (Barrera et al., 1995 [U.S. Fish and Wildlife Service (FWS)]; Ward and Armstrong, 1997 [Corpus Christi Bay National Estuary Program (CCBNEP)]; Carr et al., 1997 [CCBNEP], Fugro South, 2000 [PCCA]). Some of these studies encompassed an area greater than the study area for this FEIS, but only data from the study area are discussed here.

Barrera et al. (1995) collected sediment and biota samples from Redfish, Nueces, and Baffin bays; the Upper Laguna Madre; the Nueces River, in addition to samples from Corpus Christi Bay; and the Inner Harbor. The samples were analyzed for PAHs, organochlorine compounds, PCBs, and trace elements (Table 3.3-1). Sediment quality tables referred to in this section are contained in Appendix B (tables 3.3-1 through 3.3-3). Sediment PAHs, organochlorine compounds, and PCBs were below detection limits or were detected at very low concentrations. While Barrera et al. (1995) compared the sediment data to a number of guidelines, including data from other systems and guidelines used in Florida and Puget Sound, the comparison here is with the ERLs noted in Section 3.3 (Table 3.3-1). As an examination of Table 3.3-1 reveals, there were exceedances only in the Inner Harbor. Cadmium, copper, lead, mercury, and zinc samples in the Inner Harbor all exceeded ERLs at one or more stations.

Ward and Armstrong (1997) found that, in general, the highest metals concentrations in sediments were in the Inner Harbor and that these concentrations were often an order of magnitude higher than in other parts of their study area. Aside from the Inner Harbor, other areas found to contain elevated metals in sediments were Corpus Christi Bay for chromium and lead, the Gulf of Mexico near the Entrance Channel for copper and lead, and Nueces Bay and the Upper Laguna Madre for most metals. Note that these elevated concentrations are not relative to any guideline, like ERLs, but to other parts of the Ward and Armstrong CCBNEP study area. Ward and Armstrong also found probable temporal trends in that, for most metals in most of the system, including the Inner Harbor, concentrations are declining. However, zinc shows a possible increasing trend in many parts of Corpus Christi Bay. In contrast to the metals, sediment pesticides are not noticeably high in the Inner Harbor or Nueces Bay (Ward and Armstrong, 1997), except for toxaphene in Nueces Bay. However, they found PCBs to be high in the Inner Harbor and PAHs to be high in both the Inner Harbor and Nueces Bay (some polycyclic aromatic hydrocarbons (PAHs)). They also found a temporal trend of increasing naphthalene in both of these areas.

Carr et al. (1997) used a Sediment Quality Triad (SQT), composed of sediment chemistry, toxicity testing, and benthic invertebrate community analyses, to examine sediment quality near storm water outfalls and other selected sites. The sampling sites included 15 storm water sites, 8 reference areas, and 13 additional sites that the authors felt deserved attention. Based on the SQT results, the stations were ranked from the worst (Station S1, storm water outfall near the L-head in Corpus Christi Marina) to the best (Station 11, in the La Quinta Channel adjacent to industrial activity and dredging operations). Only a few of the stations are in a position to impact or be impacted by the CCSCCIP: Stations 11 and 12, in the La Quinta Channel (ranked 35 and 36, where 36 is the best); Station R3, a reference station near Indian Point (ranked 16); Station 5, in a PA (ranked 23); and Station 3, near the largest discharge into the Inner Harbor (ranked 19).

Construction or new work material will also be included in this section, since some of it (e.g., from channel widening) will be surficial sediments, even though other construction material will be deep sediments. However, none will be maintenance material.

There have been three studies, which evaluated construction material, that are pertinent to the CCSCCIP: U.S. Navy (1987), Fugro (2000), and Tereco (1982).

U.S. Navy (1987) took samples along the Lower Bay reach of the CCSC, from approximately Channel Station 12+55 to Channel Station 521+70. The concentrations of detected parameters are in Table 3.2-4. There are no patterns to the sediment concentrations but ERLs were exceeded for several parameters: arsenic, 8 of 9 stations; cadmium, 4 stations; and mercury, 2 stations.

However, no elutriate concentrations were greater than the TWQS for these, or any other parameters, so the meaning of the ERL exceedances is unclear.

The concentrations of detected parameters from Fugro (2000) are in Table 3.3-2. Two of the Fugro (2000) stations were in the Lower Bay (C-60 and C-67), two were in the Upper Bay (C-71A and C-76), and three were in the La Quinta Extension (L-24, L-27, L-30). The range of values for the samples collected provide such overlap that there is no notable difference among the reaches. For the three stations for which shallower and deeper samples were collected, there is no pattern concerning concentration versus depth. No ERLs were exceeded in any sample.

Tereco (1982) looked at construction material, but the study was concerned with the Inner Harbor area, and all of that material, both construction and maintenance will go into UCPAs. Therefore, elutriate is the medium of concern. Water and elutriate values for detected parameters are included in Table 3.3-3. In general, water and elutriate concentrations are similar except that oil and grease was generally higher in elutriate samples than in the respective water samples, the arsenic in the water sample from IC-1 was high compared to the IC-1 elutriate and all other water and elutriate samples, and zinc was generally lower in elutriate samples. No TWQS were exceeded, indicating that there should be no water quality concerns from the discharge from UCPAs which receive construction material from the Inner Harbor.

3.3.2 Maintenance Material

3.3.2.1 Entrance Channel

Maintenance material concentrations of detected parameters in 1984, 1990, and 1999 are found in Table 3.2-1. Since the RACT, at the recommendation of the CW, agreed that sediment concentrations would be compared to ERLs, they are also included in all tables. Arsenic was the only metal above detection limits in 1984; zinc was detected at all stations, chromium and nickel at three stations, and copper at one station in 1990, all below the ERLs. Of the metals, only mercury (three stations), silver (one station), and selenium (no stations) were not found at all stations in 1999 samples. Only one 1999 sample, CC-J-99-03, exceeded an ERL: mercury at a concentration of 0.20 milligrams per kilogram (mg/kg), versus an ERL of 0.15 mg/kg. Aside from the one exceedance noted, there is no indication of a cause for concern relative to maintenance material quality in the Entrance Channel. Sampling of any future project maintenance material will be routinely conducted to determine sediment quality prior to actual dredging. Additionally, prior to placement of maintenance material in PA 1, the material must meet all of the environmental criteria and regulatory requirements pursuant to MPRSA (40 CFR 220-228). Environmental criteria are based on toxicological and bioaccumulative effects on marine organisms.

Table 3.2-2 also presents the data for solid phase (SP, or sediment) bioassays with Entrance Channel sediments from 1980, 1985, and 1995. These bioassays were conducted according to protocols in both the old (EPA/USACE, 1978) and new (EPA/USACE, 1991) Green Books. The LC_{50} is not pertinent for SP bioassays, but the fact that test survival was not significantly less than Reference Control survival, at the 95 percent confidence level, provides reasonable assurance that no significant undesirable impacts would occur from ocean placement of the maintenance material dredged from the Entrance Channel reach of the CCSC.

3.3.2.2 Lower Bay

Maintenance material concentrations of detected parameters in 1988 and 1991 are found in Table 3.2-3. In 1988, chromium, copper, lead, and nickel were all above detection limits for one station and zinc was detected at all stations. In 1991, cadmium, chromium, copper, nickel, and zinc were found at most stations. The values for chromium, copper, nickel, and zinc for 1988 and 1991 were similar. No organics were detected in sediments, and no ERLS were exceeded. Grain size data indicate the maintenance material in this reach is coarse (72-97 percent sand). There is no indication of a cause for concern relative to maintenance material quality in the Inner Basin to La Quinta Junction Reach. Sampling of any future project maintenance material will be routinely conducted to determine sediment quality prior to actual dredging.

Table 3.2-5 also presents the data for SP bioassays with Lower Bay CCSC sediments from 1981. Test survival was not significantly less than Reference Control survival, at the 95 percent confidence level, providing reasonable assurance that no significant undesirable impacts would occur from open water placement of the maintenance material dredged from the Lower Bay reach of the CCSC.

3.3.2.3 La Quinta

Maintenance material concentrations of detected parameters in 1985, 1990, and 2000 are found in Table 3.2-6. Arsenic, chromium, nickel, and zinc were above detection limits in 1985 at most stations, and arsenic exceeded the ERL at all stations. In 1990, arsenic was not detected but chromium, copper, nickel, and zinc were detected in all sediment samples. The values for nickel were numerically higher in 1990 than in 1985 but by less than a factor of three, and no metal exceeded its ERL. In 2000, arsenic, barium, chromium, copper, lead, nickel, and zinc were detected at all stations, cadmium and mercury were found in two samples near the detection limit, and selenium was found at one station, also near the detection limit. No ERLs were exceeded. Oil and grease was detected in 1985 but was discontinued before 1990. TOC was not detected in 1990 and was the only organic detected, at a range of 2,560 mg/kg to 12,800 mg/kg. The test sediments were mostly sand. Since arsenic was not detected in 1990 and did not exceed the ERL in 2000, there is no indication of a cause for concern relative to maintenance material quality in the Channel to La Quinta Reach. Sampling of any future project maintenance material will be routinely conducted to determine sediment quality prior to actual dredging.

3.3.2.4 Upper Bay

Maintenance material concentrations of detected parameters in 1981, 1983, 1985, 1987, 1988, 1989, 1991, 1994, 1995, 1997, and 1998 are found in Table 3.2-8. Zinc was found above detection limits for all years at all stations. Lead was found at all stations, except in 1985 when it was found at all stations but one, and in all years except 1989. Chromium, copper, and nickel were detected for all years, except 1985, and at all stations, except in 1989 when chromium and copper were found at all but two stations. Arsenic was also detected in 1983, 1985, 1987, 1988, 1997, and 1998; barium in 1994, 1995, 1998, and 1998; cadmium in 1981, 1997, and 1998; mercury at all stations and selenium at one station in

1998. There are sufficient data to determine whether temporal trends exist but, although there are fluctuations, no trends are apparent. However, there are some interesting aspects to the data. For instance, in 1995, chemical concentrations from channel stations are consistently higher than those at the Reference or Placement Area (PA) stations, but for other years (1985, 1998) there is no difference in the ranges from channel stations versus Reference or PA stations. In fact, in 1989, most of the high values were found at the Reference stations. Although the ERL was exceeded for copper for three channel stations, one reference station in 1987, and one reference station in 1989, these values are suspect and may actually be typographical errors: two were reported as 40.00 mg/kg and three were reported as 50.00 mg/kg, whereas the range of all other copper concentrations was 2.20 to 5.60 mg/kg. Nickel (20.92 mg/kg) and zinc (157.9 mg/kg) exceeded their respective ERLs (20.9 and 150 mg/kg) at station CC-B-95-05 (750+00) in 1995.

TOC was above detection limits for all sediment samples in 1997 and 1998. Oil and grease was detected in 1981, 1983, 1985, 1987, and 1988. TOC concentrations in 1998 sediment samples were much higher than compared with previous years, but this is likely due to a change in methodology. Total PAH was found at most stations in 1987, ranging from 0.2 micrograms per kilogram (µg/kg) to 0.4 µg/kg. DDT was also found in 1987 at four stations, ranging from 0.2 µg/kg to 3.1 µg/kg. The latter value exceeded the ERL for DDT of 1.58 µg/kg. Fluoranthene (12 stations, 1.3 – 6.1 µg/kg) and benzo(a)pyrene (5 stations, 1.0 – 1.6 µg/kg) were also found in 1987. These values are questionable since they are below the required detection limit of 10.0 µg/kg for these two compounds in 1987. In any case, there is no ERL for fluoranthene and the ERL for benzo(a)pyrene is 430 µg/kg, so there were no exceedances for these PAHs.

An examination of all data presented above for this reach does not indicate a cause for concern relative to maintenance material quality in the La Quinta Junction to Beacon 82 Reach. Sampling of any future project maintenance material will be routinely conducted to determine sediment quality prior to actual dredging.

Table 3.2-9 also presents the data for SP bioassays with Upper Bay CCSC sediments from 1982. Test survival was not significantly less than Reference Control survival, at the 95 percent confidence level, providing reasonable assurance that no significant undesirable impacts would occur from open water placement of the maintenance material dredged from the Upper Bay reach of the CCSC.

3.3.2.5 Inner Harbor

The CW agreed that there appears to be no significant contaminant concerns with new work and maintenance materials from the CCSCCIP, except in the Inner Harbor. Because of concern with contaminants in the Inner Harbor, the workgroup supports a plan to place any dredged material from this reach in existing upland confined placement areas. Sampling of any future project maintenance material will be routinely conducted to determine sediment quality prior to actual dredging.

Since all material from this reach will be placed in UCPAs, the elutriates (Section 3.2.3.5) are of key interest. The elutriate most nearly represents the discharge from the UCPAs, which will reenter the Inner Harbor as at present. However, to determine the baseline conditions, maintenance sediment data for this reach will be discussed in this section.

Maintenance sediment concentrations of detected parameters in 1983, 1988, 1991, 1994, 1997, and 2000 are also found in Table 3.2-10. Chromium, copper, lead, and zinc were found above detection limits for all years for all stations. Arsenic was also detected in 1983, 1988, 1997, and 2000; barium in 1994, 1997, and 2000 (it was not determined in 1983-1991); and nickel in 1988, 1991, 1994, 1997, and 2000 for all stations. Cadmium was found in 1983 at one station, in 1997 at all stations, and in 2000 at nine of fifteen stations. Mercury was found only in 1997 at nine of ten stations and in 2000 at all stations. Arsenic concentrations were generally less in 1988 than in 1983, and it was not detected in 1991 or 1994. In 1997, it was detected at a range of 2.2 to 5.9 mg/kg, and in 2000, the range was 4.8 to 9.9 mg/kg. While this could indicate a trend of increasing arsenic in sediment of this reach, without sufficient data with which to conduct statistical analyses, a trend cannot be confirmed. It certainly is not supported by the concentrations of the other sediment metals, most of which were lower in 2000 than in 1994 and 1997. There is also no evidence of a similar trend for arsenic in the other reaches.

ERLs were exceeded by arsenic at four stations in 2000; cadmium at one station in 1983 and all stations in 1997; copper at two stations in 1994 and one station in 1997; lead at one station in 1994; mercury at four stations in 1997 and one reference station in 2000; and zinc at one station in 1983, six stations in 1994, and seven stations in 1997.

Oil and grease was detected in 1983 and 1988 at all stations, but was replaced by TPH, which was not detected until 2000, when it was found in all channel stations, PA samples, and Reference Stations. TOC was above detection limits for all sediment samples in 1994, 1997, and 2000. TOC concentrations were much higher in 2000 than in 1994 and 1997, but this was due to a change in methodology. Fluoranthene and benzo(a,e)pyrene were detected in 1991, 1994, and 1997, and benzo(e)pyrene was also found in 1997. Benzo(a)pyrene (637 µg/kg) exceeded the ERL (430 µg/kg) at one station in 1994.

One can see from the data presented that the detection of constituents of concern is much more prevalent in this reach than in the others. Also, the number of exceedances is much higher for this reach than for the others. Ward and Armstrong (1997) note, "Contaminants such as coliforms, metals, and trace organics show elevated levels in regions of runoff and waste discharge, with generally the highest values in the Inner Harbor..." However, as noted above, all dredged material from the Inner Harbor will be placed in Upland Confined Placement Areas, and the elutriate results discussed in Section 3.2.3.5 show no indications of concerns. The decant water from UCPA in the Inner Harbor will return to the Inner Harbor as currently done with the existing 45-foot project.

No SP bioassays have been conducted with maintenance material from the Inner Harbor reach of the CCSC because this material has not been placed in the past nor intended in the future for aquatic placement.

3.3.2.6 GIWW Across Corpus Christi Bay

Most of the GIWW across Corpus Christi Bay is in water deeper than 12 feet, and therefore, does not require maintenance dredging. However, on the south side of the Bay, where the Upper Laguna Madre begins, the channel shoals and maintenance dredging is conducted. This section discusses the data from that portion of the GIWW.

Sediment concentrations of detected parameters in 1983, 1990, and 1993 are found in Table 3.2-11. Arsenic, chromium, nickel, and zinc were above detection limits at most stations in 1983; chromium, copper, nickel, and zinc in 1990; and barium, chromium, copper, lead, nickel, and zinc in 1993. No ERLs were exceeded.

Oil and grease was detected in 1983 at all stations. Hexachlorocyclohexane was not detected in the sediments in 1983, although it was detected in the water and elutriate samples. In 1993, TOC was detected at station GIC-CBB-93-01 (0+000), but at a concentration below the required detection limit. No other organics were detected.

There is no indication of a cause for concern relative to maintenance material quality in the GIWW reach of Corpus Christi Bay. However, sampling of any future project maintenance material will be routinely conducted to determine sediment quality prior to actual dredging.

3.4 COMMUNITY TYPES

The study area lies within the southeastern portion of the Gulf Prairies and Marshes vegetational region, as described by Gould (1975). This vegetational area is a nearly level plain less than 250 feet in elevation, covering approximately 10 million acres (Hatch et al., 1990). The region is subdivided into two vegetation units: 1) the low marshes with tide water influence (where the study area is located), and 2) the prairies or grasslands farther inland (Hatch et al., 1990). The study area is a highly adaptive community that changes in response to constant environmental fluctuations. The diverse flora of this vegetational region creates a valuable resource for all forms of life. The following paragraphs provide a brief description of the various coastal habitats found within the study area.

3.4.1 Submerged Aquatic Vegetation

SAV includes the true seagrasses such as shoalgrass (*Halodule wrightii*), turtlegrass (*Thalassia testudinum*), manateegrass (*Syringodium filiforme*), and clovergrass (*Halophila engelmannii*), but also includes widgeongrass (*Ruppia maritima*) which is not considered a true seagrass because it grows in freshwater environments as well. Seagrass/SAV meadows typically occur in water shallower than –4 feet MLT. In the study area, they occur both as narrow bands along bay and channel margins and as extensive beds in broad shallow, relatively low energy areas in bays and lagoons (CCBNEP-06A, 1996a). These seagrass communities generate high primary productivity and provide refuge for numerous species including shrimp, fish, crabs and their prey. Animal abundances in seagrass beds can be 2-25 times greater than in adjacent unvegetated areas (Pulich, 1998). All five taxa are found within the study area of Corpus Christi Bay and Redfish Bay/Harbor Island with shoalgrass being the most abundant. Shoalgrass and widgeongrass occur in Nueces Bay (Pulich et al., 1997).

Figure 3-1 depicts SAV coverages for the defined study area as reported by the Texas Parks and Wildlife Department (TPWD) (1994). There are approximately 19,900 acres of seagrass beds in the study area. The net acreage of seagrass in Corpus Christi Bay and Redfish Bay/Harbor Island has remained relatively stable since 1958, although there has been fragmentation of this habitat and some local losses in Redfish Bay/Harbor Island. The acreage of seagrass beds in Nueces Bay fluctuates with inflows, but there has been a net increase since 1958. There have also been increases in seagrass coverage in the Harbor Island and Mustang Island areas.

Several factors may impact seagrass communities. A study by Quammen and Onuf (1993) has suggested that probable causes for shifts in cover of seagrass species in the Laguna Madre include changing salinity regimes (due in part to changes in Bay/Gulf interchange as channels [including ship channel and GIWW] and passes open and/or close), increased turbidity caused by maintenance dredging of the GIWW, and eutrophication resulting from nutrient inputs. Other researchers have suggested that brown tide has played a major role in the alteration of Laguna Madre seagrass communities (Buskey et al., 1996; Stockwell, 1993; Barrera et al., 1995; Pulich, 1998). Recently, the USACE funded an investigation into the potential impacts of open bay disposal of maintenance dredge material from the GIWW on seagrass beds in the Laguna Madre. This study included field verification of predictions made by sediment transport (Teeter, 2000) and seagrass modeling (Burd and Dunton, in press), which indicated no significant difference in seagrass survival or productivity for sites one mile or more from placement sites compared to sites in a non-dredging-and-placement scenario. Even sites that were 100 meters from the disposal event showed full recovery after a 2-week period of decreased biomass.

3.4.2 Coastal Wetlands

The coastal estuarine wetlands of Corpus Christi Bay, Nueces Bay and Redfish Bay/Harbor Island play an important part in sustaining the health and abundance of life within the ecosystem. Coastal wetlands are distinct areas between terrestrial and aquatic systems where the water table is at or near the surface or the land is covered by shallow water with emergent vegetation. They are extremely important natural resources that provide essential habitat for fish, shellfish, and other wildlife (McHugh, 1967; Turner, 1977; Sather and Smith, 1984). Coastal wetlands also serve to filter and process agricultural and urban runoff and buffer coastal areas against storm and wave damage. Coastal wetlands of the study area are shown on Figure 3-2.

3.4.2.1 Salt Marshes/Shrublands

In contrast to the upper Texas coast, only a small percentage of smooth cordgrass (*Spartina alterniflora*) is associated with the salt marshes of the Laguna Madre and Coastal Bend. The more common plant species include saltwort (*Batis maritima*), seashore saltgrass (*Distichlis spicata*), and seashore dropseed (*Sporobolus virginicus*). The estuarine intertidal scrub-shrub category describes coastal wetlands dominated by woody vegetation and periodically flooded by tidal waters. Examples of estuarine intertidal scrub-shrub species in the study area include black mangrove (*Avicennia germinans*) and bushy sea-ox-eye (*Borrichia frutescens*).

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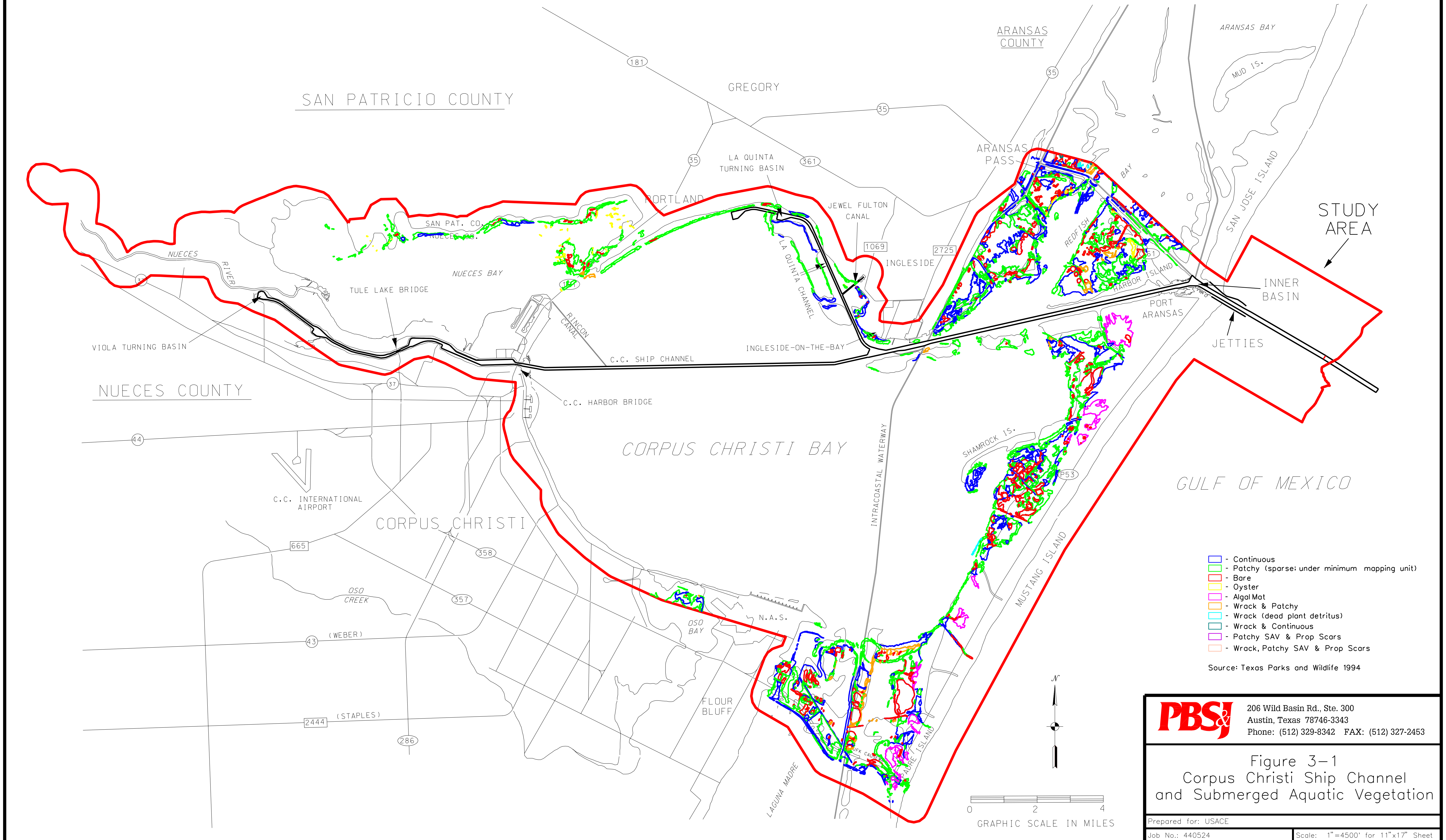

- Continuous
- Patchy (sparse; under minimum mapping unit)
- Bare
- Oyster
- Algal Mat
- Wrack & Patchy
- Wrack (dead plant detritus)
- Wrack & Continuous
- Patchy SAV & Prop Scars
- Wrack, Patchy SAV & Prop Scars

Source: Texas Parks and Wildlife 1994

PBSJ
206 Wild Basin Rd., Ste. 300
Austin, Texas 78746-3343
Phone: (512) 329-8342 FAX: (512) 327-2453

Figure 3-1
Corpus Christi Ship Channel and Submerged Aquatic Vegetation

Prepared for: USACE	
Job No.: 440524	Scale: 1"=4500' for 11"x17" Sheet
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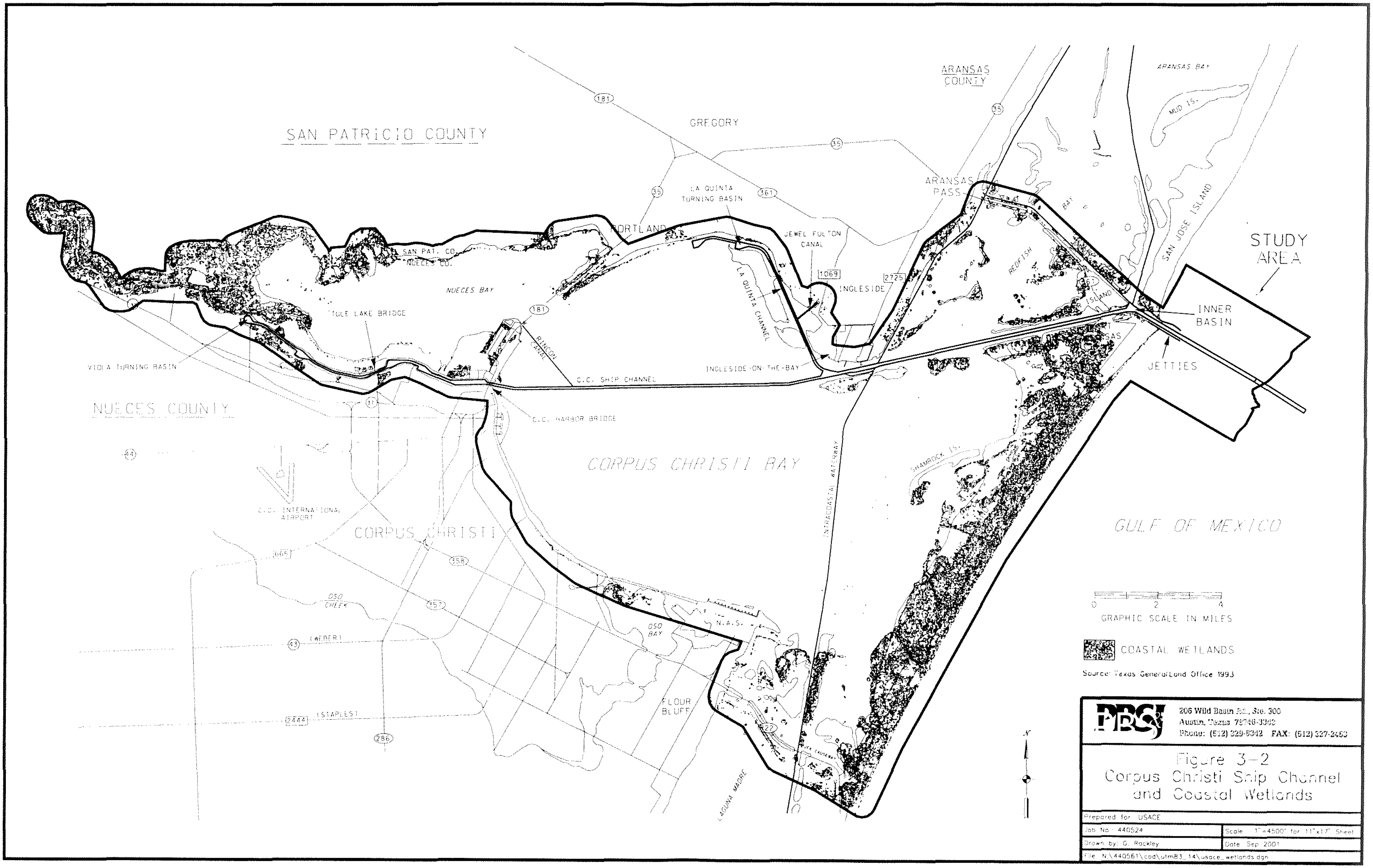

Figure 3-2
Corpus Christi Ship Channel and Coastal Wetlands

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The estuarine wetlands potentially affected by the proposed dredging would be those in close proximity to the channel itself. There are approximately 12,700 acres of estuarine wetlands (not including flats as described below) in the study area.

3.4.2.2 Estuarine Sand Flats/Mud Flats/Algal Mats

This community type includes coastal wetlands periodically flooded by tidal waters and with less than 30 percent areal coverage by vegetation. This category includes sandbars, mud flats, and other nonvegetated or sparsely vegetated habitats called salt flats. Sparse vegetation of salt flats may include glasswort (*Salicornia* spp.), saltwort, and shoregrass (*Monanthochloe littoralis*). These tidal flats serve as valuable feeding grounds for coastal shorebirds, including the threatened piping plover, fish, and invertebrates. There are approximately 5,100 acres of this category within the study area.

Many of the tidal flats in the study area are considered wind tidal flats because they are exposed primarily by wind and storm tides as opposed to astronomical tides. These areas are generally hypersaline, which prevents or restricts macrophytic vegetation. Blue-green algal mats form in these areas. There are approximately 807 acres of algal mats in Corpus Christi Bay (including Oso Bay) and 87 acres in Redfish Bay/Harbor Island (Pulich et al., 1997).

3.4.3 <u>Open Water/Reef Habitat</u>

Open water areas include the unvegetated, bottom portion (excludes hard substrates such as oyster reefs) of the subtidal estuarine environment. Open water habitats support communities of benthic organisms and corresponding fisheries populations. Approximately 154,000 acres of open water habitat are in the study area.

There are a few scattered reefs of the Eastern oyster (*Crassostrea virginica*) present in some areas of Corpus Christi Bay (1.14 acres), Redfish Bay/Harbor Island (112.6 acres) and Nueces Bay (24.99 acres) (Pulich et al., 1997). According to the Corpus Christi National Estuary report (CCNEP-06C, 1996b), Gatsoff found most oyster reefs in Corpus Christi Bay to be dead; but did find living oyster reefs in Nueces Bay and the intertidal zone. Periodic TPWD surveys since that time also support these early findings.

3.4.4 <u>Coastal Shore Areas/Beaches/Sand Dunes</u>

The coastal shore areas function primarily as buffers protecting upland habitats from erosion and storm damage, and adjacent marshes and waterways from water-quality problems. A variety of birds occur on coastal shores of the Coastal Bend, and few are restricted to one particular habitat (Britton and Morton, 1989). Cranes, rails, coots, gallinules, and other groups can be found on the shorelines and in fringing marshes of the study area.

Beaches along the south Texas and Coastal Bend coastline are dynamic habitats subject to a variety of environmental influences, such as wind and wave action, salt spray, high temperature, and moisture stress. The harsh conditions associated with the beach/dune system support a relatively small number of adapted animals and plants. Sand dunes help absorb the impacts of storm surges and high waves and also serve to slow the intrusion of water inland. In addition, dunes store sand that helps deter shoreline erosion and replenish eroded beaches after storms. The dune complexes are of two types, primary and secondary, each of which supports a unique plant community. The primary dunes are taller and offer more protection from wind and hurricane storm surge. The secondary dunes are leeward (relative to Gulf winds) of the primary dunes, shorter and more densely vegetated. On the barrier islands of the Texas Coastal Bend, typical plant species of the primary dunes include sea oats *(Uniola paniculata*), bitter panicum (*Panicum amarum*), Gulf croton (*Croton punctatus*), beach morning glory (*Ipomea pes-caprae*) and fiddleleaf morning glory *(Ipomea stolonifera*). Secondary dune species include marshhay (*Spartina patens*), seashore dropseed, seashore saltgrass, pennywort (*Hydrocotyle bonariensis*) and partridge pea (*Chamaecrista fasciculata*).

3.5 FISH AND WILDLIFE RESOURCES

3.5.1 Finfish and Shellfish

The study area includes Corpus Christi Bay, Nueces Bay, and small portions of the Upper Laguna Madre, Redfish Bay, and the Gulf nearshore waters at the entrance channel in Port Aransas. Within the study area, environmental fluctuations are extreme and the inhabitant biota reflect and are adapted to this lack of stability in the environment (Warshaw, 1975). Large changes in habitat occur on a daily basis with respect to wind, tidal action, salinity regimes, and freshwater inflow. These ongoing natural processes are coupled with other natural events such as freezes, droughts, hurricanes, and anthropogenic pressures (i.e., management practices and coastal projects) in the study area. Nevertheless, the biological community present in the study area remains diverse and abundant. For example, Tunnell et al. (1996) reports 234 fish species within the CCBNEP study area which includes the study area for this project. The Gulf nearshore fish community includes many species found in both estuarine and offshore oceanic habitats (Tunnell et al., 1996). Most of the species in the Gulf nearshore waters are temperate in biogeographic distribution with a few tropical species (Tunnell et al., 1996).

Although adding pressure to the ecosystem, natural processes and events increase the diversity and abundance of organisms in the study area. The high energy flow in the study area is attributed in part to the shallow water depth with respect to a large surface area and results in high phytoplankton primary production (Tunnell et al., 1996). Higher salinities within the Upper Laguna Madre mean a reduced level of nutrients due to the lack of freshwater inflow, and these also play major roles in increasing the ecological efficiency. This high ecological efficiency found in this portion of the study area results in high abundances of the higher level consumers, such as benthic mollusks and fishes (Tunnell et al., 1996). Salinities within the study area can vary greatly depending on the time of year and location of the system. For example, the Upper Laguna Madre, lacking any river inflow, is a hypersaline lagoon having a much higher salinity than Corpus Christi Bay, whereas Nueces Bay has the lowest salinity of the study area due to inflow from the Nueces River (Tunnell et al., 1996).

A second factor regarding the diversity and abundance of organisms is past and present management strategies. As stated in CCBNEP-06C (1996b), "Management strategies are affected by estimated population densities, biology of target organisms, habitat quality, fishing technology, consumer demand, economic value, and special interest group demands." The competing forces of recreational and commercial fisheries have led to increased management activities along the Texas coast, including the elimination of gillnets in Texas bays and designation of red drum (*Sciaenops ocellatus*) and spotted seatrout (*Cynoscion nebulosus*) as "game species" (CCBNEP-06C, 1996b). Inlets such as Aransas Pass have also played a role in biological productivity by lowering salinity concentrations and providing a means for the ingress/egress of aquatic organisms, including species of red drum and spotted seatrout. In the study area, the Nueces River is one of the major freshwater inputs and is a vital part of the system, providing nutrients and sediment and affecting salinity, nutrient levels, circulation patterns and erosion (Tunnell et al., 1996).

3.5.1.1 Recreational and Commercial Species

The principal finfish harvested by sport-boat anglers in the study area from 1982 to 1992 were spotted seatrout, red drum, Atlantic croaker (*Micropogonias undulatus*), southern flounder (*Paralichthys lethostigma*), sheepshead (*Archosargus probatocephalus*), sand seatrout (*Cynoscion arenarius*), and black drum (*Pogonias cromis*) (Warren et al., 1994). Statistics for the Texas Coastal Fisheries show the Corpus Christi Bay system received bay and pass party-boat fishing pressure of 22 percent and landings of 51 percent of the total from 1991 to 1992, whereas the Upper Laguna Madre received 11 percent of coastwide fishing pressure and 7 percent of total Texas landings from 1983 to 1992 (Warren et al., 1994). Recreational boat landings from 1983 to 1991 for all finfish have shown an increased trend in the Nueces-Corpus Christi Bay and a decreased trend in the Upper Laguna Madre (Tunnell et al., 1996). Offshore, private anglers accounted for 25 percent of landings and 54 percent of the fishing pressure (1982-1992) with sand seatrout, king mackerel (*Scomberomorus cavalla*), and red snapper the most commonly landed finfish (Warren et al., 1994).

The most important commercial finfish species currently reported from the study area are black drum, flounder (*Paralichthyes* spp.), sheepshead, and striped mullet (*Mugil cephalus*) (Robinson et al., 1998). Leading Gulf landings for commercial finfish include grouper and snapper, with lesser numbers of cobia (*Rachycentron canadum*), black drum, and flounder also caught (Robinson et al., 1998). Overall, from 1972 to 1997, black drum, flounder, and sheepshead landings have declined in the study area (Robinson et al., 1998). However, from 1972 to 1993, 48 percent of the finfish in Texas bays were landed in the study area (Tunnell et al., 1996). In 1979, 1983, 1984, 1986, and 1987 in the Nueces-Corpus Christi Bay area, there has been an upward trend in landings, whereas in the Upper Laguna Madre, there has been a downward trend. It is not known if this is due to a shift in abundance of resources, fishing effort among bay systems, or a change in consumer demands (Tunnell et al., 1996).

The main shellfish species in the study area include brown shrimp (*Penaeus aztecus*), pink shrimp (*Penaeus duorarum*), white shrimp (*Penaeus setiferus*), blue crab (*Callinectes sapidus*), and eastern oyster (*Crassostrea virginica*). Within the study area, as with the Texas coast in general, brown shrimp are far more common than the other two penaeid species. The Upper Laguna Madre does not support a significant commercial shellfish industry; however, in the Nueces-Corpus Christi Bay system, shrimp has dominated the commercial harvest since 1975 (Tunnell et al., 1996). In addition, there were no eastern oyster landings reported by TPWD from the study area from 1993 to 1997 (Robinson et al., 1998). The commercial harvest of blue crabs in the Nueces-Corpus Christi Bay system remained low between 1972 to 1984, and from this point on, the harvest has exhibited patterns of increases and decreases. In the Upper Laguna Madre, the blue crab catch has remained low from 1972 to the present (Tunnell et al., 1996).

3.5.1.2 Aquatic Communities

In addition to the finfish discussed above as having high recreational and commercial value to humans, many additional aquatic communities are present in the study area that serve to support the ecological diversity and abundance. Other species found mainly in shallow areas include the longnose killifish (*Fundulus similis*), Gulf killifish (*F. grandis*), and tidewater silverside (*Menidia peninsulae*) (Warshaw, 1975). Inhabitants of seagrass meadows include the pinfish (*Lagodon rhomboides*), silver perch (*Bairdiella chrysura*), sheepshead, and pigfish (*Orthopristis chrysoptera*) (Warshaw, 1975). Species often found in deeper water, including the GIWW, are the Atlantic croaker, Gulf menhaden (*Brevoortia patronus*), and sea catfish (*Arius felis*), while a number of fish occur in abundance in both seagrass meadows and deeper areas, including the bay anchovy (*Anchoa mitchilli*), spot (*Leiostomus xanthurus*), and striped mullet (Warshaw, 1975). A study by Shaver (1984) of surf-zone fish revealed that almost 90 percent of the species sampled were larvae and small juveniles including sardine (*Harengula jaguana*), anchovy, Atlantic croaker, mullet, Gulf menhaden, Atlantic thread herring (*Opisthonema oglinum*), and Florida pompano (*Trachinotus carolinus*).

The entire food chain is dependent on the microscopic plankton which utilizes nutrients and provides an abundant food source. The plankton community consists of small plants (phytoplankton) and animals (zooplankton) that are suspended in the water column. Diverse and abundant plankton communities exist throughout the study area. The abundance of plankton has been directly related to salinity and temperature (Tunnell et al., 1996). Seasonal patterns have also been found with phytoplankton and zooplankton (Tunnell et al., 1996).

The benthic macroinvertebrates of the study area form a highly diverse group of organisms with a wide variety of functions in the aquatic community. Their diversity is related to salinity and, as salinity levels rise, marine species are able to colonize the system. In addition to serving as a major food source for vertebrate predators such as fish, macroinvertebrates have important roles as herbivores, detritivores, and carnivores. Tunnell et al. (1996) reported that benthic macroinvertebrates found in the sediments of the study area were primarily polychaetes, bivalves, gastropods, and crustaceans. In Nueces Bay, polychaetes and bivalves comprised the majority of the benthic macroinvertebrates. Polychaetes composed 60 percent of total abundance in Corpus Christi Bay, and bivalves were seasonally abundant. The abundance of macroinvertebrates in Corpus Christi Bay is highest during the winter and spring (Tunnell et al., 1996). Benthic communities in the Gulf nearshore waters undergo widely fluctuating, dynamic, and harsh physical conditions resulting in a few dominant organisms which are low in species diversity but high in density, including polychaetes, mollusks, and crustaceans (Tunnell et al., 1996).

Benthic fauna found in natural sand mud bottom areas offshore from Corpus Christi (for the Corpus Christi Ship Channel ocean dredged material disposal site study) include polychaetes, gastropods, decapods, bivalves, echinoderms, ribbon worms (*Rhynchocoela*), and peanut worms (*Sipuncula*) (EPA, 1988). Within this EPA document, Science Applications (1984) reported on 1983 EPA findings at the CCSC site and indicated that the sampling locations in natural mixed bottom habitat represented higher numbers of individuals, taxa, and species diversity in comparison to those found in the primarily sand-bottomed disposal sites.

3.5.1.3 Essential Fish Habitat

The proposed Project is located in an area that has been identified by the Gulf of Mexico Fishery Management Council (GMFMC) as Essential Fish Habitat (EFH) for postlarval, juvenile, and subadult red drum, brown shrimp and white shrimp, adult Spanish mackerel (*Scomberomorus maculatus*), and juvenile pink shrimp. Coordination with NMFS has been completed. EFH for these species known to occur in the project area includes estuarine emergent wetlands, estuarine mud, sand and shell substrates, SAV, estuarine water column, non-vegetated bottom, and artificial reefs. Detailed information on red drum, shrimp, and other Federally managed fisheries and their EFH is provided in the 1998 amendment of the Fishery Management Plans for the Gulf of Mexico prepared by the GMFMC. The 1998 EFH amendment was prepared as required by the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) (P.L. 104–297) as amended.

The following describes the preferred habitat of each species and relative abundance of each species based on information provided by GMFMC (1998).

Juvenile brown shrimp are considered abundant within the project area from February to April with a minor peak in the fall. The density of postlarvae and juveniles is highest in marsh edge habitat and SAV, followed by tidal creeks, inner marsh, shallow open water and oyster reefs. Juveniles and sub-adults of brown shrimp occur from secondary estuarine channels out to the continental shelf but prefer shallow estuarine areas, particularly the soft, muddy areas associated with the plant-water interface. Adult brown shrimp occur in neritic Gulf waters (i.e., marine waters extending from mean low tide to the edge of the continental shelf) and are associated with silt, muddy sand, and sandy substrates (GMFMC, 1998).

Juvenile white shrimp are considered abundant within the project area from May through November with peaks in June and September. Postlarval white shrimp become benthic upon reaching the nursery areas of estuaries, where they seek shallow water with muddy-sand bottoms high in organic detritus. As juveniles, white shrimp are typically associated with estuarine mud habitats with large quantities of decaying organic matter or vegetative cover. Densities are usually highest in marsh edge and SAV, followed by marsh ponds and channels, inner marsh, and oyster reefs. As adults, white shrimp move from estuaries to coastal areas, where they are demersal and generally inhabit bottoms of soft mud or silt (GMFMC, 1998).

Red drum occur in a variety of habitats, ranging from depths of 40 meters offshore to very shallow estuarine waters. In the juvenile life stages they are considered common within the project area year-round. They are commonly known to occur in all Gulf estuaries where they are found over a variety of substrates including sand, mud and oyster reefs. An abundance of juvenile red drum has been reported around the perimeter of marshes in estuaries (Perret et al., 1980). Young fish are found in quiet, shallow, protected waters with grassy or slightly muddy bottoms (Simmons and Breuer, 1962). Shallow bay bottoms or oyster reef substrates are especially preferred by subadult and adult red drum (Miles, 1950). Spawning occurs in deeper water near the mouths of bays and inlets and on the Gulf side of the barrier islands (Pearson, 1929; Simmons and Breuer, 1962; Perret, et al., 1980). Larvae are transported into the emergent estuarine wetlands where they mature before moving back to the Gulf.

As juveniles, Spanish mackerel are considered common in relative abundance only during the high salinity season between August and October. Although nursery areas are in emergent estuarine communities, juveniles are found offshore and in beach surf and are generally not considered estuarine dependent. Adult Spanish mackerel are usually found along coastal areas, extending out to the edge of the continental shelf (GMFMC, 1998).

Postlarvae and juveniles of pink shrimp occur in estuarine waters of wide-ranging salinity (0 to >30 ppt). Juveniles are commonly found in estuarine areas with seagrass where they burrow into the substrate by day and emerge at night. Postlarvae, juveniles, and subadults may prefer coarse sand/shell/mud mixtures. Densities are highest in or near seagrasses, low in mangroves, and near zero or absent in marshes. Adults inhabit offshore marine waters with the highest concentrations in depths of 9 to 44 meters. Preferred substrate of adults is coarse sand and shell with a mixture of less than 1 percent organic material (GMFMC, 1998).

3.5.2 Wildlife Resources

The study area lies within Blair's (1950) Tamaulipan Biotic Province. The area is semi-arid and hot, with marked deficiency of moisture for plant growth. The vertebrate fauna of this province includes considerable elements of neotropical as well as grassland species. Wildlife habitats found within the study area include upland prairies, salt marsh and seagrass beds, and tidally influenced lowlands. The coastal wetlands of the bay system are represented by salt marshes (previously defined in Section 3.4) on the delta of the Nueces River and Nueces Bay. The Upper Laguna Madre supports two Audubon sanctuaries, documented migratory/waterbird nesting sites, Padre Island National Seashore, Mollie Beattie Habitat Community and Mustang Island State Park. The Audubon sanctuaries are associated with North and South Bird islands in the Upper Laguna Madre south of the study area.

The Tamaulipan Biotic Province supports a diverse fauna composed of a mixture of species that are common in neighboring biotic provinces. The fauna includes a substantial number of neotropical species from the south, a large number of grassland species from the north and northwest, a few Austroriparian species from the northeast, and some Chihuahuan species from the west and southwest (Blair, 1950).

At least 19 species of lizards and 36 species of snakes occur in the Tamaulipan Biotic Province (Blair, 1950). Reptile species of potential occurrence in the study area include such amphibians as Blanchard's cricket frog (*Acris creptians blanchardi*), Texas toad (*Bufo speciosus*), Great Plains narrowmouth toad (*Gastrophryne olivacea*), and bull frog (*Rana catesbiana*). Terrestrial reptiles of potential occurrence in the study area include the western glass lizard (*Ophisaurus attenuatus attenuatus*), six-lined racerunner (*Cnemidophorus sexlineatus sexlineatus*), keeled earless lizard (*Holbrookia propinqua propinqua*), Texas spotted whiptail (*Cnemidophorus gularis*), western coachwhip (*Masticophis flagellum tesaceus*), ground snake (*Sonora semiannulata*), and western diamondback rattlesnake

(*Crotalus atrox*). Five species of sea turtles are also known to occur within the Gulf of Mexico and associated bays. These sea turtles include the loggerhead sea turtle (*Caretta caretta*), green sea turtle (*Chelonia mydas*), leatherback sea turtle (*Dermochelys coriacea*), Atlantic hawksbill sea turtle (*Eretmochelys imbricata*), and Kemp's Ridley sea turtle (*Lepidochelys kempii*).

The immediate study area and vicinity support an abundant and diverse avifauna. Tidal flats and beaches create excellent habitat for numerous species of gulls, terns, herons, shorebirds, and wading birds. Some common species which occur within the study area include the laughing gull (*Larus atricilla*), ring-billed gull (*Larus delawarensis*), royal tern (*Sterna maxima*), sandwich tern (*Sterna sandvicensis*), great blue heron (*Ardea herodias*), little blue heron (*Egretta caerulea*), sanderlings (*Calidris alba*), least sandpiper (*Calidris minutilla*), roseate spoonbill (*Ajaia ajaja*), and white ibis (*Eudocimus albus*). Thousands of sandhill cranes (*Grus canadensis*) utilize tall grass coastal prairies and fallow agricultural fields throughout the south Texas coast.

Other bird species which are associated with prairies and marshes include many species of raptors, songbirds, and migratory waterfowl. Texas is one of the most significant waterfowl wintering regions in North America with three to five million waterfowl annually (recent years) wintering in the state (Texas Coastal Management Program (TCMP), 1996).

At least 61 mammalian species occur or have occurred within recent times in the Tamaulipan Biotic Province (Blair, 1950). Terrestrial mammals likely to occur in the study area include the black-tailed jack rabbit (*Lepus californicus*), Gulf Coast kangaroo rat (*Dipodomys compactus*), marsh rice rat (*Oryzomys palustris*), fulvous harvest mouse (*Reithrodontomys fulvescens*), common raccoon (*Procyon lotor*), striped skunk (*Mephitis mephitis*), and coyote (*Canis latrans*). Marine mammals are also likely to occur within the study area. The bottle-nosed dolphin (*Tursiops truncatus*) is the marine mammal most likely to be encountered.

3.6 THREATENED AND ENDANGERED SPECIES

The Endangered Species Act (ESA) [16 U.S.C. 1531 et. Seq.] of 1973 as amended, was enacted to provide a program for the preservation of endangered and threatened species and to provide protection for the ecosystems upon which these species depend for their survival. All Federal agencies are required to implement protection programs for these designated species and to use their authorities to further the purposes of the act. The FWS and the NMFS are the primary agencies responsible for implementing the ESA. The FWS is responsible for birds and terrestrial and freshwater species, while the NMFS is responsible for non-bird marine species.

An endangered species is one that is in danger of extinction throughout all or a significant portion of its range in the U.S. A threatened species is one likely to become endangered within the foreseeable future throughout all or a significant portion of its range. State-listed threatened and endangered species, while addressed in this assessment, are not protected under the ESA, nor are Species of Concern (SOC), which are species for which there is some information showing evidence of vulnerability, but not enough data to support a Federal listing. Only those species listed as endangered or threatened by the FWS or NMFS are afforded complete Federal protection. It should be noted that inclusion on the following lists does not imply that a species is known to occur in the study area, but only acknowledges the potential for occurrence. County lists of special species provided by the Texas Parks and Wildlife Biological Conservation Data System (TXBCD, 1999) in addition to the most recent list of threatened and endangered species of Texas by county disseminated by the FWS (2000) were reviewed. TXBCD data files were also reviewed in order to obtain specific species' locations within the study area.

3.6.1 Flora

Table 3.6-1 presents Federally and State-endangered plant species and SOC that may occur in the study area. Texas Parks and Wildlife uses the same listing designations as the FWS for plants. Plants having a geographic range including Nueces and San Patricio counties are briefly discussed.

Three plant species listed by both the FWS and TPWD as endangered may potentially occur within the study area. These plants include south Texas ambrosia (*Ambrosia cheiranthifolia*), slender rush-pea (*Hoffmannseggia tenella*), and black lace cactus (*Echinocereus reichenbachii* var. *albertii*).

South Texas ambrosia is an inhabitant of open prairies in grassland/mesquite-dominated savannah in clay loam to sandy loam soils (FR 59 43648-43652). Much of its original habitat has been converted to cropland or introduced forage species. It is known from Nueces, Kleberg, and Jim Wells counties in the U.S. and Tamaulipas in Mexico. Known stands of this species occur in rights-of-way along highways and railways, where the species is subject to weed-control measures including mowing and herbicide applications (Turner, 1983). This species has a record of occurrence within the study area adjacent to the Nueces River.

The slender rush-pea is known from only four populations in Kleberg and Nueces counties. It is found in barren openings within native grassland and brush in calcareous clay soils (FWS, 1997). Introduction of non-native grasses and conversion of prairies to agriculture are thought to be responsible for its decline. It is of possible occurrence within the study area.

One endangered cactus is known to have a geographic range which includes the study area. The black lace cactus has a range in the south Texas plains which includes Jim Wells, Kleberg, and Refugio counties (Poole and Riskind, 1987). This cactus occurs in brushy, grassy areas along streams in an area where the coastal plain meets the inland mesquite/huisache/blackbrush savannah (Poole and Riskind, 1987). The occurrence of this species within the study area is unlikely due to lack of suitable soils and habitat. Texas Parks and Wildlife includes this species on their Nueces County list of rare species (TXBCD, 1999).

Six plant species identified as SOC by the FWS have records in Nueces or San Patricio counties. These species include: lila de los llanos (*Echeandia chandleri*); Texas windmillgrass (*Chloris texensis*); Thieret's skullcap (*Scutellaria thieretii*); Roughseed sea-purslane (*Sesuvium trianthemoides*); Welder machaeranthera (*Psilactis heterocarpa*); and Mathis spiderling (*Boerhavia mathisiana*). Thieret's skullcap is known from within the study area; lila de los llanos, roughseed sea-purslane, and Texas

TABLE 3.6-1

ENDANGERED, THREATENED, AND SPECIES OF CONCERN
POTENTIALLY OCCURRING IN THE PROJECT AREA
NUECES AND SAN PATRICIO COUNTIES, TEXAS[1]

Common Name[2]	Scientific Name[2]	Status[3] FWS	Status[3] TPWD
AMPHIBIANS			
Sheep frog	*Hypopachus variolosus*	--	T
Black-spotted newt	*Notophthalmus meridionalis*	--	T
South Texas siren	*Siren* sp.[1]	--	T
Rio Grande lesser siren	*Siren intermedia texana*	SOC	--
BIRDS			
Brown pelican	*Pelecanus occidentalis*	E	E
Reddish egret	*Egretta rufescens*	--	T
White-faced ibis	*Plegadis chihi*	--	T
Bald eagle	*Haliaeetus leucocephalus*	T/PDL	T
Northern gray hawk	*Buteo mitidus maximus*	SOC	--
White-tailed hawk	*Buteo albicaudatus*	--	T
Ferruginous hawk	*Buteo regalis*	SOC	--
American peregrine falcon	*Falco peregrinus anatum*	--	E
Arctic peregrine falcon	*Falco peregrinus tundrius*	--	T
Black rail	*Lateralus jamaicensis*	SOC	--
Whooping crane	*Grus americana*	E	E
Piping plover	*Charadrius melodus*	T	T
Mountain plover	*Charadrius montanus*	PT	--
Eskimo curlew	*Numenius borealis*	E	E
Sooty tern	*Sterna fuscata*	SOC	T
Black tern	*Chilidonias niger*	SOC	--
Loggerhead shrike	*Lanius ludovicianus*	SOC	--
Cerulean warbler	*Dendroica cerulea*	SOC	--
Texas olive sparrow	*Arremonops rufivirgatus*	SOC	--
Texas Botteri's sparrow	*Aimophila botteri texana*	SOC	T
Sennett's hooded oriole	*Icterus cucullatus sennetti*	SOC	--
Audubon's oriole	*Icterus graduacauda audubonii*	SOC	--
Wood stork	*Mycteria americana*	--	T

TABLE 3.6-1 (Cont'd)

Common Name[2]	Scientific Name[2]	Status[3] FWS	TPWD
FISH			
Opossum pipefish	*Microphis brachyurus*	--	T
MAMMALS			
Southern yellow bat	*Lasiurus ega*	--	T
Maritime pocket gopher	*Geomys personatus maritimus*	SOC	--
Red wolf (extirpated)	*Canus rufus*	E	E
Ocelot	*Leopardus pardalis*	E	E
Jaguarundi	*Herpailurus yagouaroundi*	E	E
West Indian manatee	*Trichechus manatus*	E	E
REPTILES			
Loggerhead sea turtle	*Caretta caretta*	T	T
Green sea turtle	*Chelonia mydas*	T	T
Leatherback sea turtle	*Dermochelys coriacea*	E	E
Atlantic hawksbill sea turtle	*Eretmochelys imbricata*	E	E
Texas tortoise	*Gopherus berlandieri*	--	T
Kemp's Ridley sea turtle	*Lepidochelys kempii*	E	E
Texas diamondback terrapin	*Malaclemys terrapin littoralis*	SOC	--
American alligator	*Alligator mississipiensis*	T/SA	--
Texas horned lizard	*Phrynosoma cornutum*	--	T
Scarlet snake	*Cemophora coccinea*		
Timber/canebrake rattlesnake	*Crotalus horridus*		T
Indigo snake	*Drymarchon corais*	--	T
Northern cat-eyed snake	*Leptodeira septentrionalis*	--	T
Gulf saltmarsh snake	*Nerodia clarkii*	SOC	--
PLANTS			
Black-laced cactus	*Echinocereus reichenbachii* var,	E	E
South Texas ambrosia	*Ambrosia cheiranthifolia*	E	E
Slender rush-pea	*Hoffmanseggia tenella*	E	E
Lila de los llanos	*Echeandia chandleri*	SOC	--
Texas windmill grass	*Chloris texana*	SOC	--

TABLE 3.6-1 (Concluded)

Common Name[2]	Scientific Name[2]	Status[3] FWS	TPWD
PLANTS (Concluded)			
Theiret's skullcap	*Scutellaria thieretii*	SOC	--
Roughseed sea-purslane	*Sesuvium trianthemoides*	SOC	--
Welder machaeranthera	*Psilactis heterocarpa*	SOC	--
Mathis spiderling	*Boerhavia mathisiana*	SOC	--
INSECTS			
Maculated manfreda skipper	*Stallingsia maculosus*	SOC	

1 According to FWS (1995, 2000), TPWD (1997), and TXBCD (1999).

2 Nomenclature follows AOU (1998), Collins (1990), Hatch et al. (1990), and Jones et al. (1997).

3 FWS - U.S. Fish and Wildlife Service; TPWD - Texas Parks and Wildlife Department.

E Endangered; in danger of extinction E/SA, T/SA - No longer biologically threatened or endangered but because of the similarity of appearance to other protected species, it is necessary to restrict commercial activities of specimens taken in the USA to ensure the conservation of similar species that are biologically threatened or endangered.

T Threatened; severely depleted or impacted by man.

-- Not listed.

PDL Proposed delisting.

PT Federally proposed threatened.

SOC Species of concern - species for which there is some information showing evidence of vulnerability but not enough data to support listing at this time.

windmillgrass have records of occurrence near the study area, thus the potential for occurrence of these species within the study area exists.

Lila de los llanos occurs on level to gently undulating sites along and somewhat inland from the Gulf Coast of Texas. It prefers full sunlight and grows among prairies and chaparral thickets on heavy clay and loamy clay soils (Poole, 1985). Texas windmillgrass occurs along the Gulf Coast and throughout the northeastern Rio Grande Plains of Texas. It prefers silty and sandy loam soils and is known from Nueces County (Poole et al., 2000). Thieret's skullcap occurs on shell, sand, shell ridges, or sandy meadows usually not far from brackish marshes. It is also found growing in close association within woodlands dominated by honey locust (*Gleditsia tricanthos*) and sugar hackberry *(Celtis laevigata*) in non-disturbed soils (Kral, 1983). Roughseed sea-purslane occurs on dunes of south Texas (Correll and Johnston, 1970) and in brackish swales, marshes and depressions along the coast (Jones, 1977). Poole et al. (2000), show its range occurring only in Kenedy County. Welder machaeranthera occurs in shrub-invaded grasslands and open mesquite-huisache woodlands on mostly gray clays to silty soils overlying the Lissie and Beaumont formations (Texas Organization for Endangered Species [TOES], 1993). It has been documented in both Kleberg and Nueces counties (Poole et al., 2000). Mathis spiderling is recorded in San Patricio and Live Oak counties; however, the greatest known populations are located in Mexico. This small, perennial herb grows on thin soils over limestone, in limestone cracks or rubble in tall thorn shrub, growing in the open and under shrubs (54 FR 27413-27414). No known occurrence of this species has been recorded within or in the vicinity of the study area.

3.6.2 Wildlife

Table 3.6-1 lists wildlife taxa that may occur in the study area that are considered by FWS and TPWD to be endangered, threatened or SOC. Table 3.6-1 is composed of endangered and threatened species that have a geographic range which may include Nueces or San Patricio counties. As with the flora noted above, inclusion on the list does not imply that a species is known to occur in the study area, but only acknowledges the potential for occurrence. The following paragraphs present distributional data concerning each Federally or State-listed species, along with a brief evaluation of the potential for the species to occur within the study area.

3.6.2.1 Amphibians

Four amphibians are listed by the TXBCD and FWS as potentially occurring within the study area counties. Three species that are State-listed as threatened include the sheep frog (*Hypopachus variolosus*), black-spotted newt (*Notophalmus meridionalis*), and South Texas siren (*Siren* sp.). The Rio Grande lesser siren (*Siren intermedia texana*) is identified as a SOC by the FWS. The sheep frog is known to occur in moist burrows of subterranean mammals, under vegetative debris, and around pond edges and irrigation ditches (Garrett and Barker, 1987). This species has been recorded from counties within the study area (Dixon, 1987). The black-spotted newt inhabits heavily vegetated, shallow water lagoons, streams, ditches and swamps (Garrett and Barker, 1987). The black-spotted newt may occur in wetland sites within the study area. The South Texas siren is known to occur in the study area in habitat similar to that occupied by the black-spotted newt. However, the newt requires year-round open water since it cannot aestivate in dry ground like the siren. The Rio Grande lesser siren prefers warm, shallow waters with vegetative cover such as those in ponds, irrigation canals and swamps in permanently to semipermanently inundated areas in counties along the lower coast of Texas and along the Rio Grande (Bartlett and Bartlett, 1999).

3.6.2.2 Birds

Twenty-four endangered, threatened, and SOC bird species are listed by the FWS and/or TXBCD as occurring or potentially occurring in the study area. Several of these are predominantly inland species that are not ordinarily expected on the coast, or are migrants that pass through the region seasonally. Others may occur as breeding birds, permanent residents, or post-nesting visitors. Federally listed species are described below, followed by descriptions of State-listed species and then Federal SOC.

The Federally and State-endangered brown pelican (*Pelecanus occidentalis*) is primarily a coastal species that rarely ventures very far out to sea or inland. In Texas, it occurs primarily along the lower and middle coast, and now common sightings are reported on the upper coast and inland to central, north-central and eastern Texas, usually on large freshwater lakes (Texas Ornithologists Union (TOS), 1995). Brown pelicans are colonial nesters, usually nesting on undisturbed offshore islands in small bushes and trees, including mangroves (National Fish and Wildlife Laboratory (NFWL), 1980; Guzman and Schreiber, 1987). This species is a common resident of the area and is likely to occur in the open water habitat and sand/mud flats in the study area. Pelican Island, located just south of the CCSC, is a major brown pelican nesting site.

The bald eagle (*Haliaeetus leucocephalus*) has recovered sufficiently to be downlisted to threatened throughout its range, and the FWS has proposed to completely delist the species in the near future (64 FR 36453-36363; July 6, 1999). Two subspecies are currently recognized based on size and weight: the northern bald eagle and the southern bald eagle. The northern population nests from central Alaska and the Aleutian Islands through Canada into the northern U.S. The southern population primarily nests in estuarine areas of the Atlantic and Gulf coasts, northern California to Baja California, Arizona and New Mexico (Snow, 1981). Wintering ranges of the two populations overlap. The bald eagle inhabits coastal areas, rivers and large bodies of water as fish and waterfowl comprise the bulk of their diet. Nests are seldom far from a river, lake, bay, or other water body. Nest trees are generally located in woodlands, woodland edges, or open areas, and are frequently the dominant or co-dominant tree in the area (Green, 1985). The 1999 bald eagle nesting survey in Texas identified 82 nesting territories statewide, the southernmost found in Refugio, Goliad, Victoria, and Matagorda counties (Mitchell, 1999). Concentrations of wintering northern eagles are often found around the shores of reservoirs in Texas, with most wintering concentrations occurring in the eastern part of the state. Wintering bald eagles in Texas have been observed as far south as Cameron County (Oberholser, 1974), and are considered to be a rare permanent resident in the Coastal Bend (Rappole and Blacklock, 1985). No nests are known to occur in the study area, nor have any been reported from Nueces County (Mitchell, 1999). The bald eagle should occur in the study area only as a rare migrant or post-nesting visitor.

Each year, the entire breeding population of the Federal and State-endangered whooping crane (*Grus americana*) migrates 2,600 miles from Canada's Northwest Territories and winters in the prairies, salt marshes and bays along a narrow section of the Texas coast centered around the Aransas

National Wildlife Refuge. Rest areas along the migration route include the central and eastern panhandle of Texas (FWS, 1995). In Texas, the principal winter habitat is brackish bays, marshes, and salt flats, and whooping cranes will feed in nearby upland sites characterized by oak mottes, grassland swales, and ponds (Campbell, 1995). In Texas, they eat a wide variety of plant and animal foods, including blue crabs, clams, berries of Carolina wolfberry (*Lycium carolinianum*), acorns, snails, crayfish, and insects (Campbell, 1995). The whooping crane has been recorded from counties within the study area but is generally restricted to the Aransas National Wildlife Refuge in Aransas, Refugio, and Calhoun counties. Though the leeward side and interior of Padre Island provide suitable winter habitat for whooping cranes, they are unlikely to occur in the study area.

The Federally and State-threatened piping plover is a winter resident and spring and fall migrant of the study area. This small shorebird breeds in the northern Great Plains of the U.S. and Canada, along beaches of the Great Lakes, and along the Atlantic coastline from North Carolina to Newfoundland (Haig and Oring, 1987). Post-breeding and wintering sites include the southern U.S. Atlantic coastline; the Gulf of Mexico from Florida to Veracruz, Mexico; and on scattered Caribbean islands (Haig and Oring, 1985). The piping plover can be found along Texas beaches, tidal flats, mud flats, sand flats, dunes, and offshore spoil islands (American Ornithologists Union (AOU), 1998; FWS, 1995) arriving in mid- to late July (Haig and Oring, 1985). The piping plover is a regular migrant and winter resident along the lower Texas coast (Oberholser, 1974; Haig and Oring, 1985). The checklist of birds of Mustang Island State Park lists the piping plover as a fairly common winter resident and a common migrant (Pulich et al., 1985). This species is also known to occur within the Mollie Beattie Habitat Community (Zonick and Ryan, 1996; GLO and FWS, 1998). This species has been documented here as recently as August 2001 (PBS&J, in-house data). As a result of a lawsuit, critical habitat was designated for this species in its nesting and wintering grounds (65 FR 41781-41812, July 6, 2000). Designation of critical habitat became final on July 10, 2001 (66 FR 36038). Portions of the study area, but not the footprint of the project, are within Critical Habitat units TX-6, TX-7, TX-8, TX-9, TX-10, TX-11, TX-12, TX-13, TX-14, and TX-16. Designation of critical habitat became final on July 10, 2001 (66 FR 36038).

The mountain plover (*Charadrius montanus*) was proposed for listing as a Federally threatened species on February 16, 1999 (64 FR 7587). Non-breeding birds prefer short-grass plains, fields, plowed fields, sandy deserts, and sod farms (NatureServe, 2000a). The mountain plover is a rare to uncommon local winter resident on the coastal plains and inland from south Texas through the Edwards Plateau into the South Plains (TOS, 1995). The mountain plover has been recorded from Nueces County (Oberholser, 1974). It is most likely to occur in agricultural areas away from the seashore. This species appears as an uncommon migrant on the checklist for birds of the Corpus Christi area (Audubon Outdoor Club of Corpus Christi (AOCCC), 1994), but is absent from checklists for Mustang Island State Park (Pulich et al., 1985) and the Padre Island National Seashore (Southwest Parks and Monuments Association (SPMA), 1990). This species is unlikely to occur within the study area.

The current status of the Eskimo curlew (*Numenius borealis*) is considered uncertain and possibly extinct (TOS, 1995), but the species is considered Federally and State-listed as endangered. This species was extremely abundant in the nineteenth century, but was subject to extreme hunting pressures. The breeding habitat of the Eskimo curlew was treeless arctic and subarctic tundra (Gill et al., 1998). Non-breeding birds use a variety of habitats, such as grasslands, pastures, plowed fields, and less frequently, marshes and mud flats (AOU, 1983). Spring migration would bring them through Texas and the midwestern U.S. (Gill et al., 1998) from mid-March to late April in Texas (Oberholser, 1974). One record does exist from Galveston, Texas, in 1962, and others since have been reported, but the validity of these records is uncertain (TOS, 1995). The Eskimo curlew is unlikely to occur in the study area due to its extreme rarity and the lack of recent records of occurrence.

The reddish egret (*Egretta rufescens)*, a State-threatened species, typically inhabits saltwater bays and marshes. Its breeding range is restricted to the Gulf Coast where it commonly nests in yucca-prickly pear thickets (Oberholser, 1974). The white-faced ibis (*Plegadis chihi*), State-listed as threatened, is a common resident along the coast. Preferred habitats of the white-faced ibis have been described as ranging from freshwater marshes and sloughs and irrigated rice fields to salt marshes (Oberholser, 1974). Both of these species occur within the study area.

The white-tailed hawk (*Buteo albicaudatus*) is listed as State threatened and is considered an uncommon local resident along the Texas coastal plain (TOS, 1995). The white-tailed hawk could be present in savannah-like, grassland habitats within the study area.

All North American peregrine falcons were delisted from the endangered species list (64 FR 46541-46558, August 2, 1999). The Arctic peregrine falcon (*Falco peregrinus tundrius*), which was listed as endangered due to similarity of appearance (E/SA) was delisted Federally but remains on the TPWD threatened list. The Arctic peregrine falcon winters along the entire Gulf Coast and occurs statewide during migration (FWS, 1995). The American peregrine falcon (*Falco peregrinus anatum*) remains on the State endangered list.

The sooty tern (*Sterna fuscata*), State-listed as threatened and a Federal SOC, is considered a rare local summer resident along the central and lower coast (TOS, 1995). This pelagic bird spends almost its entire life at sea. Many records have been reported on the Texas coast following large tropical storms. Oberholser (1974) shows a breeding and a summer record of the sooty tern in Nueces County. This species is a rare but potential vagrant to the study area.

The Texas Botteri's sparrow (*Aimophila botterii texana*) is an uncommon to locally common summer resident on the lower coastal plain, with isolated breeding records from Duval, Jim Wells, and San Patricio counties (TOS, 1995). This sparrow is an inhabitant of tall bunch grass prairie with widely scattered shrubs and small trees mostly within 20 miles of the Gulf Coast (Oberholser, 1974). The reason for a decline in numbers of this species is attributed mostly to depletion of habitat due to agriculture practices (Oberholser, 1974). Texas Parks and Wildlife considers this sparrow to be State threatened.

The wood stork (*Mycteria americana*) is listed as threatened by TPWD. This bird is an uncommon to common post-breeding visitor to the central and upper coastal prairies and a regular visitor of lakes and reservoirs in central and east Texas. This species has been recorded within the study area counties (Oberholser, 1974; TOS, 1995).

Two additional *Buteo* species, northern gray hawk (*Buteo nitidus maximus*) and ferruginous hawk (*Buteo regalis*), are considered SOC by the FWS. The northern gray hawk is a rare to uncommon local resident in the Lower Rio Grande Valley (TOS, 1995). In Texas, this hawk inhabits mature woodlands of the river valleys and nearby semi-arid mesquite and scrub grasslands (Oberholser, 1974). Oberholser (1974) shows a fall record of the northern gray hawk from Nueces County. This species is unlikely to occur in the study area. The ferruginous hawk ranges the wide open spaces of the dry Great Plains and Great Basin in western North America (Oberholser, 1974). It may occur in the study area as a migrant or winter resident. It is considered locally uncommon on Texas' barrier islands and the central and south coastal plains (TOS, 1995). Two ferruginous hawks are known to overwinter in the study area (Beasley, 1998).

Three additional avian SOC of potential occurrence in the study area include the black rail (*Laterallus jamaicensis*), black tern (*Chlidonias niger*), and loggerhead shrike (*Lanius ludovicianus*). The black rail is a rare migrant and winter resident in the state (Oberholser, 1974) and a potential migrant to the study area. It is primarily a bird of coastal marshes, typically dominated by smooth cordgrass. The black tern is a common migrant in all parts of Texas including offshore waters (TOS, 1995). It breeds in marshy areas of the northern U.S. and Canada, and may migrate through Texas during all months except January, February, and March (Oberholser, 1974). This species occurs within the study area. The loggerhead shrike is an inhabitant of open country with scattered trees and shrubs. It is a rare to common resident throughout the state, except for portions of the South Texas Plains. It is a possible resident/migrant within the study area.

Four songbirds of potential occurrence within the study area are considered SOC by the FWS. These four species are: cerulean warbler (*Dendroica cerulea*), Texas olive sparrow (*Arremonops rufivirgatus*), Sennett's hooded oriole (*Icterus cucullatus sennettii*), and Audubon's oriole (*Icterus gradaucada audubonii*). The cerulean warbler is a rare to uncommon spring migrant in the eastern half of the state, mostly on the coast, and south to the Rio Grande Valley (TOS, 1995) and prefers deciduous or mixed woodlands near stream bottoms. It is likely to occur within the study area only during migration. The olive sparrow is a common resident in south Texas, extending north to Goliad, Karnes, Uvalde, and Val Verde counties (TOS, 1995). This sparrow inhabits dense brushy areas where it spends much of its life on or near the ground. This species is unlikely to inhabit the study area, due to lack of appropriate habitat. Sennett's oriole is a summer resident and rare winter resident in south Texas. It inhabits areas closely associated with towns where it nests in palm (*Washingtonia* sp. and *Sabal* sp.) and pecan (*Carya illinoinensis*) trees (Oberholser, 1974). Audubon's oriole is a rare to uncommon resident in south Texas and is typically found in wooded or brushy areas. During the warmer months, it tends to prefer mesquite woodlands; in winter it can be found in evergreen trees such as live oak (*Quercus virginiana*) along with huisache (*Acacia smallii*) and Texas ebony (*Pithecellobium flexicaule*) (Oberholser, 1974). The presence of either of these orioles in the study area is unlikely.

3.6.2.3 Fish

A candidate species is, as its name implies, a candidate for listing under the ESA. More specifically, it is a species or vertebrate population for which sufficient reliable information is available that a listing under the ESA may be warranted. There are no mandatory Federal protections required under the ESA for a candidate species (NMFS, 2001).

The dusky shark (*Carcharhinus obscurus*), also known as the bronze whaler or black whaler, was added to the NMFS candidate species list in 1997. It has a wide-ranging (but patchy) distribution in warm-temperate and tropical continental waters (NMFS, 2001). It is coastal and pelagic in its distribution where it occurs from the surf zone to well offshore and from surface depths to 400 meters (Compagno, 1984). Because it apparently avoids areas of lower salinities, it is not commonly found in estuaries (Compagno, 1984; Musick et al., 1993).

The Atlantic and Gulf of Mexico populations of the sand tiger shark (*Odontspis taurus*) were added to the candidate species list in 1997. Sand tiger sharks have a broad inshore distribution. In the western Atlantic, this shark occurs from the Gulf of Maine to Florida, in the northern Gulf of Mexico, in the Bahamas and in Bermuda. Although first reported in Texas in the 1960s, this species does not seem to be uncommon (Hoese and Moore, 1998). A cool temperate species, it is more common north of Cape Hatteras (Hoese and Moore, 1998). They are generally coastal, usually found from the surf zone down to depths around 75 feet. However, they may also be found in shallow bays, around coral reefs and to depths of 600 feet on the continental shelf. They usually live near the bottom, but may also be found throughout the water column (NMFS, 2001).

NMFS designated the night shark (*Carcharhinus signatus*) a candidate species in 1997. Data on this species are minimal because the shark is a deepwater shark. The shark has been reported in waters from Delaware south to Brazil, including the Gulf of Mexico. It has also been reported from West Africa. It was formerly abundant in deep waters off the northern coast of Cuba and the Straits of Florida (NMFS, 2001).

The speckled hind (*Epinephelus drummondhayi*) inhabits warm, moderately deep waters from North Carolina to Cuba, including Bermuda, the Bahamas and the Gulf of Mexico. The preferred habitat is hard bottom reefs in depths ranging from 150 to 300 feet, where the temperatures are from 60 to 85 degrees Fahrenheit (°F). The speckled hind was added to the candidate species list in 1997 (NMFS, 2001).

NMFS designated the saltmarsh topminnow (*Fundulus jenkinsi*) as a candidate species in 1997. This rare species is restricted to coastal streams and adjacent bay shores on the western side of Galveston Bay and from Vermilion Bay to the Florida Panhandle. Usually found in low salinities, it has been taken from the Chandeleur Islands (Hoese and Moore, 1998). This species tends to live in salt marshes and brackish water, although it has been known to survive in freshwater. This species can also be found in shallow tidal meanders of *Spartina* marshes (NMFS, 2001).

The goliath grouper (*Epinephelus itajara*), formerly named the jewfish, was added to the candidate species list in 1991 for the region of North Carolina southward to the Gulf of Mexico, which encompasses the entire range of this species in U.S. waters. Historically, goliath grouper were found in tropical and subtropical waters of the Atlantic Ocean, both coasts of Florida, and from the Gulf of Mexico down to the coasts of Brazil and the Caribbean. They were abundant in very shallow water, often associated with piers and jetties along the Florida Keys and southwest coast of Florida (NMFS, 2001).

The Warsaw grouper (*Epinephelus nitrigus*) was added to the candidate species list in 1997. It is a very large fish found on the deepwater reefs of the southeastern United States. Warsaw grouper range from North Carolina to the Florida Keys and throughout much of the Caribbean and Gulf of Mexico to the northern coast of South America. The species inhabits deepwater reefs on the continental shelf break in waters 350 to 650 feet deep. As for all of the candidate species above, the main threat to them has been mortality associated with fishing (NMFS, 2001).

The TXBCD includes one State-threatened fish, which may potentially occur in the project area. The opossum pipefish (*Microphis brachyurus*) has been reported from the Rio Grande River, and in *Spartina* marshes as well as in *Sargassum* mats in the Gulf of Mexico (Hoese and Moore, 1998). Brooding adults are found in fresh or low salinity waters and the young move into more saline waters (TXBCD, 1999).

3.6.2.4 Mammals

The red wolf (*Canis rufus*) has been considered extinct in the wild since 1980 according to Davis and Schmidly (1994). This species inhabited brushy and forested areas along the coastal prairies throughout the eastern half of Texas (Davis and Schmidly, 1994).

The ocelot (*Leopardus pardalis*) and the jaguarundi (*Herpailurus yagouaroundi*) are listed by the FWS and TPWD as endangered. Both of these cat species' historic range included San Patricio and Nueces counties and both are included on TXBCD's Special Species List as potentially occurring in the counties in which the study area occurs The ocelot is a medium-sized cat which ranges from southern Texas and Arizona to northern Argentina (Campbell, 1995). According to Campbell (1995), the ocelot prefers habitat described as dense thorn scrub with a dense canopy cover. Ocelots have been known to prey on small mammals, birds, reptiles, amphibians and some fish (Davis and Schmidly, 1994). The ocelot currently occurs only in the extreme southern part of the state (Davis and Schmidly, 1994) and is unlikely to occur in the study area, due to the lack of suitable brushy habitat.

The Federally and State-listed endangered jaguarundi occurs in south Texas, eastern and western portions of Mexico, and south into South America (Hall, 1981). In Texas, this cat inhabits very similar habitat as described for the ocelot: very dense thornscrub (Davis and Schmidly, 1994) with a preference for streams (Goodwyn, 1970; Davis and Schmidly, 1994). Jaguarundi distribution in Texas should be considered restricted to the Rio Grande Valley (Tewes and Everett, 1987). Due to the lack of suitable brushy habitat and any known populations in the area, this species is unlikely to occur in the study area.

The West Indian manatee (*Trichechus manatus*) is a Federally and State-listed endangered aquatic mammal which inhabits brackish water bays, large rivers, and salt water (Davis and Schmidly, 1994). They feed upon submergent, emergent, and floating vegetation with the diet varying according to plant availability (O'Shea and Ludlow, 1992). The manatee is more common in the warmer waters off of coastal Mexico, the West Indies, and Caribbean to northern South America (NatureServe, 2000b). In the U.S., populations are primarily found in Florida, but occasional vagrants migrate along the coast into Texas. Although extremely rare in Texas, recent Texas records include specimens from Cameron, Galveston, Matagorda, and Willacy counties (FWS, 1995). Davis and Schmidly (1994) describe a record of a manatee which was found dead in the surf near the Bolivar Peninsula near Galveston, Texas. Albert Oswald of the Texas State Aquarium spotted a manatee in the inlet between the Texas State Aquarium and the Lexington Museum on 23 September 2001. This is the third and probably most reliable sighting of the manatee in Corpus Christi Bay (Beaver, 2001). While the West Indian manatee has been recently sighted in Corpus Christi Bay, such occurrences are rare.

The southern yellow bat (*Lasiurus ega*) is a neotropical bat that is listed as State threatened. In the U.S., this bat has been recorded from southern California, southern Arizona, extreme southwestern New Mexico and south Texas (Schmidly, 1991). In Texas, the southern yellow bat occurs in the extreme south where it utilizes trees as roosting sites. In some areas of south Texas, palm trees appear to be preferred roosting sites (Davis and Schmidly, 1994). This mammal is unlikely to be found in the study area.

The maritime Texas pocket gopher (*Geomys personatus maritimus*), a Federal SOC, is known from Kleberg and Nueces counties (TOES, 1995; TXBCD, 1999). It inhabits areas with deep, sandy soils where it constructs its burrows and tunnels. It is a possible resident of the study area.

3.6.2.5 Reptiles

Five sea turtles are Federally and State endangered within Nueces and San Patricio counties. These sea turtles include the loggerhead sea turtle (*Caretta caretta*), green sea turtle (*Chelonia mydas*), leatherback sea turtle (*Dermochelys coriacea*), Atlantic hawksbill sea turtle (*Eretmochelys imbricata*), and Kemp's Ridley sea turtle (*Lepidochelys kempii*). These sea turtles are known to occur in the Gulf of Mexico, including associated bay and estuarine waters and sometimes nest along the Gulf beaches (Garrett and Barker, 1987). It is a possibility for any of these species to be observed within the study area.

The loggerhead sea turtle is widely distributed within its range. It can be found in waters hundreds of miles offshore as well as inshore areas such as bays, lagoons, salt marshes, ship channels, and mouths of large rivers (FWS, 1995). This species feeds on various marine invertebrates – crustaceans, mollusks, sponges, echinoderms, gastropods and some plants, fish, and jellyfish. They nest on high energy beaches on barrier islands with steeply sloped beaches and gradually sloped offshore approaches. The nesting range in the U.S. is mainly the Atlantic Coast, although nesting on barrier islands along the Texas coast has been recorded (NMFS and FWS, 1991a; Shaver, 2000).

The green sea turtle's favored habitat appears to be lagoons and shoals with an abundance of marine grasses and algae (FWS, 1995). The adults are primarily herbivorous while the juveniles consume more invertebrates. Foods consumed include seagrasses, macroalgae and other marine plants, mollusks, sponges, crustaceans, and jellyfish (Mortimer, 1982). Terrestrial habitat is typically limited to nesting activities on deep, coarse to fine sands with little organic content, along high energy beaches. Major nesting activity occurs in Costa Rica and Surinam with small numbers nesting in

Florida and rarely in Texas, Georgia and North Carolina (NMFS and FWS, 1991b). This species has been recorded in Nueces County (Dixon, 2000).

Leatherback sea turtles are considered to be the most pelagic of the sea turtles, seldom approaching land except for nesting. They are mainly found in coastal water only when nesting and when following concentrations of jellyfish, which is the principal food source (TPWD, 2000; FWS, 1995; Garrett and Barker, 1987). The leatherback nests on sandy, sloping beaches, often near deepwater and rough seas (NMFS and FWS, 1992). The largest nesting beaches are found in the U.S. Virgin Islands, Puerto Rico, and Florida (NMFS, 2000).

The Atlantic hawksbill sea turtle is found in rocky bottom, shallow, coastal water areas, lagoons, estuaries, and mangrove-bordered bays in water generally less than 60 feet deep (FWS, 1995). This species prefers foraging habitat of coral reefs, rocky outcrops, and high energy shoals, which are optimum sites for sponge growth; sponge being one of their principal food sources. Other forage foods include crabs, sea urchins, shellfish, jellyfish, plant material, and fishes. Nesting activities may include deep sand beaches of low energy to high energy beaches. Nesting in the Continental U.S. is limited to the southeast coast of Florida, Florida Keys, Puerto Rico, and U.S. Virgin Islands. Most of the Texas sightings involve posthatchlings and juveniles which are primarily associated with stone jetties and originated from nesting beaches in Mexico (NMFS, 2000).

The Kemp's Ridley sea turtle is known to inhabit shallow coastal and estuarine waters usually over sand or mud bottoms where a food source of crabs can be found (FWS, 1995). Other food items include shrimp, snails, bivalves, sea urchins, jellyfish, sea stars, fish, and occasional marine plants (Campbell, 1995). Nesting activities are essentially restricted to the Gulf of Mexico at Rancho Nuevo, Tamulipas, Mexico. Sporadic nesting has been reported from Mustang Island, Texas southward to Isla Aquada, Campeche, Mexico (NMFS, 2000; Hildebrand 1983, 1986, 1987).

The American alligator (*Alligator mississippiensis*) was first Federally-listed as endangered in 1967 because hunting and poaching had substantially reduced its numbers. It was reclassified as threatened in certain parts of Texas in 1977 because of partial recovery. In 1983, it was further reclassified in Texas as threatened due to similarity of appearance (T/SA) reflecting complete recovery of the species in the state. Thus, in Texas, the alligator is no longer biologically threatened or endangered, but because of the similarity of appearance of its hides and parts to those of protected crocodilians elsewhere, it is necessary to restrict commercial activities involving alligators taken in Texas to safeguard against excessive harvesting, and to ensure the conservation of other crocodilians that are still biologically threatened or endangered. The potential for this species to occur within the study area is low.

The Texas tortoise (*Gopherus berlandieri*) and Texas horned lizard (*Holbrookia lacerata*) are listed as threatened species by TPWD. Texas tortoise is confined to arid south Texas and northeastern Mexico. The Texas tortoise prefers sandy soils in areas of low, sparse vegetation (Garrett and Barker, 1987). If appropriate habitat is present then some potential for their occurrence exists within the study area. The Texas horned lizard was historically found throughout the state in areas with flat, open terrain, scattered vegetation, and sandy or loamy soils. Over the past 20 years, it has almost vanished from the eastern half of the state, but still maintains relatively stable numbers in west Texas. This species has been recorded from counties within the study area (Dixon, 1987) and may occur within the study area.

Three snakes that are listed as threatened by TPWD, but not by the FWS, and may potentially occur in the study area are scarlet snake (*Cemophora coccinea*), timber/canebrake rattlesnake (*Crotalus horridus*), and Texas indigo snake (*Drymarchon corais*) (Dixon, 1987; TXBCD, 1999). In addition, the Gulf salt marsh snake (*Nerodia clarkii*) is considered a SOC by the FWS (2000). The scarlet snake inhabits loose, sandy soil potentially associated with baygall thickets, live oaks scattered across sand dunes, watermelon patches, and dry, sandy land dominated by honey mesquite, huisache and prickly pear (*Opuntia* sp.) (Werler and Dixon, 2000; Tennant, 1984). The timber rattlesnake prefers moist lowland forests and hilly woodlands near rivers, streams, and lakes characterized by hollow logs and decaying tree stumps within the eastern third of Texas (Werler and Dixon, 2000). Potential for occurrence would likely be associated with brushy or woody lowland areas adjacent to the bay or Nueces River. The Texas indigo snake is most common in thorn brush woodland in riparian corridors and in mesquite savannah (Tennant, 1984). The Gulf salt marsh snake inhabits crayfish and fiddler crab burrows in the saltgrass-lined margins of tidal mud flats (Garrett and Barker, 1987). This species is shown to be outside of its range in Nueces County by Dixon (1987), yet the FWS (2000) indicates Nueces County to be within its range. Although there is potential for the scarlet snake to occur within the study area, this rare snake is unlikely to be found. Potential occurrence of the Texas indigo snake is low due to the lack of suitable habitat, except inland or on Padre Island. Habitat for the Gulf salt marsh snake is present in the study area, thus there is potential for its occurrence.

The Texas diamondback terrapin (*Malaclemys terrapin littoralis*) is identified as a SOC by the FWS (2000) in Nueces County. This species occurs from the Texas-Louisiana border south to Nueces County (Dixon, 1987). The Texas diamondback terrapin is the only turtle in the world entirely restricted to estuarine habitat, where it lives in coastal marshes, tidal mudflats, and tidal creeks (Garrett and Barker, 1987). This species has been observed in the Upper Laguna Madre (EH&A, 1993) and may occur in the study area.

3.6.2.6 Insects

One insect species, the maculated manfreda skipper (*Stallingsia maculosus*), is a rare butterfly known from several south Texas counties and northern Mexico. The FWS (2000) identifies this species as a SOC in Nueces and Kleberg counties. The larvae of this species are closely associated with Texas tuberose (*Manfreda maculosus*) which grows on prairies and chaparral covered hills of the Rio Grande Valley and Plains (Tilden and Smith, 1986; Correll and Johnston, 1970). Its presence in the study area is unlikely.

3.7 HAZARDOUS, TOXIC, RADIOACTIVE WASTE

The purpose of the Hazardous, Toxic, Radioactive Waste (HTRW) assessment is to identify indicators of potential hazardous materials or waste issues relating to the study area. A review of a regulatory agency database information search, an aerial photographic review, interviews with regulatory officials, and a site reconnaissance were conducted to determine the location and status of sites regulated by the State of Texas and the EPA and any unreported hazardous material sites. The support data for the assessment can be found in PBS&J Document No. 010095 entitled "Hazardous, Toxic, and Radioactive Waste Assessment, Corpus Christi Ship Channel – Channel Improvements Project, Corpus Christi and Nueces Bays, Nueces and San Patricio Counties, Texas" dated April 2001. A review of oil and gas wells and pipelines located within the study area was also conducted.

The review of the regulatory agency database search indicated a total of 1,611 sites or listings associated with 257 facilities or properties located within the study area. Several of these listings were associated with the same facilities or property (e.g., a facility/property containing multiple petroleum storage tanks and is the site of several reported spills or emergency response actions). On the basis of the results of the regulatory database searches, the following sites are located within the subject area:

- 16 CERCLIS/NFRAP/CORRACT sites;
- 27 RCRA generators sites;
- 5 RCRA treatment, storage, and disposal sites;
- 296 petroleum storage tanks;
- 55 leaking underground storage tank sites;
- 2 State voluntary cleanup sites;
- 528 reported emergency response actions at 60 facilities/properties;
- 323 reported spills at 58 facilities/properties;
- 7 NPDES sites;
- 152 TRI listings associated with one facility; and
- 200 FINDS listings associated with 69 facilities/properties.

No National Priority List, State Superfund or City/County solid waste landfill sites were located within the study area.

Examination of the aerial photographic coverage indicated that the study area includes a variety of land uses which include highly developed residential-urban, heavy industrial, government land, recreational, range-pasture, and saline and brackish-water marsh. Generally, the land immediately adjacent to the southern shore of Corpus Christi and Nueces Bays is highly developed, while the land immediately adjacent to northern shore is moderately developed to undeveloped. Mustang Island is sparsely developed.

The urban areas of the cities of Corpus Christi (including Flour Bluff), Port Aransas, Aransas Pass, Ingleside, and Portland include residential, commercial, governmental, and some industrial development. The Inner Harbor, which is identified as the land-locked segment of the CCSC, is a highly developed industrial area. Similarly, the northern shore of Corpus Christi Bay includes industrial development and a U.S. Department of Defense (DoD) facility.

According to TNRCC regional officials, the industrial activity adjacent to the Inner Harbor of the CCSC and La Quinta Channel has caused measurable impacts to the groundwater adjacent to the waterways. The seepage of contaminated groundwater to the waterway has been nearly contained through the efforts of the TNRCC and the responsible parties. Historically, the groundwater seepage to the Inner Harbor is reported to occur adjacent to Elementis Chrome and involves hydrocarbon from an upgradient petroleum refinery and chrome from the Elementis facility. The release of hydrocarbon contaminated groundwater has been under control since mid-2000, while some contaminated groundwater containing chromium has likely seeped into the surface water in the channel within the last year. Groundwater seepage to La Quinta Channel is reported by the TNRCC to occur adjacent to the DuPont Corpus Christi Plant. A total of five contaminate plumes are documented to exist at the facility. According to a DuPont Baseline Risk Assessment Report (March 7, 1997), which presents results from groundwater modeling and a risk assessment, contaminants are discharging to Corpus Christi Bay. The TNRCC approved a Response Action Plan for one of the areas of concern (Bulk Storage and Rail Loading Area) in January 2000. The constituents of concern are carbon tetrachloride and perchloroethane (PCE).

The results of the oil/gas well review indicate a total of 1,568 permitted well sites located within the study area. These well sites include 1,368 vertical wells and 200 directional wells. The database indicates that the vertical well sites include the following types/status:

- 378 are listed as active producing oil/gas wells;
- 573 as plugged;
- 291 as dry holes;
- 75 as permitted locations;
- 41 as abandoned locations;
- 5 as injection wells; and
- 5 well sites as unknown.

The database indicates that the directional well sites include the following types/status:

- 67 active producing oil/gas wells;
- 56 plugged wells;
- 40 dry holes;
- 20 permitted well sites;
- 10 abandoned locations;
- 3 shut-in wells;
- 1 injection well; and
- 3 well sites were listed as the type/status of unknown.

A total of 473 pipelines/pipeline segments were identified within the study area. Two hundred sixty-six of the pipelines are listed as active, 193 are listed as inactive, and the status of 14 pipelines was unknown. The pipelines are reported to transport the following material:

- 199 transport natural gas;
- 93 crude oil;
- 91 oil and gas;
- 25 gasoline;
- 12 gas and condensate;
- 7 condensate;
- 10 propane/propylene;
- 6 ethane/ethylene;

- 22 miscellaneous gases and products; and
- 8 were listed as idle.

Based on the findings of the HTRW survey, there is moderate potential of encountering contaminated material during construction of the project. According to TNRCC regional officials, the industrial activity adjacent to the Inner Harbor of the CCSC and the turning basin of La Quinta Channel has caused measurable impacts to the groundwater adjacent to the waterways. The seepage of contaminated groundwater to these waterways has resulted in the potential of impacting channel sediments (refer to Section 3.3 for sediment quality). However, all material from the Inner Harbor will be placed in confined upland areas and the only project activity for the La Quinta Channel is extension beyond the turning basin.

The TNRCC reported a contaminate plume containing hydrocarbons and chromium seeping into the Inner Harbor adjacent to the Elementis Chrome facility. According to analytical results of sediment samples collected from the channel in 1983, 1988, 1991, 1994, 1997, and 2000, chromium was found above detection limits, but well below the ERL, at all sampling stations for each year. Hydrocarbons were not detected in the samples until the 2000 sampling event. The TNRCC reports that the release of hydrocarbon-contaminated groundwater to the waterway has been significantly reduced or eliminated since mid-2000.

The TNRCC also reported a contaminate plume containing carbon tetrachloride and perchloroethane seeping into the La Quinta Channel turning basin adjacent to the DuPont Corpus Christi Plant. Previous analytical testing of water and sediment samples included basic and supplemental parameters but did not include these two constituents of concern.

In addition, with the laws and regulations which govern the handling of hazardous material, there is a decreased risk of future releases of hazardous material causing long-term detrimental impacts to the sediments of the study area. However, any activity regarding releases of hazardous material into the waters of the study area and the resulting remediation should be monitored through the regulatory agencies.

3.8 HISTORIC RESOURCES

The Corpus Christi study area is located in the Southern Coastal Corridor (SCC) Archeological Region of the Central and Southern Planning Region of Texas as delineated by the Texas Historical Commission (Mercado-Allinger and Ricklis, 1996). This Archeological Region encompasses the Coastal Bend from the Colorado River in Matagorda County south to the Rio Grande (Bailey, 1987; Ricklis, 1990). The study area is confined to the Corpus Christi and Nueces bays in San Patricio and Nueces counties.

The SCC Archeological Region contains five subareas, each possessing unique geographic and cultural features. The current study area in Corpus Christi Bay is in the Aransas/Guadalupe subarea with a small portion in Nueces County being included in the Baffin/Oso subarea. In these subareas the primary resource zones are the coastal estuaries and terrestrial flood plains with adjacent prairies.

3.8.1 Cultural History Overview

Archaeological evidence supports the continued presence of indigenous groups in the SCC Archeological Region from at least 10,000 B.C. through the time of European contact and colonization (Mercado-Allinger and Ricklis, 1996). The generally accepted cultural history of the area is divided into four periods, the Paleoindian, Archaic, Late Prehistoric, and Historic. Each of these periods is briefly summarized below.

3.8.1.1 Paleoindian Period

The Paleoindian period in the SCC Archeological Region is the earliest recognized cultural period, dating from at least 10,000 B.C. to circa 6,000 B.C. Little is known about this initial adaptation of the region, but researchers have suggested that this period was marked by a very low population density, small band sizes, and extremely large territorial range (Black, 1989). Material indications of the Paleoindian period include projectile point types such as *Clovis*, *Folsom*, *Scottsbluff*, and *Angostura*. Many of the Paleoindian diagnostic materials are surface finds although some have been from subsurface contexts. In Nueces County the presence of early materials along Oso and Petronila creeks demonstrates that assemblages dating to Paleoindian times occur in this region (Shafer and Bond, 1983). A site in Nueces County with a possible Paleoindian component is 41NU246, the Petronila Creek Site. This site is not located within the Corpus Christi study area.

3.8.1.2 Archaic Period

The Archaic period (approximately 6000 B.C. to A.D. 1200) is identified during the early and middle Holocene by intensive human utilization of a wide variety of ecological niches including the coastal zone. The tripartite division of the Archaic is the Early (6000 B.C. to 2500 B.C.), Middle (2500 to 1000), and Late (1000 B.C. to 1000 A.D.) subperiods. The Early Archaic is the least well understood, but represents a period of transition beyond the Paleoindian period. Some characteristics of the earlier period are still present, such as careful chipping of stone tools and occupation of older sites, yet distinctive artifact styles are found. Large triangular points, corner notched points, stemmed points (*Gower*) and large-barbed points (*Bell*) begin to appear. Population density remains low during this time and large territorial ranges are still utilized (Black, 1989). Sites dating to this subperiod occur in the SCC Archeological Region. Sites with identified Early Archaic deposits in Nueces County include 41NU124, the Means Site (Fox and Hester, 1976) and sites at White's Point on Nueces Bay (Ricklis, 1993).

During the Middle Archaic subperiod exploitation of marine resources appears to have accelerated. This may be evidenced by the thicker shell strata evident in shell middens as well as the more abundant fish remains. The presence of central Texas related groups in the study area during the Middle Archaic and later periods is more conclusively indicated. Clear Fork Phase, *Nolan* and *Travis* type dart points, dated to the beginning of the Middle Archaic period (Prewitt, 1981) occur at three sites, 41KL5, 41KL8, and 41KL9 (Campbell, 1964). Single specimens of later Middle Archaic *Lange* points (Prewitt, 1981) were collected from site 41KL3 (Campbell, 1964).

During the Late Archaic the sea level stabilized at its modern position and remains from this period are abundant and varied. Sites dating to the Late Archaic in the SCC Archeological Region are shell middens with thick deposits that yield a greater range and quantity of artifacts than do the shell middens dating to the Early Archaic. All of this suggests more frequent and/or intensive occupations than previously, and perhaps a higher regional population density (Ricklis, 1995). Settlement during this time is also characterized by summer occupations in the interior portions of the study area resulting in open lithic scatters. Numerous cemeteries have been identified in the SCC Archeological Region dating to the Late Archaic and Late Archaic/Late Prehistoric associations.

3.8.1.3 Late Prehistoric Period

The Late Prehistoric Period is represented by the Rockport phase in the SCC Archeological Region. With the advent of the bow and arrow and ceramic vessels, the Rockport focus replaces the Aransas focus. The later phase is characterized by the exploitation of larger game and an intensified exploitation of fish (Campbell, 1964). Settlement and subsistence patterns during the Rockport phase involved, to some significant degree, shifting seasonal emphases, with occupation of shoreline fishing camps during the fall through winter-early spring, and later spring through summer residences at hunting camps commonly located along the upland margins of stream valleys (Ricklis, 1995). Both shell middens and lithic sites of this phase tend to be stratified, indicating seasonally inhabited sites. This is probably a result of food resources along the coast and on the barrier islands being more seasonally specific (Thomas and Weed, 1980a).

Artifacts representative of the Rockport phase include, *Perdiz* projectile points as well as *Fresno*, *Young*, *Cliffton*, *Scallorn*, and *Starr* types and *Rockport* ceramic wares (Campbell, 1956). In terms of resource exploitation and cultural assemblages, the pattern for this phase tentatively established a link between the Rockport phase sites and the Karankawas, a historically known coastal group of Coahuiltecan speaking indigenous people (Thomas and Weed, 1980a). The Rockport phase dates from about A.D. 100 until the extinction of the Karankawas in the mid-nineteenth century (Newcomb, 1993). Most of the prehistoric sites thus far investigated in depth in the area are interpreted as reflecting a littoral adaptation with a secondary dependence on inland prairie resources (Prewitt, 1984). Historically, the Karankawa are reported to have camped on shell middens located near sources of fresh water whenever possible. Artifacts associated with Rockport phase sites include shell containers, jewelry, shell working-tools, asphaltum, burned clay nodules, sandstone shaft straighteners, and decorated ceramics including polychrome (Calhoun, 1964), asphaltum-painted black on gray (Fitzpatrick et al., 1964) and scallop-shell scored (Calhoun, 1964).

Late Prehistoric cemeteries and burials are relatively common along the Texas coast and are often found in clay dunes (Headrick, 1993). One coastal cemetery is documented for the Oso Creek/Oso Bay area in Nueces County. According to Hester (1980) the Texas coast encompasses the largest number of prehistoric cemeteries in the region. One of these cemetery sites 41NU2 (Calle del Oso) is one of the largest known. At one time it may have contained as many as 600 burials. Unfortunately, this site has been largely destroyed by development and adequate studies were never conducted at the site. It is believed that site 41NU2 may have also been in use during the Late Archaic period. Another cemetery located in Nueces County is the Berryman Site (41NU173) (Hall, 1987).

3.8.1.4 Historic Period

The post-contact historic period for the Texas coast and south Texas effectively begins with the explorations of the Gulf of Mexico by Spanish explorers seeking to locate new land and economic resources for the Spanish royal crown in Madrid. The first European explorer known to have visited the area of Corpus Christi and Nueces bays was Alonso Alvarez de Piñeda in 1519. Piñeda explored and mapped the Gulf Coast from Apalachicola to the Yucatan and became the first European to sail through Aransas Pass into a shallow body of water he named Corpus Christi Bay. Following Alonzo Piñeda's initial mapping of the Gulf of Mexico and Corpus Christi Bay in 1519, Cabeza de Vaca traversed the area in the 1520s (Webb, 1952).

Two historic Indian groups inhabited the Texas coastal area at that time: the Coahuiltecan and the Karankawas. These nomadic hunters and gatherers were decimated by European diseases and by encroachment of the Spaniards from the south and the Apaches and Comanches from the north, as well as by the Anglo-Americans from the east. By 1850 neither the Coahuiltecans nor the Karankawas occupied the coastal area (Campbell, 1956).

Coahuiltecans

The Coahuiltecans settled primarily on the mainland and only after contact with the Spaniards did they venture out onto some of the islands (Thomas and Weed, 1980a). Some of the Coahuiltecan bands were the Orejon, west of Corpus Christi Bay; the Malaquite, along the coast from Corpus Christi Bay to Baffin Bay; and the Borrado, in the area from Baffin Bay to the Rio Grande (Scurlock, et al., 1974). Each band occupied a territory that included both inland and coastal areas at either end of their yearly-round. Population was estimated to be about 15,000 individuals with about 220 bands identified in 1690; however, by 1870 only remnants of the population remained (Thomas and Weed, 1980a). The influence of the Coahuiltecans on Padre Island was primarily from their trade with the Karankawa. The Coahuiltecan worked extensively with basketry, which they traded with the Karankawa, and worked to a lesser degree with ceramics.

As mentioned above the Coahultecans were not, nor are they today, one group of people, rather they were a conglomerate of different bands probably joined by the Coahuilteco language. Currently there are groups from the coastal plains of northeastern Mexico and adjacent southern Texas that have organized into the Coahuiltecan Nation (Gardner, 2001). Even though they are not an Indian tribe *per se*, on December 2, 1997 the Coahuiltecan Nation submitted a Letter of Intent to Petition for Federal recognition to the Bureau of Indian Affairs. However, as of now, they are not a Federally recognized Indian tribe (Gardner, 2001).

Karankawas

The Karankawa, unlike the Coahuiltecan, occupied the coastline and barrier islands from Trinity to Aransas bays (Thomas and Weed, 1980a). Five major groups were historically documented and included the Capoques and Hans to the north; the Kohanis around the mouth of the Colorado; the Karenkake, Clamcoets, and Carancaquacas on Matagorda Bay and Matagorda Island; and the Kopanos, along Copano Bay and St. Joseph's Island (Scurlock et al., 1974). According to early European accounts, the Karankawa subsisted primarily on oysters, clams, scallops, other mollusks, turtles, various fish species, porpoises, and several marine plant species (Thomas and Weed, 1980a). Other ethnographic and archaeological evidence supports the contention that historic Karankawas resided during the fall and winter in large shoreline camps of 400-500 people, during the spring and summer they camped along stream courses in bands averaging about 55 individuals (Ricklis, 1992). Karankawa sites were generally located in sheltered bays or on the leeward side of stabilized dunes on the Laguna Madre side of Padre Island (Thomas and Weed, 1980a).

Like the Coahuiltecans, cultural material of the Karankawa was sparse. Huts were constructed of willow branches covered with brush, with hearths in the center of each hut. They did, however, have several varieties of ceramics used for cooking and eating. These were decorated and sometimes coated with asphaltum. The ceramics were globular in shape, reminiscent of Rockport phase types (Thomas and Weed, 1980a).

By the 1700s, the indigenous populations were being affected by Spanish missions and presidios such as the Goliad missions of Espiritu Santo and Rosario, as well as by raiding Lipan Apaches and other central and southwestern groups (Mounger, 1959; Headrick, 1993). Due to the ill treatment the indigenous populations received from the Spanish, especially the Spanish military, prior friendly relations became increasing hostile (Newcomb, 1993). By the early-nineteenth century the increase in Anglo and Mexican ranchers and the establishment of coastal ports and towns left the indigenous populations without access to the coastal resources needed for subsistence. By the early 1840s, most remaining members of the Karankawa tribe had migrated to Mexico. After this time the Karankawa either dispersed or assimilated into other groups. Currently the Karankawa are not a Federally recognized tribe nor is there an extant Karankawa tribe (Gardner, 2001).

European Settlement

Little exploration or settlement took place in the Corpus Christi Bay region during the first two centuries following Piñeda's discovery of the bay in 1519. The Spanish government only regained interest in colonizing this region after the French explorer Réne Robert Cavelier, Sieur de La Salle claimed land in the Northern Gulf of Mexico for France in 1685. La Salle mistakenly entered Matagorda Bay while searching for the entrance to the Mississippi River. His expedition established the settlement of Fort St. Louis there on Garcitas Creek, some 50 miles north of Aransas Bay (Weddle, 1991). This colonization attempt failed, and most of the colonists perished, but the significance of its attempt spurred the Spanish to action. Wanting to protect their interests in Texas and their silver mines in Northern Mexico, Spain sent Alonso de León to reconnoiter the French fort and report back his findings. De León made several attempts and in 1688, he reported to the Spanish government that the threat from La Salle was over and that the fort had been destroyed (Weddle, 1991).

Hostilities between the French and Spanish over what was to become Texas continued into the eighteenth century. In 1720, France sent Jean Béranger to explore and map the Gulf Coast. He visited Aransas Bay and described the local inhabitants and their environment in detail. This expedition and that of La Salle, forced Spain to realize a more aggressive approach had to be taken in regards to Texas. In response to this conclusion, by 1726, Spanish missions or presidios had been established from

East Texas near the French post of Natchitoches on the Red River to Matagorda Bay and the Guadalupe River. This arrangement of presidios and missions provided Spain with a continuous system of communication across Texas and helped curb the immigration of Anglo-American settlers.

Spain's ability to control Texas began to deteriorate when Mexico waged war for independence. Over the next 10 years (1811-1821), resources were pulled away from the Texas frontier and an influx of Anglo-American immigrants came to Texas. This immigration was illegal until 1823, when the newly formed Mexican government passed the Imperial Colonization Law. The law invited individuals of Roman Catholic faith to settle in Mexico including Texas (Freeman, 1990). In addition, Mexico granted large tracts of land to immigration agents, called empresarios, who were given the authority to parcel out the land to settling families. Stephen F. Austin became the first empresario in Texas and was granted permission to search for land to colonize. Austin traveled the entire coastline of Texas, including the region of Corpus Christi Bay before he settled on the land between the Lavaca and Brazos rivers. Further development came in 1824 when the Mexican Congress incorporated all of Texas into a new state, Coahuila y Tejas, with its capital at Saltillo. At that time, states within the Mexican interior were given the power to set up land grants for colonization. As a result, Coahuila y Tejas granted more than 2 dozen empresario contracts.

As the numbers of Anglo-American's increased due to immigration, the tension between the Mexican government and the new settlers increased. Prior to 1821, the majority of American settlers in Texas were not actively seeking independence. Most settlers sought more influence over local affairs and greater control over their economy. Mexico, hoping to halt further American incursions into the region, enacted a law on April 6, 1830, supporting further military occupation of Texas, and increased colonization by Mexicans and Europeans. Mexico also insisted on increased trade between Texas and Mexico. The American settlers resented this action and in response, organized the Conventions of 1832 and 1833 to voice their complaints about the Mexican Government and to draft a constitution for Texas. As a result of the growing unrest by the American settlers, the Mexican Government sent General Juan N. Almonte to Texas on a tour of inspection in 1834. Almonte's recommendations were delivered to the Government but were never carried out (Guthrie, 1988). At this same time, the Mexican government placed the schooner *Santa Pia* in Copano Bay, hoping to help control spreading Anglo influence in Texas. None of these actions improved conditions and in 1835 armed rebellion broke out. As the war concluded with an independent Texas, settlement and economic growth of the area resumed.

Henry Kinney and his partner William P. Aubrey established Corpus Christi as a trading post in 1839. With more settlers coming to the region, overland trade developed between their post and Mexico and other inland posts (Pearson and James, 1997). As a maritime port however, Corpus Christi was slow to develop. With the shallowness of the bay and the numerous obstacles hampering navigation, only shallow draft vessels could service the town. Even with the development of overland trade, it was not until General Zachary Taylor stationed 4,000 troops at the post in 1845 during the Mexican American War that Corpus Christi began to flourish (Guthrie, 1988). With the conclusion of the war, the town was deserted almost overnight when Taylor's troops left. This soon changed as the California Gold Rush brought gold-seekers to Corpus Christi to purchase supplies and transportation west (Pearson and Simmons, 1995).

During the Civil War the area became an important center for Confederate commerce. According to Tyler (1996) not less than forty-five small vessels carried trade between Corpus Christi and Indianola. Small boats sailing inside the barrier islands transported goods from the Brazos River to the Rio Grande, while inland cotton was moved along the Cotton Road through Banquete to Matamoros and on to the mills in England. In an effort to halt the trade, Union forces seized control of Mustang Island in the fall of 1863, and twice Federal gunboats bombarded Corpus Christi and disrupted water transportation. The overland trade, however, continued without interruption until the end of the war.

After the Civil War, ranching developments characterized the area's economy. The expanding cattle industry came to dominate maritime commerce in the bays. With the growth of the packing industry, stockyards and packeries sprang up around Corpus Christi and other small settlements along the coast. These developments stimulated the growth of the area and increased the need for shipping to transport cattle out of the region and supplies back to the local populations. The use of Aransas Pass increased significantly, corresponding to the growth in these stockyards and packeries.

In the years 1871-1875, 171 ships made a total of 1452 crossings through Aransas Pass (Kuehne, 1973). During this period, the Morgan Line steamer *Mary* made 120 appearances, more than any other ship (Hoyt, 1990). By the late 1870s, when the cattle industry again started transporting their herds overland, cotton began to replace the tonnage lost from the cattle industry. By 1882, 364 bales were transported and it was predicted that in the near future, thousands of bales would be shipped yearly (USACE, 1882).

CATTLE EXPORTS FROM CORPUS CHRISTI BAY

Year	No. of Head Exported
1873	23,000
1874	26,000
1875	21,600
1876	18,300
1877	15,700
1878	One load
1879	None

Source: Hoyt, 1990.

History of Waterway Improvements in Corpus Christi Bay

Aransas Pass has remained the main entrance into Corpus Christi Bay since early historic times. Its dynamic nature, harsh environment and lack of deepwater channels has been a hindrance to traffic in and out of the bay throughout its development. The first navigation improvement in the bay system was a lighthouse that was erected on Harbor Island in Aransas Pass in 1856. This improvement quickly became immaterial as the unstable and shifting nature of the pass soon placed the lighthouse too far north to be effective. It was because of this migration that one of the primary local navigation goals became stabilizing Aransas Pass (Pearson and Simmons, 1995).

Realizing the need to have a secure entrance into Corpus Christi Bay, a 600-foot-long wooden dike on St. Joseph's Island in 1868 was constructed. This project was an attempt to halt the migration and shoaling of the pass. The dike reportedly opened a 12-foot channel for several months. It was destroyed soon after, possibly by wood boring worms (mainly *Teredo navalis* [shipworm]) and wave action, and the pass shoaled back to 7.5 feet (Hoyt, 1990).

The shoaling of Aransas Pass became a serious problem for Corpus Christi Bay commerce by the late 1870s. Steamships could no longer enter the bay and after 1878, the majority of commercial products were sent via lighter to Indianola for long distance shipment (USACE, 1880 reported in Hoyt, 1990). It was obvious that the citizens around Corpus Christi Bay and their economic survival depended on a means to have a permanent entrance into the bay, and Aransas Pass was the only option.

In 1874, the Corpus Christi Navigation Company and Messrs. Morris and Cummings dredged the first deep-water channel into Corpus Christi Bay. This channel, known as the Morris and Cummings Cut, ran along the inshore side of Harbor Island and connected with Aransas Pass through the Lydia Ann Channel that lay between Harbor Island and St. Joseph's Island. The channel was approximately 8 feet deep, 100 feet wide and 6 miles long (Alperin, 1977; James and Pearson, 1991). It was later abandoned with the development of the Corpus Christi Channel (USACE, 1910:552).

While Galveston was initially chosen as the best location along the Texas coast for a deepwater port, several towns in the Corpus Christi Bay area were vying for government approval to be designated the main U.S. port in south Texas. The local inhabitants realized that without a continuous, direct deep-water route to its port facilities, in addition to a stable entrance into the bay, Corpus Christi Bay would not be able to compete. In response to this need, the Turtle Cove Channel Project was adopted in 1907 with the intention of dredging a channel 10 feet deep and 100 feet wide into Corpus Christi Bay. By 1910, the cut had been expanded to a depth of 12 feet. The channel, also known as the Corpus Christi Channel, extended 21 miles to Corpus Christi in 1926, of which only 12 miles between Port Aransas and McGloins Bluff required dredging.

With the completion of this channel, Corpus Christi had fulfilled its need for a deep-water route to its harbor, and thus could lead the economic development of the area. The Port of Corpus Christi was officially opened September 14, 1926, and chosen as the principle port in south Texas. At that time, a 25- by 200-foot channel extended across Corpus Christi Bay to Corpus Christi. The Corpus Christi Ship Channel was again closed for improvement in 1932 with the realization that an increase in vessel sizes led to an increase in vessel groundings. With the coming of larger ships with deeper drafts, the depth of the channel had to be increased to accommodate their size. A proposal to enlarge the channel to 37 feet deep and 400 feet wide was soon adopted (James and Pearson, 1991; Schmidt and Hoyt, 1995).

Another attempt at improving the navigation into Corpus Christi Bay is historically under documented. Packery Channel extended northward from its Gulf outlet, along the west edge of Mustang Island, passing to the east of the Crane Islands before entering the Bay. Historic documentation is made more difficult because Packery Channel, currently one of three passes in the area, was originally referenced and documented on early maps as Corpus Christi Pass (Board of Engineers 1846; U.S. Coast Survey 1869).

During the nineteenth century, there was no channel outlet into the Laguna Madre, and much of the area between north Mustang Island and Flour Bluff is depicted on 1887 Coast Chart No. 210 as "...flats with less than 6 inches of water." Early maps and navigation charts list a maximum depth at both the Gulf and Corpus Christi Bay outlets of Packery Channel as no more than 2 to 3 feet. C.W. Howell, in an 1879 USACE annual report on a survey of the pass noted that "A man of ordinary stature can wade it now at several points" (1879:930). A notation on one of the USACE maps by Assistant Engineer H.C. Collins (Collins et al. 1878) states that water at the Gulf entrance did not exceed 2 feet in depth and was breaking across the bar. Collins' description of the survey states that their schooner could not enter the pass, and that a "yawl-boat" drawing only 1.5 feet was necessary to sail as close to shore as possible to take soundings.

At the time of Howell's survey and report Packery Channel was apparently little used, and he proposed constructing a dam to further restrict its flow (1879:930). The proposed dam was to be of stone construction approximately 1,900 feet in length, with the crest of the dam being no higher than the plane of mean low tide. Howell proposed that the dam would enable the pass to continue to act as a safety valve for major storm surges while at the same time increasing the tidal flows at the more important Aransas Pass. Howell also thought that the dam would improve the channel connecting Corpus Christi Bay and Laguna Madre to the south, noting that the latter bay was important because the beef packers along that portion of the coast required its salt production.

Although the USACE had concluded that the maintenance of Packery Channel was not a viable option, promoter and land developer Colonel E.H. Ropes was not dissuaded. In 1890 Ropes commissioned the steam powered "dipper dredge" *Josephine* to establish a cut through Padre Island at Packery Channel. While Ropes succeeded in cutting through the island the cut quickly filled. His dredge was unable to extricate itself and had to be abandoned (Alexander et al. 1950).

The role of Packery Channel in navigation to Corpus Christi Bay was seriously reduced by its tendency to shoal and by the economic interests in the last half of the nineteenth century, which favored the development of Aransas Pass for a shipping outlet. There are several reports of beef products being shipped outbound from Packery Channel to overseas destinations (Alexander et al. 1950:168) although some references suggest that the shallow pass required the use of lighter vessels to make the seaward connection. In one instance shallow-draft vessels were reported to be carrying packery products north through Corpus Christi Bay rather than seaward through Packery Channel.

Other improvements in the bay area included a channel through Harbor Island 25 feet deep and 250 feet wide to connect the town of Aransas to Aransas Pass in 1922 (USACE, 1922). Later, in the mid-1900s, the USACE was requested to dredge a channel through Ingleside Cove along the western side of McGloin's Bluff. This channel, known as the La Quinta Channel, was necessary for the development of the Reynolds Metal Company located northeast of McGloins Bluff. Bauxite ore would be brought from Jamaica to be processed at the plant. The Reynolds Metal Company requested that the

USACE dredge a 32-foot channel to its aluminum plant wharf at La Quinta in order for vessels to load and unload cargoes. Work began in 1954 on the 6-mile-long, 150-foot-wide La Quinta Channel. It was completed at 36 feet deep and 200 feet wide in 1958 (Alperin, 1977).

Potential Shipwrecks in the Project Vicinity

There have been a number of ships wrecked in Corpus Christi Bay and Aransas Pass during the historic period. Vessel losses, documented in numerous historic sources, have been summarized in several archaeological reports, among them Hoyt (1990), James and Pearson (1991), Schmidt and Hoyt (1995), Pearson and Wells (1995), Pearson and Simmons (1995), and Pearson and James (1997). Seventy-six shipwrecks are listed in those combined publications. Most of those wrecks are listed in the THC's shipwreck database. The THC gleaned information about those wrecks from a number of sources. James and Pearson (1991) added wrecks to the THC's list from government sources, including the U.S. Life-Saving Service, the U.S. Army Corps of Engineers and the U.S. Coast Guard. Other wrecks, especially more recent ones, are known from sources such as the Automated Wreck and Obstruction Information System (AWOIS) maintained by the National Atmospheric and Oceanic Administration. The AWOIS database contains information about wrecks and obstructions that appear on modern navigation charts. A combined list of shipwrecks from Pearson and Simmons (1995) and Pearson and James (1997) is reproduced below as Table 3.8-1.

The majority of wrecks are known to have occurred in the vicinity of Aransas Pass (the bay entrance, not the town), owing to the concentration of vessel traffic there combined with the hazards of shifting sandbars prior to construction of the jetties. At least 48 vessels wrecked in this vicinity. Another 28 wrecks are known from within Corpus Christi Bay, including Nueces Bay and adjacent portions of Laguna Madre. Vessel names are known for only 46 of the total 76 shipwrecks. These shipwrecks range in age from 1830 to 1981. At least 39 wrecks occurred prior to 1952. Vessels wrecked earlier than 1952 are at least 50 years old, thus meet the suggested age criterion for NRHP eligibility. Some vessels which wrecked within the past 50 years are, no doubt, older than 50 years, thus vessels should not be automatically disregarded based upon the year in which they were wrecked.

The number of shipwrecks that have been archaeologically documented in the vicinity of impact areas is significantly smaller than the total number of wrecks listed in the historic record. Only four shipwrecks have been confirmed in the vicinity of project impacts. This number includes the S.S. *Mary* (41NU252) (Hoyt, 1990; Pearson and Simmons, 1995) located on the southern channel margin between the jetties at Aransas Pass, an unidentified wreck (41NU264) located just south of the channel near the seaward end of the southern jetty (formerly identified as the *Utina* in both Pearson and Simmons, 1995 and Schmidt and Hoyt, 1995), a wreck believed to be the *Utina* (designated as Anomaly M39 until a trinomial site number is assigned) which lies against the submerged seaward end of the south jetty, and an unidentified wreck (designated as Anomaly M39 until a trinomial site number is assigned) located slightly south of the Corpus Christi Ship Channel opposite McGloin's Bluff. The latter wreck, discovered by PBS&J during the summer of 2001, may be the remains of the steamboat *Dayton* whose boiler exploded within a quarter mile of McGloin's Bluff in 1845 (Enright, et al., in preparation). Three other vessels, which may have a higher than average chance of occurring near project impact areas, include the small Confederate boats *Elma, A. Bee* and *Hanna.* These vessels reportedly were scuttled in Corpus

TABLE 3.8-1

LIST OF VESSELS REPORTED LOST
IN THE PROJECT STUDY AREA

Name of Vessel	THC Number	Vessel Type	Year Lost	Location
Vessels Lost in the Vicinity of Aransas Pass				
Unknown	113	Unknown	1830	Aransas Pass Vicinity
Cardena	115	Sail	1834	Aransas Pass Vicinity
Unknown	1678	Schooner	1834	Aransas Pass Vicinity
Wildcat	114	Unknown	1834	Aransas Pass Vicinity
Colonel Yell	192	Sidewheeler	1847	Aransas Pass Vicinity
Umpire	512	Sailing/ Steam	1852	Aransas Pass Vicinity
Unknown	1056	Unknown	1853	Aransas Pass Vicinity
Mary Agnes	655	Schooner	1862	Aransas Pass Vicinity
William Bagley	1045	Sidewheeler	1863	Aransas Pass Vicinity
Louisa	659	Schooner	1865	Aransas Pass Vicinity
L'éclair	1272	Schooner	1866	Aransas Pass Vicinity
Philadelphia	423	Sailing/ Steam	1868	Aransas Pass Vicinity
Mattie	653	Sailing	1873	Aransas Pass Vicinity
Mary	51	Sidewheeler	1876	Aransas Pass Vicinity
St. Mary	1004	Sailing/ Steam	1876	Aransas Pass Vicinity
Ramyrez	1049	Sail	1882	Aransas Pass Vicinity
Tex Mex	1412	Schooner	1882	Aransas Pass Vicinity
Two Marys	1411	Schooner	1882	Aransas Pass Vicinity
O. Jennings Gill	1386	Schooner	1887	Aransas Pass Vicinity
Henrietta	5	Schooner	1888	Aransas Pass Vicinity
Mystery	623	Sail	1899	Aransas Pass Vicinity
Mary Lorena	None	Schooner	1900	Aransas Pass Vicinity
Ellen	None	Schooner	1902	Aransas Pass Vicinity
Mary E. Lynch	None	Schooner	1902	Aransas Pass Vicinity
Silas	None	Schooner	1902	Aransas Pass Vicinity
Lake Austin	None	Schooner	1904	Aransas Pass Vicinity
Pilot Boy	None	Steamer	1916	Aransas Pass Vicinity
Utina	513	Steamer	1920	Aransas Pass Vicinity
Baddacock	None	Steam Tug	1920	Aransas Pass Vicinity
Unknown	1047	Unknown	1935	Aransas Pass Vicinity
Unknown	1048	Unknown	1935	Aransas Pass Vicinity
Coral Sands	197	Oil Steamer	1955	Aransas Pass Vicinity
Jiffie	None	Unknown	1955	Aransas Pass Vicinity
Princess Pat	None	Unknown	1958	Aransas Pass Vicinity
Cabezon	None	Unknown	1959	Aransas Pass Vicinity
Chuck A Dee II	175	Unknown	1963	Aransas Pass Vicinity
Liberia C	None	Unknown	1964	Aransas Pass Vicinity
Desco	214	Unknown	1966	Aransas Pass Vicinity
Unknown	1534	Unknown	1970	Aransas Pass Vicinity
Unknown	1535	Unknown	1970	Aransas Pass Vicinity
Unknown	1536	Unknown	1970	Aransas Pass Vicinity
Unknown	1537	Unknown	1970	Aransas Pass Vicinity
Jimbo	1031	Cabin Cruiser	1971	Aransas Pass Vicinity
De Rail	None	Cabin Cruiser	1972	Aransas Pass Vicinity
Unknown	1028	Unknown	1974	Aransas Pass Vicinity
Unknown	1019	Unknown	Unknown	Aransas Pass Vicinity
Jane and Julie	None	Fishing Vessel	1981	Aransas Pass Vicinity
Eagles Cliff	None	Cargo Ship	1981	Aransas Pass Vicinity

TABLE 3.8-1 (Concluded)

Name of Vessel	THC Number	Vessel Type	Year Lost	Location
Vessels Lost in the Corpus Christi Bay				
Dayton	208	Sidewheel Steamer	1845	McGloin's Bluff
Swallow	155	Unknown	1845	Nueces Bay
A. Bee	1797	Unknown	1862	Corpus Christi
Unknown	1787	Schooner	1862	Corpus Christi
Elma	1802	Schooner	1862	Corpus Christi
Hanna	637	Schooner	1862	Corpus Christi
Catha Minerva	1388	Schooner	1874	Corpus Christi
Captiva II	165	Lugger	1949	Nueces Bay
40 Fathom No. 12	256	Unknown	1955	Corpus Christi
Captain Steve	163	Unknown	1968	Laguna Madre
Unknown	1288	Unknown	1970	Corpus Christi
Unknown	1289	Unknown	1970	Corpus Christi
Unknown	1529	Unknown	1970	Corpus Christi
Unknown	1533	Unknown	1970	Laguna Madre
Unknown	1538	Unknown	1976	Corpus Christi
Unknown	1539	Unknown	1976	Corpus Christi
Unknown	1130	Unknown	1976	Laguna Madre
Unknown	1086	Unknown	1977	Corpus Christi
Unknown	1087	Unknown	1977	Corpus Christi
Unknown	1088	Unknown	1977	Corpus Christi
Unknown	1089	Unknown	1977	Corpus Christi
Unknown	1090	Unknown	1977	Laguna Madre
Unknown	1091	Unknown	1977	Corpus Christi
Unknown	1092	Unknown	1977	Corpus Christi
Unknown	1180	Unknown	1977	Corpus Christi
Unknown	1181	Unknown	1977	Corpus Christi
Unknown	1234	Unknown	1977	Corpus Christi
Unknown	1085	Unknown	1977	Laguna Madre

Source: Pearson and Simmons, 1995; Pearson and James, 1997.

Christi Bay to prevent their capture by Union forces. Their location is reported by Pearson and James (1997: 18) as either near the town of Corpus Christi or near the mouth of the Nueces River.

3.8.2 Previous Investigations

Some of the earliest archaeological investigations in this region were conducted in the 1920s. Syntheses of this work have been prepared by Suhm et al. (1954), Campbell (1958) and Briggs (1971). E.B. Sayles and two avocational archaeologists, George C. Martin and Wendell H. Potter, carried out some of this early work. They conducted an archaeological survey of much of the coastal zone north of Corpus Christi between 1927 and 1929 (Martin and Potter, n.d.; Sayles, 1953). In some instances, limited excavation was performed, but most of the materials were recovered from beaches and eroded bluffs. During the 1930s and 1940s, major archaeological excavations were conducted using Works Progress Administration assistance at the Johnson, Kent-Crane, and Live Oak Point sites on Live Oak Peninsula. These three shell midden sites were the first controlled excavations in the area. The Johnson and Kent-Crane sites were primarily associated with the Late Archaic subperiod.

Since the acquisition of the land by the National Park Service, two major archaeological investigations have been conducted within Padre Island National Seashore, as well as a number of more limited surveys related to proposed oil exploration and extraction activities. The first professional investigations on Padre Island were conducted by T.N. Campbell in 1963. Dr. Campbell relied on a number of avocational archaeologists during his reconnaissance survey of the then-proposed Padre Island National Seashore (Campbell, 1964). His survey areas were located between Corpus Christi Bay and a point about 15 miles north of Mansfield Pass. A total of 15 prehistoric and proto-historic sites were recorded, 12 of which were found within the proposed National Seashore boundaries. Three distinct clusters of sites were documented but were confined to the northern end of the island. The significance of this distribution, however, is uncertain because of erratic ground surface visibility and other problems in site identification.

From 1957 to 1963, Corbin (1963) conducted a number of surface surveys on the northern shore of Corpus Christi Bay that further defined the range of variability in Rockport ceramics. All of the sites recorded by Corbin (1963) were shell middens, except for one, the McGloin Bluff Site (41SP11). The McGloin Bluff Site is described in the site form as a large, open habitation site which yielded ceramics, lithic debitage and tools, and shell artifacts. The shell midden sites were all located along a narrow strip of land adjacent to the shoreline and were described as small, thin, and diffuse components probably due to short term occupation by small groups (Ricklis, 1999).

In 1968, Story excavated a midden at Ingleside Cove, north of Corpus Christi Bay in San Patricio County, that had been exposed by Hurricane Carla. This site exhibited several stratified Archaic and Late Prehistoric occupations with a subsistence base oriented heavily toward marine procurement. The Ingleside Cove Site provided an enormous amount of information regarding coastal adaptation and marine exploitation.

Limited archaeological investigations completed in the SCC Archeological Region include two cultural resource surveys located near the mouth of Baffin Bay. Both surveys were conducted by New

World Research (NWR) in 1980 (Thomas and Weed, 1980a, 1980b). Those surveys, combined, covered 5.5 miles of proposed pipeline easement. The survey corridor was examined at 66-foot intervals. The ground surface was generally visible, but grass was removed in an attempt to improve the visibility in heavily vegetated areas (Thomas and Weed, 1980a). In both surveys, systematic and intuitively placed auger holes were also excavated in an attempt to locate buried cultural materials. No evidence of either prehistoric or historic occupations was observed. In the following year, NWR also completed two surveys of proposed seismic lines opposite Port Mansfield (NWR, 1981a, 1981b).

The Center for Archeological Research (CAR) conducted surveys at three proposed well pad drilling sites (Gibson and Hester, 1982; Valdez 1982; Warren, 1985). Two of the drilling sites are within the Padre Island National Seashore near Yarborough Pass (Valdez, 1982; Warren, 1985) and the third is located in the vicinity of South Bird Island (Gibson and Hester, 1982). Investigations at all three of the drilling sites consisted of a surface examination only. No subsurface excavations were conducted. No cultural resources were observed at any of the well pad locations. Two alternative well pad locations within the National Seashore also were surveyed in 1984 by Prewitt & Associates, Inc. (Fields, 1984). The surface examination encountered areas of both poor and good visibility but found no evidence of either prehistoric or historic occupations. Two shallow trowel tests were dug at each pad location in order to document subsurface sediments.

Several major archaeological investigations have been conducted in the project vicinity. In 1977, the CAR conducted a survey of the Tule Lake Tract (Highley et al., 1977) for the USACE. Only one site, 41NU157, was located. That site was a large, heavily disturbed rangia midden with Rockport ceramics. In 1980, the Texas Department of Water Resources conducted a survey of the proposed Allison Wastewater Treatment Plant. Two large prehistoric sites, 41NU185 and 41NU186, were identified. Site 41NU185, a multi-component prehistoric midden, was subsequently tested by Texas A&M University (Carlson et al., 1982). In 1984, the USACE conducted a survey of two large proposed dredge disposal areas (Good, 1984). The survey resulted in the identification of one archaeological site, 41NU211, a large prehistoric occupation site.

In 1985 and 1986, Ricklis conducted excavations at the McKinzie Site (41NU221), a small multi-component occupation site in the Baffin/Oso subarea (Ricklis, 1986). Site 41NU221 is located on the edge of the uplands overlooking the floodplain of the Nueces River (Mercado-Allinger and Ricklis, 1996). The archaeological work conducted at the site identified two discrete prehistoric components, one Archaic and the other Late Prehistoric. Based on lithics and diagnostic ceramics the Late Prehistoric component has been assigned to the Rockport complex (Ricklis, 1988). The work at site 41NU221 yielded data that was incorporated into studies of seasonality and subsistence strategies.

Texas Parks and Wildlife has also completed an archaeological survey and history of Mustang Island in eastern Nueces County (Howard et al., 1997). The survey recorded two previously unknown sites, 41NU284 and 41NU285 and relocated previously recorded site 41NU224. All three sites contain prehistoric components, and two of the sites, 41NU224 and 41NU284, also contain late-nineteenth-century and early-twentieth-century components.

Cultural resource management surveys and testing programs have proliferated in the Baffin/Oso Subarea since the 1970s (Mercado-Allinger and Ricklis, 1996). This work has provided models of Late Prehistoric settlement and subsistence patterns, as well as native responses to Spanish colonization (Patterson and Ford, 1974; Carlson, 1983; Warren, 1987). Additionally, these investigations have also contributed to the enhancement of the Archaic chronology of the region (Ricklis and Cox, 1991; Ricklis, 1993, 1995). Three previous archaeological studies have been conducted in the vicinity of a new upland beneficial use area, BU Site E, proposed for use under the preferred alternative. Those studies include Corbin's (1963) investigations, a survey by McDonald and Dibble (1973) of a 2,300-acre tract for the Port of Corpus Christi Authority, and a recent survey and excavation conducted by Ricklis (1999). Ricklis' survey is particularly applicable to BU Site E. Ricklis' pedestrian survey of the La Quinta Terminal expansion area investigated 10 sites (41SP32-35, 41SP105-108, 41SP198 and 41SP199) all of which were recommended as ineligible for the NRHP. The THC concurred with that assessment. The Ricklis survey covered the entire area of BU Site E.

Several underwater archaeological investigations have been conducted in the Aransas Pass and Corpus Christi Bay areas, beginning in the late 1980s. Those studies incorporated historical research, remote-sensing surveys, diver evaluations, and data recovery. In 1989, Espey, Huston and Associates, Inc. (EH&A), now PBS&J, conducted a remote-sensing survey over an area within the Aransas Pass Channel to locate the remains of a sidewheel steamer *SS Mary* that sank in 1876 (Hoyt, 1990). Subsequent diving was conducted on the wreck to assess its condition and its possible eligibility for the National Register of Historic Places (NRHP). That work was performed as part of the Section 106 compliance process for the USACE, Galveston District (Hoyt, 1990). EH&A determined that the *Mary* was in poor condition. Nevertheless, the vessel was recommended as eligible for the NRHP based upon several factors, including its association with the Morgan Line, its long service as a typical coastal steamer of the period, and its construction by the innovative H&H Corporation (Hoyt, 1999). The THC concurred with their recommendation. The *Mary* is also eligible for designation as a SAL under the criteria specified in The Antiquities Code of Texas, Section 191.091.

In 1991 Coastal Environments Inc. (CEI) surveyed Aransas Pass and located seven magnetic anomalies (James and Pearson, 1991). Then in 1993, CEI conducted diver evaluations of those seven targets (Pearson and Simmons, 1995). The latter study included additional assessment of the *SS Mary*. During their survey and subsequent diver evaluations, CEI located the fragmentary remains of a vessel that was tentatively identified as the *Utina*, a ship built for the U.S. Emergency Fleet in World War I and wrecked on the south jetty at Port Aransas in 1920.

EH&A undertook further investigation of the same wreck in 1994 (Schmidt and Hoyt, 1995). Their investigations consisted of diving on the site in order to map and delineate the wreck's extent and prominent structures. That study suggested that the site was not archaeologically significant nor eligible for the NRHP because of its fragmentary condition and due to the fact that better preserved examples of the *Utina* vessel type exist elsewhere. Schmidt and Hoyt agreed with CEI's tentative identification of the site as the *Utina*, although they noted some inconsistency between the site and the physical description of the *Utina*. For example, there was no evidence of the heavy iron hull strapping known from historic documents to have been an integral part of the *Utina's* heavy construction.

A more likely candidate for the *Utina* was discovered inadvertently by PBS&J during the summer of 2000. A second wreck was discovered at the end of the south jetty while conducting a close-order magnetometer survey of the wreck CEI and EH&A had tentatively identified as the *Utina*. PBS&J designated that site, investigated by divers during the 1990s, as Anomaly M2. The latter wreck, first located by archaeologists in 2000, has been designated Anomaly M39. Dimensions of the side-scan sonar target associated with M39 closely match the size of the *Utina*. Furthermore, the *Utina* is known from historic documents, including photography, to have stranded on the Gulf end of the south jetty (Schmidt and Hoyt, 1995), precisely where M39 is located. Anomaly M2, on the other hand, is located in deep water between the jetties on the southern margin of the ship channel.

A strong case can now be made that the vessel at Anomaly M2, investigated by CEI and EH&A during the 1990s, is not the *Utina*. Schmidt and Hoyt (1995) had concluded that the M2 wreck was not archaeologically significant based largely on the fact that several better preserved Emergency Fleet vessels, constructed similarly to the *Utina,* exist in the Sabine River. Given this new information, however, the M2 wreck must once again be considered potentially eligible for the NRHP until such time as its identity can be firmly established.

CEI also conducted a remote-sensing survey of a 45-mile-long segment of the GIWW extending from the Ship Channel at the northern end of Corpus Christi Bay to Point Penascal, Texas (Pearson and Wells, 1995). A total of twenty features were recorded during this study. One of the targets exhibited characteristics similar to historic shipwrecks. A diver assessment of that target was conducted, given that the wreck of the *Dayton*, a sidewheel steamer that sank in 1845, had been reported in the vicinity. In 1996, CEI returned to conduct diving operations on the site to further investigate the remains. The examination revealed the target to be modern debris rather than the remains of an historic vessel (Pearson and James, 1997).

Under the direction of PBS&J, additional marine remote-sensing surveys were completed in June and December of 2000 and in June 2001 to determine whether any unrecorded shipwrecks possibly lie within the study area (Enright et al., in prep.). Those surveys were conducted specifically to investigate proposed impact areas under study in this FEIS. The surveys covered all impact areas that had not already been addressed either by previous studies or through consultation with the State Historic Preservation Office (SHPO). Areas adjacent the CCSC, surveyed in June 2000, included the proposed Outer Bar Channel Extension (an area measuring 800 feet x 1.9 miles and centered on the proposed channel), the existing Outer Bar Channel (a 200-foot-wide x 2.8-mile-long area on each side of the channel beginning 50 feet inside the existing top of cut), the Inner Basin (just inside Aransas Pass jetties) to La Quinta Junction (200 feet x 10.8 miles on each side of channel), La Quinta Junction to Light Beacon 82 (400 feet x 9.7 miles on each side of channel), and Light Beacon 82 to Inner Harbor (200 feet x 1 mile on each side of channel). Areas adjacent the La Quinta Channel, surveyed in June 2000, include areas measuring 200 feet wide on each side of the existing channel (5.3 miles long) and a block to encompass the proposed La Quinta Channel Extension and Turning Basin (5,000 x 7,400 feet). Proposed BU sites surveyed in June 2001 include sites CQ (4,975 x 5,175 feet, 591 acres), I (4,825 x 6,875 feet, 762 acres), P (650 x 2,550 feet, 28 acres), R (4,500 x 6,000 feet, 620 acres), and S (4,900 x 5,375 feet, 605 acres). Marine impact areas which were not surveyed include landlocked portions of the CCSC Inner Harbor Reach, offshore BU sites MN and ZZ, BU Pelican, BU Site L, the western 20 percent of BU Site

GH, and all existing open-water PAs (both bay and offshore). Anticipated impacts to all areas were discussed with the SHPO. Low probability areas and previously disturbed areas, the latter including all existing PAs, BU Pelican and BU Site L, were excluded from survey. The inner harbor reach, the offshore BU's and the western 20 percent of BU Site GH were considered low probability areas. In the case of the Inner Harbor Reach this was because of it's recent construction date (from 1934 to 1958).

Thirty-seven magnetic anomalies were recommended for avoidance or further investigation based upon PBS&J's initial survey completed in June 2000 (see interim letter report, Remote-Sensing Survey of Corpus Christi and La Quinta Channels, DACW64-97-D-0004, Delivery Order No. 0013, PBS&J Project No. 440507.00, Texas Antiquities Permit No. 2407). Those anomalies shared characteristics with anomalies recorded over documented shipwrecks. Anomalies M01-M37 include twenty-three along the Corpus Christi Ship Channel, thirteen along the existing La Quinta Channel and turning basin, and one in the proposed extension of the La Quinta Channel turning basin and placement area.

A close-order remote-sensing survey was conducted in December 2000 over the 37 anomalies identified by the initial survey. The purpose of the close-order survey was to increase the resolution of the data over the recommended anomalies in an effort to better discriminate between significant and insignificant anomalies. As a result of the close-order survey, 28 of the original 37 anomalies were removed from further consideration. Ten anomalies (M1, M2, M3, M7, M9, M14, M17, M21, M25 and M38), including one newly discovered during the close-order survey (M38), were recommended for either avoidance of diver assessment. Two additional anomalies, M12 and M13, were recommended for further investigation provisional upon the findings at M38. If M38 was determined to be potentially associated with the wreck of the *Dayton*, then M12 and M13 were thought likely to contain scattered elements from the explosion of the *Dayton's* boilers (see interim letter report, Close-Order Remote-Sensing Survey of 37 Anomalies along Corpus Christi and La Quinta Ship Channels, DACW64-97-D-0004, Delivery Order No. 0013, Modification 01, PBS&J Project No. 440507.00, Texas Antiquities Permit No. 2407).

Consultation with the SHPO reduced the number of anomalies requiring further investigation to nine. Anomaly M2, the wreck formerly identified as the *Utina*, was excluded from further investigation due to the previous diver investigations of the site. Diver assessment of the nine remaining anomalies took place during June and July of 2001. A remote-sensing survey of 5 BU sites (CQ, P, I, R and S) took place simultaneously. As a result of the BU survey, diver assessment of two additional anomalies (I1 and I3) was appended to the diving on the other nine anomalies. Based on the diver assessments, ten of the eleven anomalies investigated were determined to be unassociated with historic shipwrecks. Anomaly M38, on the other hand, was determined to be associated with a shipwreck. Furthermore, the location, construction style and width of the wreck were all consistent with what is known of the *Dayton* (see interim letter report, Remote-Sensing Survey of Beneficial Use Areas and Diver Assessment of Eleven Anomalies, Corpus Christi and La Quinta Ship Channels, DACW64-97-D-0004, Delivery Order No. 0018 and Modification 01 to the same, PBS&J Project No. 440879.00, Texas Antiquities Permit No. 2407).

Additional consultation with the SHPO following discovery of the shipwreck at M38 resulted in concurrence with PBS&J's recommendation for further investigation of anomalies M12 and M13, both located adjacent M38. Diver assessment of M12 and M13 was conducted in October 2001. None of the objects causing those two anomalies appear to be associated with a shipwreck (see interim letter report, Diver Assessment of Two Anomalies for Historic Properties Investigations, Corpus Christi Ship Channel Improvements and La Quinta Channel Improvements and Extension, DACW64-97-D-0004, Delivery Order No. 0020, PBS&J Project No. 440966.00, Texas Antiquities Permit No. 2407). Anomaly M38 is considered potentially eligible for the NRHP and should be avoided by all future bottom disturbing activities.

3.8.3 Records Review

Records were reviewed at the Texas Archeological Research Laboratory (TARL) and at the THC to identify known cultural resource sites and to determine the location and type of sites previously identified in the study area vicinity. The listings on the National Register of Historic Places (NRHP) were reviewed for sites listed on, or determined eligible for, inclusion on the NRHP. The list of State Archeological Landmarks (SAL) prepared by the Department of Antiquities Protection at the THC was consulted for sites determined significant by the State. The Historical Marker Program of the THC was also consulted.

Based on the site maps at TARL, the review revealed 143 previously recorded terrestrial sites within 500 feet of the coastline, in the Corpus Christi Study Area. The THC records identified two of those 143 sites as having been determined eligible for listing to the NRHP. Those two sites, 41NU185 and 41NU219 are both prehistoric occupations. Ten SAL designated terrestrial sites (41NU7, 41NU15, 41NU40, 41NU41, 41NU86, 41NU87, 41NU88, 41NU89, 41NU185, and 41NU286) were also identified during the THC file review. The SAL sites are all prehistoric shell middens or campsites.

None of the NRHP eligible properties or SALs are located within the project impact areas. Site 41NU185 is located approximately 2.5 miles west of PA 7 (Site Tule Lake) and 41NU219 is located about 15 miles to the southeast of the impact locations. Site 41NU7 is at the northern end of Padre Island approximately 1.5 miles northeast of the eastern end of the causeway across the Laguna Madre. The South Guth Park Site, 41NU15, is located on the Oso Creek NE quadrangle map on the eastern bank of Oso Bay. This location is approximately 12 miles from the impact locations. The six King Ranch Prehistoric Sites (41NU40, 41NU41, 41NU86, 41NU87, 41NU88, 41NU89) that are designated SALs are located on the south bank of Oso Creek about 10 miles southeast of the impact locations. Site 41NU286 is located on the Estes topographic 7.5-minute quadrangle. The site is on Hog Island north of the Port Aransas Causeway.

Records for 81 historical markers were found for Nueces County and records for twenty-seven markers were found for San Patricio County. Some of these markers are 1936 Centennial Markers and some of the sites marked are Registered Texas Historical Landmarks.

PBS&J researched the THC shipwreck files recent AWOIS listings, and previous archaeological publications to determine whether any known shipwrecks are located within the current study area. Three shipwrecks have been confirmed in the immediate vicinity of project impacts. This includes the wreck of the S.S. *Mary* (41NU252) (Hoyt, 1990; Pearson and Simmons, 1995) located on the southern channel margin between the jetties at Aransas Pass, an unidentified wreck (41NU264) located just south of the channel near the seaward end of the southern jetty (formerly identified as the *Utina* in Pearson and Simmons, 1995, and Schmidt and Hoyt, 1995), and an unidentified wreck (site number unassigned at present) located slightly south of the Corpus Christi Ship Channel opposite McGloin's Bluff. The latter wreck, discovered by PBS&J during the summer of 2001, may be the remains of the *Dayton* whose boiler exploded within a quarter mile of McGloin's Bluff in 1845 (Enright, et al., in preparation). The S.S. *Mary* has been determined eligible for the NRHP. Site 41NU264 and the vessel discovered recently near McGloin's Bluff are believed to be potentially eligible for the NRHP, although a formal determination has not been made for either site.

3.9 AIR QUALITY

The Clean Air Act, which was last amended in 1990, requires the EPA to set National Ambient Air Quality Standards (NAAQS) for pollutants considered harmful to public health and the environment. The Clean Air Act established two types of national air quality standards:

- Primary standards set limits to protect public health, including the health of "sensitive" populations such as asthmatics, children, and the elderly.
- Secondary standards set limits to protect public welfare, including protection against decreased visibility, damage to animals, crops, vegetation, and buildings.

The EPA Office of Air Quality Planning and Standards has set NAAQSs for six principal pollutants that are called "criteria" pollutants. They are carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), lead (Pb), particulate matter with particle diameters of 10 micrometers or less (PM_{10}), particulate matter with particle diameters of 2.5 micrometers or less ($PM_{2.5}$), and sulfur dioxide (SO_2). In its General Air Quality Rules, the State of Texas provides for enforcement of the Federal NAAQSs. In addition, the TNRCC has set standards for net ground-level concentrations for particulate matter and sulfur compounds. Resulting air concentrations from sources on a property that emit these air contaminants should not exceed the applicable property-line standards. Air quality is generally considered acceptable if pollutant levels are less than or equal to established standards on a continuous basis. These pollutants are summarized in Table 3.9-1.

The Clean Air Act also requires EPA to assign a designation of each area of the U.S. regarding compliance with the NAAQS. EPA categorizes the level of compliance or noncompliance as follows:

1. Attainment – area currently meets the NAAQS
2. Maintenance – area currently meets the NAAQS, but has previously been out of compliance
3. Nonattainment – area currently does not meet the NAAQS

Nueces County is considered to be "near nonattainment" for ozone under Federal air quality standards and, therefore, is monitored closely by State and Federal environmental agencies. Once

TABLE 3.9-1

NATIONAL AMBIENT AIR QUALITY STANDARDS
AND TNRCC PROPERTY-LINE NET
GROUND-LEVEL CONCENTRATION STANDARDS

Air Constituent	Averaging Time	NAAQS Primary	NAAQS Secondary	TNRCC Regulation Standard
Sulfur Dioxide (SO_2)	30-min.	---	---	0.4 ppm (1,021 µg/m^3) 0.28 ppm (for Galveston or Harris County) 0.32 ppm (for Jefferson or Orange County)
	3-hr.	---	0.50 ppm	
	24-hr.	0.14 ppm		
	Annual Arithmetic Mean	0.03 ppm		
Particulate Matter (PM)	1-hr.	---	---	400 µg/m^3
	3-hr.	---	---	200 µg/m^3
Inhalable Particulate Matter (PM_{10})	24-hr.	150 µg/m^3	150 µg/m^3	---
	Annual Arithmetic Mean	50 µg/m^3	50 µg/m^3	---
Fine Particulate Matter ($PM_{2.5}$)	24-hr.	65 µg/m^3	65 µg/m^3	---
	Annual Arithmetic Mean	15 µg/m^3	15 µg/m^3	---
Nitrogen Dioxide (NO_2)	Annual Arithmetic Mean	0.053 ppm	0.053 ppm	---
Carbon Monoxide (CO)	1-hr.	35 ppm	---	
			---	---
	8-hr.	9 ppm		
Lead (Elemental) (Pb)	3-mo. (Calendar Quarter)	1.5 µg/m^3	1.5 µg/m^3	---
Ozone (O_3)	1-hr.	0.12 ppm	0.12 ppm	---
	8-hr.	0.08 ppm	0.08 ppm	

Source: EPA, 2002a.

µg/m3 – micrograms per cubic meter.

ppm – parts per million.

a metropolitan area has violated ozone levels over a 3-year period, the EPA can require stringent measures to bring that area back into compliance with the NAAQS.

The TNRCC is responsible for monitoring air and water quality within the State and for reporting that information to the public. The staff examines and interprets the causes, nature, and behavior of air pollution in Texas. The TNRCC operates several monitors located in the Corpus Christi area. TNRCC'S Corpus Christi Regional Office maintains these monitors. Four of the eight active monitoring stations measure the concentrations of the criteria pollutants in the air. All are used to measure meteorological parameters such as air temperature, wind velocity, and other meteorological parameters. The ozone monitors operate continuously 24 hours a day, 7 days a week, and are checked by technicians who perform equipment maintenance and conduct quality assurance checks.

Monitored values for the criteria pollutants in Nueces County are shown in Table 3.9-2. No data are available for CO, NO_2 or Pb. The monitoring data show that in 1995, the area exceeded the ozone and sulfur dioxide NAAQS standards (0.12 parts per million (ppm) and 0.14 ppm, respectively) for the 1-hour value. Since then, monitored values have been below the NAAQS.

When measured by the EPA's newer 8-hour standard, instituted in 1997, Corpus Christi has shown exceedances of the standard. Although challenged in federal court, the U.S. Supreme Court recently upheld the standard. Therefore, this 8-hour standard will apply to the Corpus Christi area in lieu of the 1-hour standard.

The air quality issues associated with port activities include non-road mobile air emission sources associated with waterborne traffic, including ships, barges, tugs, dredges, and various other types of marine and commercial vessels. Other activities include the loading and unloading of bulk cargo vessels and tankers. In addition, the port is supported by inland railway and highway transportation systems with associated emissions from combustion of fuel in railcars and vehicular traffic. Although the surrounding area is typically rural, air quality is hampered with dust from agricultural plowing, other automobile emissions, and manufacturing and industrial activities. (TNRCC, 1998).

In 1996, Nueces and San Patricio counties, acting through the Corpus Christi Air Quality Committee, finalized a 5-year plan for identifying actions that have been implemented by residents and businesses on a voluntary basis to control and reduce air pollution including ambient ozone. The plan was formalized in a Flexible Attainment Region memorandum of agreement approved by the EPA and TNRCC. Since then, residents and businesses of Nueces and San Patricio counties have carried out the provisions of the plan embodied in that agreement, successfully reducing and controlling ambient ozone. According to the TNRCC (2001b), key controls include:

- Controls of dockside emissions by industry
- Use of cleaner gasoline
- Training aimed at small and large businesses

As part of the TNRCC State Implementation Plan, regional strategies aimed at the eastern portion of the State, including Corpus Christi, will require the use of cleaner diesel fuel in vehicles such as tractors and bulldozers, and cleaner low-sulfur gasoline. As a result, Nueces and San Patricio

TABLE 3.9-2

MONITORED VALUES COMPARED WITH PRIMARY NAAQS
CORPUS CHRISTI, NUECES COUNTY

	Monitoring Year							
Value/Constituent	1995	1996	1997	1998	1999	2000	2001	NAAQS
2nd 24-hour value for PM_{10} ($\mu g/m^3$)	56	45	74	67	88	71	48	150
Annual mean value for PM_{10} ($\mu g/m^3$)	31.1	25.1	30.5	34.9	35.2	35.7	27.6	50
2nd max. 1-hour value for O_3 (ppm)	0.128	0.103	0.094	0.102	0.103	0.099	0.090	0.12
4^{th} highest 8-hour value for O_3 (ppm)	no data	no data	0.077	0.082	0.085	0.083	0.077	0.08
2nd max. 24-hour value for SO_2 (ppm)	0.144	0.015	0.020	0.029	0.019	0.017	0.017	0.14
Annual mean value for SO_2 (ppm)	0.002	0.002	0.003	0.003	0.002	0.003	0.002	0.03
2nd max. 1-hour value for CO (ppm)	no data	no data	no data	no data	no data	no data	no data	35
2nd max. 8-hour value for CO (ppm)	no data	no data	no data	no data	no data	no data	no data	9
Annual mean value for NO_2 (ppm)	no data	no data	no data	no data	no data	no data	no data	0.053
Quarterly mean value for Pb ($\mu g/m^3$)	no data	no data	no data	no data	no data	no data	no data	1.5

Source: EPA, 2002a.

µg/m3 – micrograms per cubic meter.

ppm – parts per million.

counties, which compose the Corpus Christi urban air shed, are currently in attainment of the NAAQS for ozone adopted by the EPA pursuant to the Clean Air Act.

3.10 NOISE

As directed by Congress in The Noise Control Act of 1972 as amended by the Quiet Communities Act of 1978, the EPA has developed appropriate noise-level guidelines. The EPA generally recognizes rural areas to have an average day-night noise level (L_{dn}) of less than 50 decibels A-weighting (dBA) (EPA, 1978) and urban areas between 55 and 60 dBA. Average outdoor noise levels in excess of 70 dBA or more for 24 hours per day over a 40-year period can result in hearing loss (EPA, 1974). Several factors affect response to noise levels including background level, noise character, level fluctuation, time of year, time of day, history of exposure, community attitudes and individual emotional factors. Typically, people are more tolerant of a given noise level if the background level is closer to the level of the noise source. People are more tolerant of noises during daytime than at night. Residents are more tolerant of a facility or activity if it is considered to benefit the economic or social well being of the community or them individually. Noise levels also affect outdoor activities greater than indoor activities. The immediate activities within the study area affecting noise levels could include waterborne transportation (i.e., barges, commercial fishing vessels, sport and recreational boats, etc.) and dredging. Other noise sources on land include nearby airports and transportation corridors. The noise levels within the study area would increase in proximity to urban communities due to vehicular traffic and major construction activities.

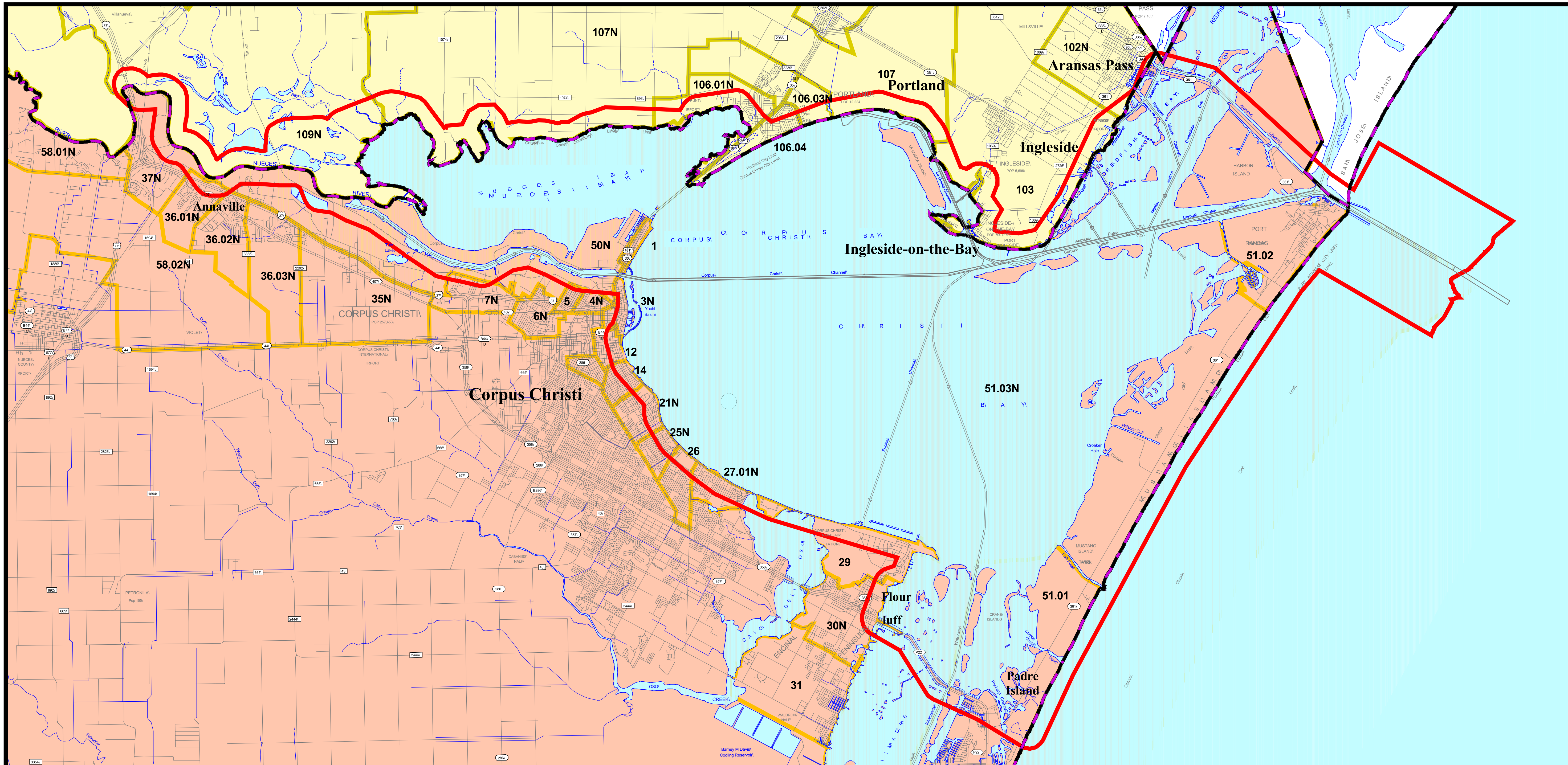
3.11 SOCIOECONOMIC RESOURCES

This section presents a summary of economic and demographic characteristics of the study area and surrounding areas within Nueces and San Patricio counties. The scope of this review includes both county level research and census tract level research (see Figure 3-3). Population, employment, the area economy, a historical perspective of economic development, land use, and Environmental Justice (EJ) are key areas of discussion. Also, a visual survey of the vicinity surrounding the study area was conducted on August 16 and 17, 2001, as a source of information for the land use section.

3.11.1 Population

The proposed project involves improvements to the existing CCSC and extension of the La Quinta Channel. The study area includes Nueces County on the south and San Patricio County on the north, as well as a number of port towns. Vessels enter the CCSC east of Port Aransas, immediately passing north of the City of Port Aransas and then traversing the east end of Corpus Christi Bay toward Ingleside and Aransas Pass. The channel extends west into the Inner Harbor where it parallels the Corpus Christi shoreline. The La Quinta Channel extends to the north bordering Ingleside-On-The-Bay toward Portland.

The proposed project is located in Nueces and San Patricio counties. The 2000 population of Nueces County was 313,645 persons. The City of Corpus Christi, population 277,454, is located within Nueces County on the south side of Corpus Christi Bay. Nueces County maintained steady growth, increasing by 8.5 percent between 1980 and 1990 and by 7.7 percent between 1990 and 2000



1990 Census TractsN

San Patricio CountyN

ueces CountyN

unty BoundaryN

Study AreaN

N(W(E(S(

5000\ 0\ 5000\ 10000\ Meters

3 0 3 6 Miles\ \

206 Wild Basin Rd., Ste. 300(
Austin, Texas 78746-3343(
Phone: (512) 329-8342 Fax: (512) 327-2453(

Figure 3-3N

rpus Christi Ship ChannelN
Census TractsN

Prepared for: USACE\
Job No.: 440524\
Prepared by: G. Rackley\
Date: Feb 2002\
Scale: 1" = 3 Miles\
File: N:\440524\av\census.apr (census_B_size layout)\

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(Table 3.11-1). Aransas Pass (pop. 8,138), Port Aransas (pop. 3,370), Ingleside (pop. 9,388), Ingleside-On-The-Bay (pop. 659), and Portland (pop. 14,827) border the northern part of the study area within San Patricio County. The 2000 census places San Patricio County's population at 67,138 persons, an increase of 14.3 percent since 1990. The county maintained a steady population between 1980 and 1990 increasing by only 1.3 percent (from 58,013 to 58,749) over that decade. Neither county grew as fast as the State during the 1980s or the 1990s.

As shown in Table 3.11-2, population projections provided by the Texas State Data Center (TSDC) indicate that growth in both counties is expected to continue; however, neither county is expected to surpass state growth rates through 2030. Nueces County is projected to grow at 0.5 percent per year, while San Patricio County is projected to grow at 1.2 percent per year. Growth rates in both counties are expected to remain positive but decline steadily after 2000. Year 2000 projections have proven to be substantially higher than current 2000 counts for Nueces County and lower than 2000 counts for San Patricio County. The resulting 2010 to 2030 projections may prove to be similarly skewed.

Generally speaking, the populations of Nueces and San Patricio counties are more ethnically diverse than that of the State of Texas (Table 3.11-3). Largely, this is attributable to a higher percentage of Hispanic people living in the two counties. In 2000, both Nueces and San Patricio counties had percentages of White persons (37.7 and 45.8 percent, respectively) that are substantially less than that of the State of Texas (at 52.4 percent). The percentage of African-Americans for both Nueces and San Patricio counties (4.1 and 2.6 percent, respectively) was substantially less than that of the State (at 11.3 percent). The percentage of Hispanics for these two counties (55.8 percent and 49.4 percent, respectively) was substantially higher than for the State (at 32 percent). The percentage of persons of all other races for the two counties (2.4 and 2.1 percent, respectively) was slightly less than for the State (at 4.2 percent).

3.11.1.1 Population and Community Cohesion

This section provides an assessment of various population demographics. Provided below is USBOC information collected for the following categories: family households, household tenure, length of residency, average per capita income, average median household incomes, and poverty levels.

The USBOC classification of "family households" (homes that are occupied by a family) is the dominant form of household composition in both Nueces and San Patricio County census tracts (USBOC, 1990) (Table 3.11-4). Within the Nueces County census tracts located in the study area, households are categorized as follows: family households represent 86.4 percent of all households; non-family households were 11.8 percent of all households, and group quarter households represent 1.8 percent of all households. Within the San Patricio County census tracts located in the study area, the breakdown of household types are as follows: family households represent 92.3 percent of all households; non-family households were 7.2 percent of all households, and group quarter households were 0.5 percent of all households. Unusually high percentages of non-family and/or group quarters households were found in the following census tracts: Nueces County study area census tracts 3, 4, 12, 14, 21, 25, 26, 29, 30, 50, 51.01, 51.02, and 51.03, and San Patricio County study area census tracts 102, and 106.01.

TABLE 3.11-1

POPULATION TRENDS 1980-2000

	Population			Percent Change		
Place	1980	1990	2000	1980-90	1990-2000	Average Annual 1980-2000
San Patricio County	58,013	58,749	67,138	1.3%	14.3%	0.7%
Nueces County	268,215	291,145	313,645	8.5%	7.7%	0.8%
State of Texas *(in 1,000s)*	14,229	16,987	20,852	19.4%	22.8%	1.9%

Source: USBOC, 1980, 1990; TSDC, 2000.

TABLE 3.11-2

POPULATION PROJECTIONS 2000-2030

	Population					Percent Change				
Place	1990	2000	2010	2020	2030	1900-2000	2000-10	2010-20	2020-30	Average Annual 1990-2030
San Patricio County	58,749	68,958	78,443	87,716	95,581	17.4%	13.8%	11.8%	9.0%	1.2%
Nueces County	291,145	318,690	339,100	351,885	355,000	9.5%	6.4%	3.8%	0.9%	0.5%
State of Texas *(in 1,000s)*	16,987	20,345	24,129	28,685	33,912	19.8%	18.6%	18.9%	18.2%	1.7%

Source: USBOC, 1990; TSDC, 2000.

TABLE 3.11-3

DETAILED 1990 POPULATION CHARACTERISTICS BY STATE AND COUNTY

	Population	Number White	Percent White	Number African American	Percent African American	Hispanic Origin	Percent Hispanic	Number Other	Percent Other	Number Below Poverty	Percent Below Poverty
Texas	16,986,510	10,291,680	60.6%	1,976,360	11.6%	4,339,905	25.5%	378,565	2.2%	3,074,558	18.10%
Nueces County	58,749	28,005	47.7%	745	1.3%	29,586	50.4%	413	0.7%	14,686	25.0%
San Patricio County	291,145	124,643	42.8%	12,206	4.2%	151,000	51.9%	3,296	1.1%	59,528	20.4%

Source: USBOC, 1990.

TABLE 3.11-4

HOUSEHOLD COMPOSITION BY STUDY AREA CENSUS TRACTS, 1990

Nueces County Census Tracts	Number of Households	Family Households	% Family Households	Non-Family Households	% Non-Family Households	Living in Group Quarters	% in Group Quarters
3	1,618	419	25.9%	424	26.2%	775	47.9%
4	2,503	2,094	83.7%	337	13.5%	72	2.9%
5	2,433	2,186	89.8%	247	10.2%	0	0.0%
6	8,012	7,286	90.9%	641	8.0%	85	1.1%
7	3,902	3,421	87.7%	428	11.0%	53	1.4%
12	4,342	3,223	74.2%	838	19.3%	281	6.5%
14	4,726	3,636	76.9%	1,030	21.8%	60	1.3%
21	7,180	5,709	79.5%	1,396	19.4%	75	1.0%
25	4,374	3,743	85.6%	590	13.5%	41	0.9%
26	7,520	6,207	82.5%	1,313	17.5%	0	0.0%
27.01	4,994	4,430	88.7%	564	11.3%	0	0.0%
29	1,827	1,426	78.1%	0	0.0%	401	21.9%
30	8,121	6,967	85.8%	1,154	14.2%	0	0.0%
31	8,688	8,056	92.7%	632	7.3%	0	0.0%
35	2,371	2,123	89.5%	248	10.5%	0	0.0%
36.01	5,779	5,389	93.3%	390	6.7%	0	0.0%
36.02	6,359	5,908	92.9%	451	7.1%	0	0.0%
36.03	2,356	2,231	94.7%	125	5.3%	0	0.0%
37	3,136	2,983	95.1%	153	4.9%	0	0.0%
50	1,344	1,174	87.4%	170	12.6%	0	0.0%
51.01	2,741	2,371	86.5%	370	13.5%	0	0.0%
51.02	2,191	1,730	79.0%	461	21.0%	0	0.0%
51.03	84	68	81.0%	16	19.0%	0	0.0%
58.01	3,939	3,739	94.9%	200	5.1%	0	0.0%
58.02	4,251	3,994	94.0%	221	5.2%	36	0.8%
Total/Average	104,791	90,513	86.4%	12,399	11.8%	1,879	1.8%

San Patricio County Census Tracts	Number of Households	Family Households	% Family Households	Non-Family Households	% Non-Family Households	Living in Group Quarters	% in Group Quarters
102	7187	6300	87.7%	740	10.3%	147	2.0%
103	6656	6195	93.1%	461	6.9%	0	0.0%
106.01	5382	4932	91.6%	450	8.4%	0	0.0%
106.03	1045	1036	99.1%	9	0.9%	0	0.0%
106.04	3107	2883	92.8%	224	7.2%	0	0.0%
107	1894	1794	94.7%	100	5.3%	0	0.0%
109	4430	4264	96.3%	166	3.7%	0	0.0%
Total/Average	29,701	27,404	92.3%	2,150	7.2%	147	0.5%
Total/Average Both Counties	134,492	117,917	87.7%	14,549	10.8%	2,026	1.5%

Source: USBOC, 1990.

"Household tenure" is a category that distinguishes between owner-occupied housing units and renter-occupied housing units. The 1990 census data within the study area shows that owner-occupied housing units are more abundant than renter occupied housing units in both Nueces and San Patricio counties (Table 3.11-5). Within the Nueces County census tracts, occupied housing units can be categorized as follows: owner-occupied units represent 61 percent, and renter-occupied units represent 39 percent. Within the San Patricio County census tracts, occupied housing units can be categorized as follows: owner-occupied units represent 66.6 percent, and renter-occupied units represent 33.4 percent. Unusually high percentages of renter-occupied housing units were found in the following census tracts: Nueces County study area census tracts 3, 4, 5, 12, 21, 26, 29, 30, 36.01, 51.01, 51.02, and 51.03, and San Patricio County study area census tracts 102, 103, and 106.01.

The "Length of Residency" category shows the average number of years that housing units are occupied. The 1990 census data within the study area shows that a majority of residents moved into their homes between 1980 and 1990 (Table 3.11-6). Within the Nueces County census tracts, the percentage of homes occupied was 28.4 percent between 1989 and 1990, 26.1 percent between 1985 and 1988, 13.1 percent between 1980 and 1984, 15.7 percent between 1970 and 1979, 9 percent between 1960 and 1969, and 7.7 percent of the homes have been occupied since 1959 or earlier. Within the San Patricio County census tracts, the percentage of homes occupied was: 23.9 percent between 1989 and 1990, 24.6 percent between 1985 and 1988, 15 percent between 1980 and 1984, 20.8 percent between 1970 and 1979, 9.2 percent between 1960 and 1969, and 6.5 percent of the homes have been occupied since 1959 or earlier.

Table 3.11-7 shows the age characteristics for the study area census tracts, and provides a comparison with the overall age characteristics in Nueces and San Patricio counties and the State. Relative to the State, the study area population had higher proportions of the population within the following age cohorts: 5 to 9 (8.6 percent), 10 to 14 (8.3 percent), 15 to 19 (7.8 percent), 35 to 44 (15.6 percent), 45 to 54 (10.1 percent), 55 to 59 (4.3 percent), 60 to 64 (4.1 percent), 65 to 74 (6.5 percent), and 75 to 84 (3.5 percent). The study area population had lower proportions than the State for the following age cohorts: 0 to 5 (7.9 percent), 20 to 24 (6.2 percent), 25 to 34 (16.3 percent), and 85 and over (0.9 percent).

An examination of per capita incomes for census tracts within the study area in Nueces County shows that the average per capita income in 1989 was $14,536. There were significant variations among the census tracts in the study area (Table 3.11-8). Unusually low per capita incomes were recorded for the following Nueces County study area census tracts: 4, 5, 6, 7, 12, 29, 30, 35, and 36.03. For study area census tracts in San Patricio County, the average per capita income in 1989 was $13,138. There were also significant variations among these census tracts. Unusually low per capita incomes were recorded for the following San Patricio County study area census tracts: 102, 103, and 109.

Average median household incomes (average of all median household income values reported by the USBOC for all study area census tracts) were also examined in the study area. For study area census tracts in Nueces County, the average median household income in 1989 was $28,013 although there were significant variations among the census tracts (see Table 3.11-8). Comparatively low median household incomes were recorded for the following Nueces County study area census tracts: 3, 4, 5, 6, 7, 12, 30, 35, and 51.02. For study area census tracts in San Patricio County, the average median

TABLE 3.11-5

STUDY AREA TENURE BY STUDY AREA CENSUS TRACTS, 1990

Nueces County Census Tracts	# Occupied Household Units	Owner Occupied Units	% Owner Occupied Units	Renter Occupied Units	% Renter Occupied Units
3	546	31	5.7%	515	94.3%
4	830	127	15.3%	703	84.7%
5	842	389	46.2%	453	53.8%
6	2,501	1,673	66.9%	828	33.1%
7	3,902	3,421	87.7%	428	11.0%
12	1,598	414	25.9%	1,184	74.1%
14	2,039	1,258	61.7%	781	38.3%
21	3,144	1,587	50.5%	1,557	49.5%
25	1,818	1,270	69.9%	548	30.1%
26	3,142	1,784	56.8%	1,358	43.2%
27.01	1,981	1,430	72.2%	551	27.8%
29	385	22	5.7%	363	94.3%
30	3,018	1,336	44.3%	1,682	55.7%
31	2,895	2,021	69.8%	874	30.2%
35	710	505	71.1%	205	28.9%
36.01	1,827	1,104	60.4%	723	39.6%
36.02	2,179	1,368	62.8%	811	37.2%
36.03	825	644	78.1%	181	21.9%
37	986	682	69.2%	304	30.8%
50	488	313	64.1%	175	35.9%
51.01	1,245	643	51.6%	602	48.4%
51.02	963	571	59.3%	392	40.7%
51.03	45	22	48.9%	23	51.1%
58.01	1,320	964	73.0%	356	27.0%
58.02	1,255	1,074	85.6%	181	14.4%
Total/Average	40,484	24,653	61.0%	15,778	39.0%

San Patricio County Census Tracts	# Occupied Household Units	Owner Occupied Units	% Owner Occupied Units	Renter Occupied Units	% Renter Occupied Units
102	2,504	1,483	59.2%	1,021	40.8%
103	2,239	1,415	63.2%	824	36.8%
106.01	1,880	1,022	54.4%	858	45.6%
106.03	293	254	86.7%	39	13.3%
106.04	1,101	897	81.5%	204	18.5%
107	580	442	76.2%	138	23.8%
109	1,300	1,081	83.2%	219	16.8%
Total/Average	9,897	6,594	66.6%	3,303	33.4%
Total/Average Both Counties	50,381	31,247	62.0%	19,081	38.0%

Source: USBOC, 1990.

TABLE 3.11-6
STUDY AREA LENGTH OF RESIDENCY, 1990
Year Householder Moved Into Residence

Nueces County Census Tracts	# Occupied Housing Units	1989 to 1990	%	1985 to 1988	%	1980 to 1984	%	1970 to 1979	%	1960 to 1969	%	1959 or Earlier	%
3	546	228	41.8%	209	38.3%	43	7.9%	39	7.1%	19	3.5%	8	1.5%
4	830	248	29.9%	222	26.7%	137	16.5%	76	9.2%	70	8.4%	77	9.3%
5	842	244	29.0%	186	22.1%	71	8.4%	134	15.9%	125	14.8%	82	9.7%
6	2,501	596	23.8%	353	14.1%	240	9.6%	440	17.6%	438	17.5%	434	17.4%
7	1,338	365	27.3%	272	20.3%	122	9.1%	286	21.4%	109	8.1%	184	13.8%
12	1,598	608	38.0%	331	20.7%	171	10.7%	303	19.0%	82	5.1%	103	6.4%
14	2,039	534	26.2%	528	25.9%	192	9.4%	228	11.2%	230	11.3%	327	16.0%
21	3,144	778	24.7%	640	20.4%	451	14.3%	574	18.3%	251	8.0%	450	14.3%
25	1,818	350	19.3%	388	21.3%	198	10.9%	339	18.6%	282	15.5%	261	14.4%
26	3,142	842	26.8%	713	22.7%	342	10.9%	573	18.2%	460	14.6%	212	6.7%
27.01	1,981	427	21.6%	431	21.8%	242	12.2%	473	23.9%	264	13.3%	144	7.3%
29	385	218	56.6%	167	43.4%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
30	3,018	1,196	39.6%	1,025	34.0%	444	14.7%	220	7.3%	92	3.0%	41	1.4%
31	2,895	667	23.0%	1,000	34.5%	531	18.3%	497	17.2%	132	4.6%	68	2.3%
35	710	222	31.3%	88	12.4%	112	15.8%	126	17.7%	98	13.8%	64	9.0%
36.01	1,827	572	31.3%	734	40.2%	318	17.4%	104	5.7%	53	2.9%	46	2.5%
36.02	2,179	658	30.2%	548	25.1%	300	13.8%	405	18.6%	200	9.2%	68	3.1%
36.03	825	117	14.2%	180	21.8%	79	9.6%	199	24.1%	161	19.5%	89	10.8%
37	986	182	18.5%	249	25.3%	158	16.0%	227	23.0%	105	10.6%	65	6.6%
50	488	149	30.5%	171	35.0%	110	22.5%	31	6.4%	14	2.9%	13	2.7%
51.01	1,245	733	58.9%	349	28.0%	100	8.0%	52	4.2%	11	0.9%	0	0.0%
51.02	963	299	31.0%	292	30.3%	129	13.4%	177	18.4%	39	4.0%	27	2.8%
51.03	45	12	26.7%	19	42.2%	14	31.1%	0	0.0%	0	0.0%	0	0.0%
58.01	1,320	401	30.4%	444	33.6%	186	14.1%	230	17.4%	50	3.8%	9	0.7%
58.02	1,255	112	8.9%	372	29.6%	260	20.7%	235	18.7%	125	10.0%	151	12.0%
Total/Average	37,920	10,758	28.4%	9,911	26.1%	4,950	13.1%	5,968	15.7%	3,410	9.0%	2,923	7.7%

San Patricio County Census Tracts	# Occupied Housing Units	1989 to 1990	%	1985 to 1988	%	1980 to 1984	%	1970 to 1979	%	1960 to 1969	%	1959 or Earlier	%
102	2,504	676	27.0%	686	27.4%	332	13.3%	540	21.6%	153	6.1%	117	4.7%
103	2,239	530	23.7%	527	23.5%	324	14.5%	469	20.9%	234	10.5%	155	6.9%
106.01	1,880	623	33.1%	435	23.1%	193	10.3%	333	17.7%	230	12.2%	66	3.5%
106.03	293	54	18.4%	104	35.5%	87	29.7%	48	16.4%	0	0.0%	0	0.0%
106.04	1,101	262	23.8%	208	18.9%	65	5.9%	323	29.3%	136	12.4%	107	9.7%
107	580	86	14.8%	166	28.6%	130	22.4%	117	20.2%	35	6.0%	46	7.9%
109	1,300	132	10.2%	311	23.9%	355	27.3%	224	17.2%	127	9.8%	151	11.6%
Total/Average	9,897	2,363	23.9%	2,437	24.6%	1,486	15.0%	2,054	20.8%	915	9.2%	642	6.5%
Total/Average Both Counties	47,817	13,121	27.4%	12,348	25.8%	6,436	13.5%	8,022	16.8%	4,325	9.0%	3,565	7.5%

Source: USBOC 1990.

Table 3.11-7
Age Characteristics of Study Area Census Tracts, 1990

Place	under 5		5 to 9		10 to 14		15 to 19		20 to 24		25 to 34		35 to 44		45 to 54		55 to 59		60 to 64		65 to 74		75 to 84		85 and over		Total
	Years of Age																										
Nueces County Census Tracts	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	Persons
3	37	2.3%	32	2.0%	25	1.5%	110	6.8%	177	10.9%	402	24.8%	246	15.2%	119	7.3%	39	2.4%	43	2.7%	118	7.3%	166	10.2%	107	6.6%	1,621
4	354	14.4%	329	13.4%	249	10.1%	210	8.5%	183	7.4%	318	12.9%	218	8.8%	170	6.9%	72	2.9%	69	2.8%	164	6.7%	101	4.1%	27	1.1%	2,464
5	182	7.5%	219	9.0%	200	8.2%	222	9.1%	160	6.6%	351	14.4%	318	13.1%	196	8.1%	107	4.4%	135	5.5%	216	8.9%	100	4.1%	27	1.1%	2,433
6	602	7.5%	750	9.4%	801	10.0%	758	9.5%	514	6.4%	1,125	14.0%	1112	13.9%	745	9.3%	291	3.6%	343	4.3%	561	7.0%	343	4.3%	67	0.8%	8,012
7	381	9.8%	351	9.0%	303	7.8%	277	7.1%	278	7.1%	655	16.8%	527	13.5%	334	8.6%	170	4.4%	160	4.1%	297	7.6%	129	3.3%	42	1.1%	3,904
12	421	9.7%	317	7.3%	283	6.5%	283	6.5%	352	8.1%	780	18.0%	533	12.3%	296	6.8%	151	3.5%	178	4.1%	320	7.4%	266	6.1%	147	3.4%	4,327
14	366	7.7%	295	6.2%	246	5.2%	247	5.2%	264	5.6%	897	19.0%	831	17.6%	402	8.5%	204	4.3%	180	3.8%	362	7.7%	339	7.2%	93	2.0%	4,726
21	538	7.5%	529	7.4%	476	6.6%	450	6.3%	385	5.4%	1186	16.5%	1078	15.0%	608	8.5%	261	3.6%	297	4.1%	672	9.4%	554	7.7%	146	2.0%	7,180
25	275	6.3%	291	6.7%	279	6.4%	229	5.2%	221	5.1%	599	13.7%	698	16.0%	466	10.7%	209	4.8%	257	5.9%	507	11.6%	286	6.5%	57	1.3%	4,374
26	450	6.0%	491	6.5%	477	6.3%	478	6.4%	454	6.0%	1211	16.1%	1093	14.5%	760	10.1%	392	5.2%	491	6.5%	779	10.4%	363	4.8%	81	1.1%	7,520
27.01	308	6.1%	356	7.0%	336	6.6%	315	6.2%	251	4.9%	694	13.6%	802	15.8%	581	11.4%	278	5.5%	353	6.9%	591	11.6%	183	3.6%	39	0.8%	5,087
29	330	17.7%	183	9.8%	108	5.8%	87	4.7%	337	18.1%	586	31.4%	185	9.9%	38	2.0%	7	0.4%	1	0.1%	2	0.1%	0	0.0%	1	0.1%	1,865
30	705	8.7%	751	9.3%	729	9.0%	649	8.0%	602	7.4%	1524	18.9%	1317	16.3%	748	9.3%	280	3.5%	244	3.0%	362	4.5%	147	1.8%	25	0.3%	8,083
31	642	7.4%	794	9.1%	855	9.8%	792	9.1%	384	4.4%	1338	15.4%	1567	18.0%	1081	12.4%	392	4.5%	313	3.6%	394	4.5%	120	1.4%	16	0.2%	8,688
35	179	7.6%	207	8.8%	248	10.6%	255	10.9%	130	5.6%	357	15.3%	422	18.0%	220	9.4%	79	3.4%	78	3.3%	106	4.5%	53	2.3%	6	0.3%	2,340
36.01	611	10.6%	701	12.1%	597	10.3%	448	7.8%	331	5.7%	1252	21.7%	1021	17.7%	405	7.0%	134	2.3%	83	1.4%	128	2.2%	59	1.0%	9	0.2%	5,779
36.02	488	7.7%	585	9.2%	588	9.2%	564	8.9%	403	6.3%	1080	17.0%	1083	17.0%	697	11.0%	260	4.1%	209	3.3%	252	4.0%	122	1.9%	28	0.4%	6,359
36.03	145	6.1%	184	7.7%	239	10.0%	194	8.1%	137	5.7%	316	13.2%	319	13.4%	258	10.8%	136	5.7%	146	6.1%	206	8.6%	89	3.7%	19	0.8%	2,388
37	303	9.6%	270	8.6%	292	9.3%	285	9.1%	222	7.1%	510	16.2%	504	16.0%	322	10.2%	138	4.4%	95	3.0%	130	4.1%	58	1.8%	14	0.4%	3,143
50	99	7.9%	133	10.6%	132	10.5%	113	9.0%	73	5.8%	181	14.5%	200	16.0%	125	10.0%	56	4.5%	41	3.3%	62	5.0%	34	2.7%	3	0.2%	1,252
51.01	140	4.9%	124	4.4%	128	4.5%	157	5.5%	201	7.1%	509	18.0%	548	19.3%	399	14.1%	195	6.9%	166	5.9%	212	7.5%	44	1.6%	12	0.4%	2,835
51.02	114	5.2%	156	7.1%	131	5.9%	129	5.8%	99	4.5%	308	13.9%	422	19.1%	289	13.1%	145	6.6%	116	5.2%	200	9.0%	86	3.9%	17	0.8%	2,212
51.03	4	3.8%	7	6.6%	2	1.9%	4	3.8%	4	3.8%	10	9.4%	16	15.1%	19	17.9%	8	7.5%	5	4.7%	20	18.9%	4	3.8%	3	2.8%	106
58.01	280	7.0%	369	9.2%	383	9.5%	365	9.1%	145	3.6%	611	15.2%	797	19.8%	529	13.2%	185	4.6%	133	3.3%	153	3.8%	52	1.3%	14	0.3%	4,016
58.02	296	7.1%	450	10.8%	434	10.5%	360	8.7%	207	5.0%	650	15.7%	587	14.1%	431	10.4%	224	5.4%	166	4.0%	217	5.2%	107	2.6%	22	0.5%	4,151
Total/Average	8,250	7.9%	8,874	8.5%	8,541	8.1%	7,981	7.6%	6,514	6.2%	17,450	16.6%	16,444	15.7%	10,238	9.8%	4,413	4.2%	4,302	4.1%	7,031	6.7%	3,805	3.6%	1,022	1.0%	104,865
San Patricio County Census Tracts																											
102	591	8.2%	689	9.5%	621	8.6%	545	7.5%	438	6.1%	1,019	14.1%	975	13.5%	676	9.3%	338	4.7%	343	4.7%	555	7.7%	347	4.8%	97	1.3%	7,234
103	550	8.2%	625	9.3%	577	8.6%	583	8.7%	406	6.1%	1,035	15.5%	992	14.8%	797	11.9%	272	4.1%	261	3.9%	361	5.4%	198	3.0%	34	0.5%	6,691
106.01	501	9.3%	495	9.2%	459	8.5%	434	8.0%	377	7.0%	1,008	18.6%	859	15.9%	548	10.1%	218	4.0%	178	3.3%	212	3.9%	99	1.8%	17	0.3%	5,405
106.03	66	6.2%	123	11.6%	96	9.1%	112	10.6%	38	3.6%	114	10.8%	240	22.6%	176	16.6%	38	3.6%	27	2.5%	27	2.5%	2	0.2%	1	0.1%	1,060
106.04	176	5.7%	229	7.4%	261	8.4%	273	8.8%	165	5.3%	348	11.3%	505	16.3%	467	15.1%	219	7.1%	171	5.5%	185	6.0%	80	2.6%	13	0.4%	3,092
107	142	8.1%	159	9.1%	166	9.5%	165	9.4%	87	5.0%	281	16.1%	253	14.5%	189	10.8%	70	4.0%	73	4.2%	116	6.6%	42	2.4%	7	0.4%	1,750
109	299	7.0%	418	9.8%	414	9.7%	386	9.1%	262	6.2%	578	13.6%	644	15.1%	457	10.7%	202	4.7%	214	5.0%	251	5.9%	100	2.4%	28	0.7%	4,253
Total/Average	2,325	7.9%	2,738	9.3%	2,594	8.8%	2,498	8.5%	1,773	6.0%	4,383	14.9%	4,468	15.2%	3,310	11.2%	1,357	4.6%	1,267	4.3%	1,707	5.8%	868	2.9%	197	0.7%	29,485
Study Area Average Both Counties	10,575	7.9%	11,612	8.6%	11,135	8.3%	10,479	7.8%	8,287	6.2%	21,833	16.3%	20,912	15.6%	13,548	10.1%	5,770	4.3%	5,569	4.1%	8,738	6.5%	4,673	3.5%	1,219	0.9%	134,350
Nueces County	24,043	8.3%	25,838	8.9%	24,759	8.5%	23,331	8.0%	19,960	6.9%	50,538	17.4%	43,049	14.8%	27,025	9.3%	11,696	4.0%	11,484	3.9%	17,879	6.1%	9,079	3.1%	2,464	0.8%	291,145
San Patricio County	4,827	8.2%	5,639	9.6%	5,382	9.2%	5,097	8.7%	3,790	6.5%	8,614	14.7%	8,332	14.2%	5,924	10.1%	2,568	4.4%	2,479	4.2%	3,615	6.2%	1,946	3.3%	536	0.9%	58,749
Texas (in 1,000s)	1,390	8.2%	1,396	8.2%	1,294	7.6%	1,312	7.7%	1,334	7.9%	3,086	18.2%	2,539	14.9%	1,629	9.6%	662	3.9%	628	3.7%	998	5.9%	552	3.2%	167	1.0%	16,987

Source: USBOC, 1990.

TABLE 3.11-8
INCOME BY STUDY AREA CENSUS TRACTS, 1990

Nueces County Census Tracts	Number of Persons	Per Capita Income	Median Household Income	# Below Poverty	% Below Poverty
3	1,618	$20,276	$12,576	313	19.3%
4	2,503	$4,351	$4,999	1,710	68.3%
5	2,433	$5,727	$11,734	1,041	42.8%
6	8,012	$7,634	$17,791	2,552	31.9%
7	3,902	$8,276	$21,907	906	23.2%
12	4,342	$7,889	$13,341	1,714	39.5%
14	4,726	$20,973	$28,382	564	11.9%
21	7,180	$16,739	$26,293	1,046	14.6%
25	4,374	$23,736	$37,246	406	9.3%
26	7,520	$15,216	$26,182	1,316	17.5%
27.01	5,087	$28,576	$37,136	493	9.7%
29	1,827	$9,005	$26,010	88	4.8%
30	8,121	$9,799	$22,125	1,561	19.2%
31	8,688	$12,388	$32,351	1,110	12.8%
35	2,371	$8,655	$23,169	400	16.9%
36.01	5,779	$13,084	$37,804	503	8.7%
36.02	6,359	$12,051	$32,423	559	8.8%
36.03	2,356	$10,444	$30,000	414	17.6%
37	3,136	$11,408	$32,151	405	12.9%
50	1,344	$11,902	$27,316	343	25.5%
51.01	2,750	$24,196	$47,348	149	5.4%
51.02	2,207	$14,688	$23,224	349	15.8%
51.03	84	$38,300	$51,869	6	7.1%
58.01	3,954	$16,671	$45,966	210	5.3%
58.02	4,251	$11,425	$30,970	602	14.2%
Total/Average	104,924	$14,536	$28,013	18,760	17.9%

San Patricio County Census Tracts	Number of Persons	Per Capita Income	Median Household Income	# Below Poverty	% Below Poverty
102	7,187	$8,938	$16,318	2,596	36.1%
103	6,656	$10,096	$24,634	1,009	15.2%
106.01	5,382	$11,216	$27,094	669	12.4%
106.03	1,045	$23,232	$63,907	11	1.1%
106.04	3,107	$16,509	$40,625	73	2.3%
107	1,894	$12,100	$37,115	380	20.1%
109	4,430	$9,872	$26,119	785	17.7%
Total/Average	29,701	$13,138	$33,687	5,523	18.6%
Total/Average Both Counties	134,625	$14,230	$29,254	24,283	18.0%

Source: USBOC, 1990.

household income in 1989 was $33,687. There were fairly moderate variations among these census tracts. Comparatively low median household incomes were recorded for the following San Patricio County study area census tracts: 102, 103, 106.01, and 109.

Poverty levels were examined in the study area. For study area census tracts in Nueces County, the average percentage of the population living below the poverty line ($15,000) in 1989 was 17.9 percent. There were significant variations among the census tracts (see Table 3.11-8). Relatively high percentages of persons living below the poverty line were recorded for the following Nueces County study area census tracts: 4, 5, 6, 12, and 37. For study area census tracts in San Patricio County, the average percentage of the population living below the poverty line in 1989 was 18.6 percent, and there were fairly moderate variations among these census tracts. A high percentage of persons living below the poverty line was recorded for San Patricio County study area census tract 102.

3.11.2 Employment

According to the Texas Workforce Commission, most of the jobs in Nueces County fall within the Service sector (32 percent) and Trade sector (26 percent). In San Patricio County, manufacturing is the dominant economic sector employing 3,472 persons, or 24 percent of the labor force; the trade and service sectors employ 19 and 16 percent of the workforce, respectively. In Nueces County, the total civilian labor force increased 8.6 percent between 1990 and 2000 from 136,056 to 147,857. The unemployment rate remained constant at approximately 6.6 percent during this period. In San Patricio County, the civilian labor force increased by 21 percent from 24,981 in 1990 to 30,208 in September of 1998. During the same period, the unemployment rate remained relatively constant, decreasing from 6.9 percent in 1990 to 6.7 percent in September 2000 (Texas Workforce Commission, 2001).

Table 3.11-9 provides a list of the top 20 major employers within the Corpus Christi area. The top employers are concentrated in the government (including public school and military employees), healthcare, telecommunications, petroleum refining, and petrochemical manufacturing industries, and other oil industry/port-related enterprises. The employers listed in Table 3.11-9 that are associated with the operations of the Port of Corpus Christi appear with an asterisk following the company name. Within the top 20 employers, seven have operations directly related to the Port of Corpus Christi, providing just over 10,900 jobs within the Corpus Christi area. The Corpus Christi Chamber of Commerce estimates that port-related companies employed approximately 50,000 people in the Corpus Christi area in 2001 (Corpus Christi Chamber of Commerce, 2001).

3.11.3 Economics

3.11.3.1 Historical Perspective

Corpus Christi began as a small supply post for the Mexican war in the early 1800s. Throughout its history, it has been dependent upon a channel to accommodate its burgeoning ship trade. After the Civil War, the Corpus Christi Bay became a shipping point for moving notable Texas crops (e.g., cattle and cotton) to eastern markets. By 1874, an 8-foot channel, known as the Corpus Christi Channel, was dredged through the bay that allowed steamships to dock at Corpus Christi markets (Heines and Williams, 2001; San Patricio County, 2001).

TABLE 3.11-9

STUDY AREA MAJOR EMPLOYERS, 2002

Top 20 Study Area Employers	Number of Employees
Naval Air Station Corpus Christi	8,800
Corpus Christi ISD	5,355
Christus Spohn Health System	4,500
Naval Station Ingleside*	3,400
Corpus Christi Army Depot	3,000
City of Corpus Christi	3,000
Columbia Healthcare Corp.	2,882
Bay, Inc.*	2,200
HEB Grocery Co.	2,200
Koch Refining Company*	1,253
First Data Corp	1,200
Walmart, Inc.	1,200
APAC Teleservices	1,200
Driscoll Children's Hospital	1,100
Celanese*	1,050
Sherwin Alumina*	1,000
Gulf Marine Fabricators*	1,000
Kiewit Offshore Service, Ltd.*	1,000
Whataburger, Inc.	967
Sam Kane Beef Processors	840

Sources: Corpus Christi Chamber of Commerce, 2002; Portland Chamber of Commerce, 2002; Ingleside Chamber of Commerce, 2002; Corpus Christi Regional Economic Development Corporation, 2002.

* Employer associated with the operations of the Port of Corpus Christi.

In 1911, the first causeway was built across Nueces Bay linking Corpus Christi with the North Bay area. The following year, a major natural gas field was discovered in San Patricio County on the north side of Nueces Bay. Eventually, Corpus Christi became a major center for oil refining and petrochemical industries (San Patricio County, 2001).

In 1907, the channel (under the auspices of the Turtle Cove Channel Project) was deepened to 10 feet and widened to 100 feet. By 1910, the channel was deepened again to a depth of 12 feet. The channel was extended 21 miles to Corpus Christi in 1926 of which only 12 miles between Port Aransas and McGloins Bluff required dredging. On September 14, 1926, the Port of Corpus Christi's 25- by 200-foot channel was opened as the principal port in south Texas (Heines and Williams, 2001).

The channel was dredged to 37 feet wide by 400 feet deep in 1932 (James and Pearson, 1991; Schmidt and Hoyt, 1995). The deep-water port supported the simultaneously occurring oil boom. Between 1935 and 1937, Nueces County increased its number of oil fields from two to 894 (Heines and Williams, 2001).

Throughout the second half of the twentieth century, the bay area's infrastructure and channel related commerce thrived. In 1938, the U.S. Navy opened a training base in the city, and in 1945 the Intracoastal Canal opened a 12-foot-deep canal from Galveston to Corpus Christi, allowing free trade to move quickly between the two cities. In 1947, the University of Corpus Christi (Now Texas A&M University–Corpus Christi) opened at the former U.S. Navy facility on the city's southern end (Heines and Williams, 2001). In 1950, the 4-mile-long Padre Island Causeway (later renamed the John F. Kennedy Causeway) connected the city with Padre and Mustang Islands, and in 1959 the Harbor Bridge over the CCSC was completed (Heines and Williams, 2001). Also in the late 1950s, at the request of Reynolds Metal Company, the USACE dredged a channel through Ingleside Cove along the western side of McGloin's Bluff known as the La Quinta Channel. The 36-foot-deep and 200-foot-wide channel facilitated the development of Reynolds Metal Company (Alperin, 1977). In 1960, the Corpus Christi International Airport was built. In 1962, President Kennedy authorized the purchase of 80.5 miles of Padre Island for a national seashore, with the construction of Interstate Highway 37 (IH 37) connecting Corpus Christi to San Antonio beginning soon after (Heines and Williams, 2001). In 1972, Mustang Island State Park was purchased and added into the park system. By the mid-1980s, the Port of Corpus Christi was ranked the sixth largest port in the nation in terms of tonnage (Heines and Williams, 2001).

Tourism has become a major industry in the area. In 1997, tourism in Corpus Christi and the surrounding area generated over $700 million in local spending, an increase of $204 million compared with 1996 spending estimates. Oil and gas are still important within both Nueces and San Patricio County economies, but its role is declining. The services industry has been the fastest growing job industry in the area in the 1990s. Five out of six jobs in the area are in the service sector. Between 1970 and 1997, the local economy created 35,450 new service jobs, and the mining industry and oil and gas lost 1,500 jobs (San Patricio County, 2001).

The Coastal Bend's petrochemical industry pumps more than $1 billion into the area's economy and provides an estimated 30,000 jobs. Four major operations are located along the north shore of Corpus Christi Bay: DuPont, Occidental Chemical Corporation, Reynolds Metals Company, and Aker-Gulf Marine which is the second largest off-shore platform builder in the country (San Patricio County, 2001).

3.11.3.2 Current Regional Economics

The economy of the Corpus Christi Bay area is broadly based in manufacturing, agriculture and fishing. The port of Corpus Christi handles large volumes of commodities including crude petroleum and petroleum products, aluminum ores, and agricultural products (USACE, 2000). The port ranks fifth in the nation in total cargo tonnage and fourth in foreign trade volume (Port of Corpus Christi, 1999). Industrial development in the area consists of plants devoted to processing agricultural products, petrochemicals, and chemical derivatives; manufacturing fishing and offshore service vessels, drilling rigs, offshore producing platforms, and offshore service equipment; and reducing ores to produce aluminum, zinc, and chrome products.

The CCSC was the first waterway in Texas to be completed to a 45-foot depth. The channel ranks fifth in the nation in tonnage shipped on deep-draft vessels. This amount of deep-draft tonnage transport through the channel has been increasing steadily since 1965. In Texas, only the Houston Ship Channel handles more traffic (Figure 3-4).

Government also contributes greatly to the area economy. The military is the single largest employer in the Corpus Christi area with the Army Depot and Naval Air Station located on the south side of Corpus Christi Bay, employing 11,800 persons. This 4,400-acre facility has eight runways and provides a $226 million civilian and $107 million military economic contribution to the area. Also within the study area, Naval Station Ingleside is located on the north side of Corpus Christi Bay. Selected as Gulf homeport in 1985, Naval Station Ingleside is currently home to twenty-five minesweepers and three reserve frigates (U.S. Navy, 2000; Corpus Christi Regional Economic Development Corporation, 2002).

3.11.3.3 Tourism and Recreation

Tourism is a major contributor to the Corpus Christi area economy. According to the Corpus Christi Chamber of Commerce, tourism revenues were estimated at $603 million (in constant dollars) in 1994 and increased by 11 percent to $670 million in 2000. Corpus Christi is the second most frequented visitor destination in Texas, with approximately 4 million visitors annually (Corpus Christi Chamber of Commerce, 2000). A majority of the tourism (approximately 70 percent) is drawn from the intrastate travel market, primarily from the largest metropolitan areas of Texas (Hammer, Siler, George Associates, 1997). Much of the tourism in the Corpus Christi area occurs due to the extensive opportunities for outdoor recreation, and the natural beauty of the Corpus Christi Bay, Mustang Island, North Padre Island, and the Gulf of Mexico. Also, the Corpus Christi area is a popular destination for conventions. Man-made tourism destinations within the area include the Texas State Aquarium, the Greyhound Racetrack, and the USS *Lexington* Museum by the Bay (Corpus Christi Chamber of Commerce, 2000).

The natural resources of the Corpus Christi Bay and the Gulf of Mexico provide extensive recreational opportunities in the Corpus Christi area. Outdoor recreation in the area includes fishing, bird-watching, waterfowl hunting, windsurfing, camping, boating, jet skiing, swimming, horseback riding, shelling and beach combing (among others). There are several marinas located within the Corpus Christi Bay area, Port Aransas, and Aransas Pass that support recreational as well as commercial fishing. The Padre Island National Seashore is a popular destination, providing approximately 60 miles of protected beaches along North Padre Island just south of the Corpus Christi city limits. Mustang Island State Park contains 3,703 acres and is located within the southern portion of Mustang Island. This park provides RV spaces, rest rooms and campsites and provides another popular point for beach access. Also, located within the vicinity of the study area is the Corpus Christi Bay Loop of the Great Texas Coastal Birding Trail, that is managed by the TPWD. Fourteen separate trails used for bird-watching make up the Corpus Christi Bay Loop (TPWD, 1999).

3.11.3.4 Commercial Fisheries

Commercial fishing within the Corpus Christi Bay system is a relatively moderate contributor to the Corpus Christi area economy compared to other industry sectors. Table 3.11-10

Figure 3-4
Corpus Christi Ship Channel Transport

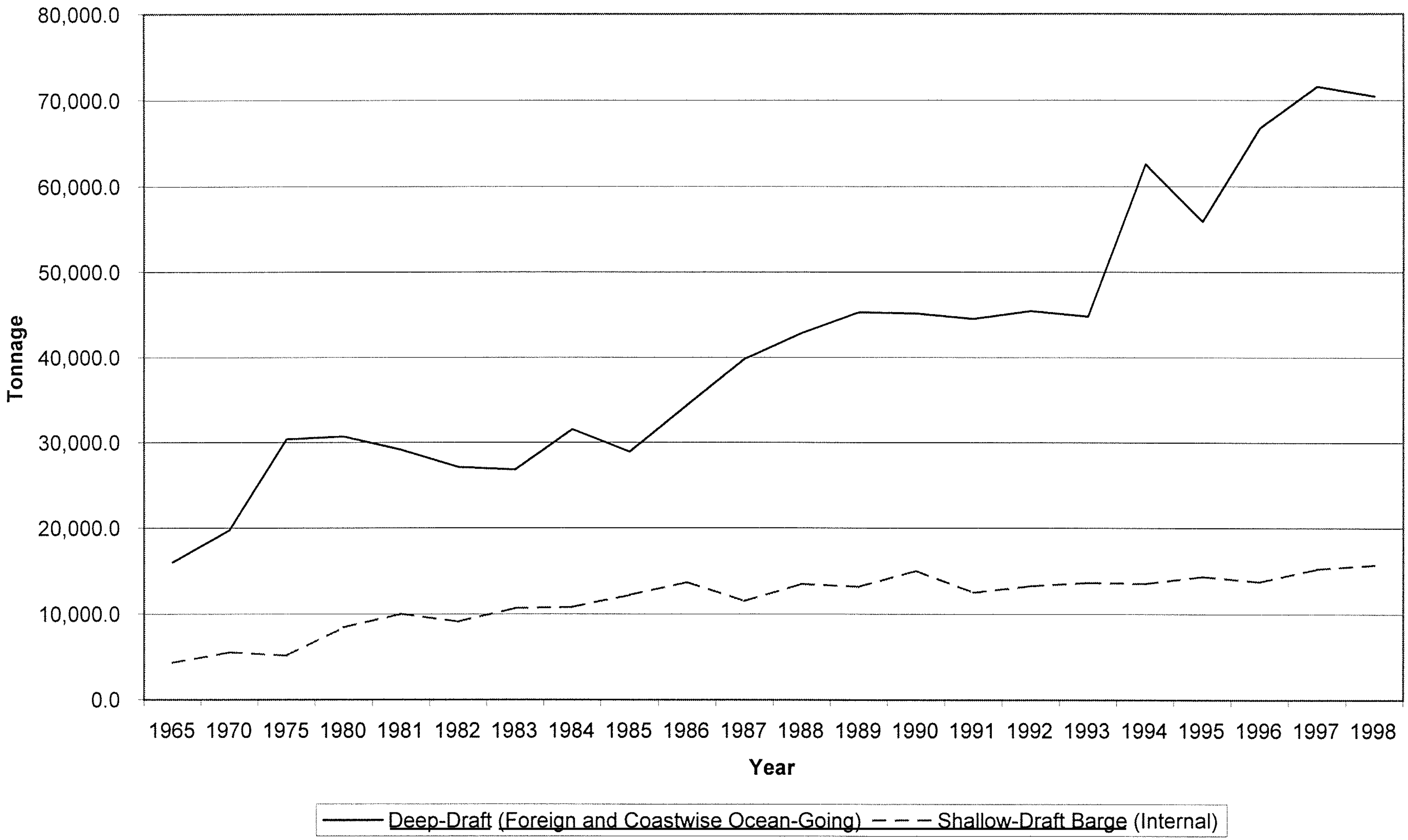

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Table 3.11-10
Trends in Commercial Fishery Landings
Corpus Christi Bay Compared With All Texas Bay Systems, 1999

	Corpus Christi Bay System						All Texas Bay Systems	
	weight (lbs) of fish landed	% of total weight of all Corpus Christi Bay finfish and shellfish	% of total weight from all Texas bay system landings	wholesale value of fish landed	% of total wholesale value from all Corpus Christi Bay finfish and shellfish	% of total wholesale value from all Texas bay system landings	weight (lb x 1,000) from all Texas bay system landings	wholesale value ($ x 1,000) from all Texas bay system landings
Black drum	134,920	18.8%	4.8%	$136,549	14.8%	5.1%	2,798.5	$2,689.8
Flounder	1,841	0.3%	0.6%	$4,039	0.4%	0.7%	284.2	$597.1
Sheeps-head	2,893	0.4%	2.5%	$1,546	0.2%	3.2%	117.4	$47.7
Mullet	1,488	0.2%	2.5%	$3,112	0.3%	4.6%	60.2	$68.0
other finfish	18,719	2.6%	10.8%	$88,569	9.6%	16.1%	173.7	$551.7
Total finfish	159,861	22.2%	4.7%	$233,815	25.3%	5.9%	3,434.0	$3,954.2
Brown and Pink shrimp	512,867	71.4%	9.1%	$568,355	61.5%	11.7%	5,637.7	$4,857.8
White shrimp	33,755	4.7%	0.7%	$113,347	12.3%	1.4%	4,837.0	$8,095.6
Other shrimp	137	0.0%	0.2%	$137	0.0%	0.7%	59.8	$18.8
Total shrimp	546,759	76.1%	5.2%	$681,839	73.7%	5.3%	10,534.6	$12,972.2
Blue crab	8,039	1.1%	0.1%	$3,707	0.4%	0.1%	6,471.9	$4,294.7
Eastern oyster	0	0.0%	0.0%	$0	0.0%	0.0%	5,183.3	$11,216.4
other shellfish	3,994	0.6%	4.6%	$5,190	0.6%	3.4%	86.5	$151.3
Total shellfish	558,792	77.8%	2.5%	$690,737	74.7%	2.4%	22,276.4	$28,634.5
Total finfish and shellfish	**718,653**	**100.0%**	**2.8%**	**$924,552**	**100.0%**	**2.8%**	**25,710.4**	**$32,588.8**

Source: TPWD, 2001.

compares the commercial fishery landings of the Corpus Christi Bay with all Texas bay systems in 1999. The total wholesale value for all finfish and shellfish landings in the Corpus Christi Bay system in 1999 was $924,552, or 2.8 percent of the wholesale value of all such landings for all Texas bay systems in that same year (at $32.6 million). For the Corpus Christi Bay system, shrimp had the greatest wholesale value, by far, worth $681,839 in 1999, or 73.7 percent of wholesale value for all finfish and shellfish. Black drum and "other finfish" also represented substantial shares of the overall wholesale value of finfish and shellfish from landings in the Corpus Christi Bay system, at $136,549 (or 14.8 percent) and $88,569 (9.6 percent) in 1999. The total weight of all finfish and shellfish landings in the Corpus Christi Bay system in 1999 was 718,653 pounds, or 2.8 percent of the weight of all such landings for all Texas bay systems in 1999 (at 25.7 million pounds). Shrimp and black drum landings represented the greatest share of the weight of all finfish and shellfish landings in 1999, at 546,759 pounds (or 76.1 percent) and 134,920 pounds (18.8 percent), respectively. It is noteworthy, however, that 1999 was not a particularly good year for commercial fishing in the Corpus Christi Bay system. During the 1990s, 1992 had the greatest total value for all finfish and shellfish landings, at $6.0 million, or 549 percent greater than the 1999 value (TPWD, 2001).

3.11.3.5 Tax Base

In Texas, the state sales tax is 6.25 percent, with local sales/use tax not to exceed 8.25 percent. Within the general vicinity of the study area, local sales/use taxes are as follows (Texas Comptroller of Public Accounts, 2001a):

- The City of Corpus Christi sales/use tax is 8.125 percent and includes 1.25 percent Corpus Christi City Tax, 0.125 percent Corpus Christi Crime Control District, and 0.5 percent Corpus Christi MTA Tax.
- The City of Port Aransas sales/use tax is 8.25 percent and includes 1.5 percent Port Aransas City Tax and 0.5 percent Corpus Christi MTA Tax.
- The City of Ingleside sales/use tax is 8.25 percent and includes 2 percent Ingleside City Tax.
- The City of Portland sales/use tax is 7.75 percent and includes 1.5 percent Portland City Tax.
- The City of Aransas Pass sales/use tax is 7.75 percent and includes 1 percent Aransas Pass City Tax, and 0.5 percent Aransas Pass Municipal Development District Tax.

In Texas, property is appraised and property tax is collected by local (county) tax offices or appraisal districts, and these funds are used to fund many local needs including public schools, city streets, county roads, and police and fire protection (Texas Comptroller of Public Accounts, 2001b). Property taxes within Nueces County are collected by the Nueces County Tax Office; in San Patricio County, they are collected by the San Patricio County Appraisal District. Table 3.11-11 provides a summary of property tax jurisdictions and tax rates for jurisdictions that affect large portions of the population living in the vicinity of the study area.

TABLE 3.11-11

PROPERTY TAX JURISDICTIONS, NUECES AND SAN PATRICIO COUNTIES – 2000

Tax Jurisdictions	Tax Rate per $100 of Appraised Valuation
Nueces County	
Nueces County	0.352742
Port of Corpus Christi	0.023718
City of Port Arthur	0.470000
Corpus Christi Independent School District	1.570000
Port Aransas Independent School District	1.449057
Hospital	0.228028
Farm-to-Market Road	0.002738
San Patricio County	
San Patricio County/Drainage District	0.628500
San Patricio County Navigation District	0.036800
City of Ingleside	0.810000
Ingleside Independent School District	1.389180
City of Aransas Pass	0.831850
Aransas Pass Independent School District	1.487000
City of Ingleside-by-the-Bay	0.184620
City of Portland	0.570000
Gregory-Portland Independent School District	1.639100
Ingleside Industrial	0.810000

Sources: Nueces County Tax Office, 2001;
San Patricio County Appraisal District, 2001.

3.11.4 Land Use

Nueces and San Patricio counties lie in the Coastal Bend region of Texas. Land use within the two-county area consists of agricultural land, range-pasture land, industrial land, urban-residential and urban-commercial land, recreational land and facilities, military installations, and marshlands. Water use includes mineral production, commercial and sport fishing, recreation, and transportation.

In San Patricio County, agriculture has historically been, and continues to be, an important part of the economy despite the highly variable rainfall. Approximately 83 percent of the land is used for agriculture, of which about 36 percent is used for range and pastureland, and the remaining 64 percent is cultivated. Only about 9 percent is considered urban. In Nueces County, about 61 percent of the land is used for agriculture, 79 percent of which is under cultivation. Similarly, about 10 percent is considered urban (NRCS, 1992).

The study area for the proposed project encompasses Corpus Christi Bay, including the southern section of Redfish Bay and the northern section of the Laguna Madre, Nueces Bay, the lower Nueces River (12 miles), Tule Lake Channel, Viola Channel, La Quinta Channel and the watershed surrounding these water bodies up to roughly one-half mile inland from all shorelines (see Figure 1-1). The coastline of this area extends across Nueces and San Patricio counties and is adjacent to the cities of Corpus Christi, Portland, Ingleside-On-The-Bay, and Port Aransas.

Along the southern shore of Corpus Christi Bay, is the City of Corpus Christi. With a population of over a quarter million persons, Corpus Christi is the seventh largest city in Texas. Corpus Christi is also South Texas's regional center for banking, retailing, healthcare, and business. The Corpus Christi central business district (CBD) is located southeast of the ship channel entrance to the Inner Harbor (or the Port of Corpus Christi). The Corpus Christi CBD is the most densely urbanized of any area within the vicinity of the study area. Included in this area are skyscrapers, hotels, office buildings, apartment buildings, parks, civic buildings, and other businesses. Also, included in this area is the Convention and Visitors Bureau, the Art Center of Corpus Christi, the Memorial Medical Center, and the Corpus Christi Municipal Marina. Along the shoreline of the Corpus Christi Bay is Shoreline Boulevard and the Seawall, which serves as a gathering place for visitors, joggers, strollers, bikers, and others (Heines and Williams, 2001).

To the southeast of the Corpus Christi CBD along Ocean Drive (which parallels the Corpus Christi Bay Shoreline), land uses consist primarily of large single-family homes, apartments, condos, and a few businesses. Further to the east along Ocean Drive is the campus of Texas A&M University–Corpus Christi, which is built on a thin isthmus between Corpus Christi Bay and Cayo del Oso Bay. Located at the eastern end of Ocean Drive is the Corpus Christi Naval Air Station, a 4,400-acre facility.

The community of Flour Bluff extends south of the Corpus Christi Naval Air Station. This area is dominated by single-family homes with some schools, businesses, and vacant land. Boat docks, small private marinas, and gulf marshes border the western shore of the Laguna Madre within Flour Bluff.

The JFK Causeway crosses the Laguna Madre and connects Flour Bluff and Corpus Christi with North Padre Island. This causeway crosses a few small islands where a variety of restaurants, boat ramps, bait shops, and other fishing related businesses are located.

North Padre Island is located on the east side of JFK Causeway. The portion of this barrier island that is located within the vicinity of the study area contains a variety of land uses, including single-family homes, condominiums, apartments, hotels, restaurants, and other businesses. Businesses in this area cater to beachgoers, and fishermen who frequent this area. The Padre Isles residential community includes waterways and canals adjacent to large single-family homes. Packery Channel is a waterway that cuts through this portion of North Padre Island, but does not connect with the Gulf of Mexico. Nueces County manages the beaches along the Gulf of Mexico shoreline of North Padre Island.

Mustang Island is located north of North Padre Island and along State Highway 361 (SH 361). The southern end of Mustang Island is very sparsely developed, with only a few condos and single-family residences. Also located along the southern portion of Mustang Island is Mustang Island State Park. This state park includes beach access, campgrounds, and RV hookups. Traveling further north along Mustang Island toward the City of Port Aransas, the island becomes progressively more developed. Land uses consist of single-family homes, condos, apartments, hotels, and businesses that are located along SH 361. Also located in this area are the Island Moorings Marina and the Port Aransas Airport, a small landing strip. At the northern end of Mustang Island is the City of Port Aransas, a small coastal community that attracts surfers, beachcombers, anglers, artists, and tourists. Land uses in this area include single-family homes, condos, hotels, restaurants, civic buildings, and shops. The University of Texas – Marine Science Institute is located on the northeastern side of Port Aransas adjacent to the CCSC. The Port Aransas Municipal Marina, which provides docks for fishing and recreational boats, is also adjacent to the CCSC. The channel entrance to the CCSC is located on the north side of Port Aransas where ferries shuttle cars across the channel to Harbor Island to the north allowing cars to access Aransas Pass.

Harbor Island has a variety of land uses including petroleum tanks, industrial uses, fishing docks, bait shops, and a terminal site for the Texas Treasures Casino Cruises. SH 361 connects Harbor Island with the City of Aransas Pass. Aransas Pass is a small coastal community developed with single-family homes, condos, businesses, civic buildings, waterways and canals, and the Conn Brown Harbor.

Along the western shore of the Redfish Bay, south of Aransas Pass, land uses are mostly industrial, including the Gulf Coast Fabricators, a builder of offshore oil drilling platforms. Also within this area are two small private harbors with associated apartments, RV parks, and a wastewater treatment plant.

The City of Ingleside consists of residential, commercial, civic, industrial, and parkland uses. The Naval Station at Ingleside is located on the south side of town and is the headquarters for the Navy's mine warfare fleet and equipment. On the west side of Ingleside's CBD along the Corpus Christi Bay shoreline are a few major manufacturing plants, such as Reynolds Aluminum, DuPont, and OxyChem. Southeast of Ingleside are the south yards of the Gulf Marine Fabricators. South of Ingleside is the small community of Ingleside-On-The-Bay. Land use in Ingleside-On-The-Bay is mostly residential, concentrated near the Bahia Mar Marina. The CCSC passes just to the south of Ingleside-On-The-Bay.

The City of Portland is located west of Ingleside and north of Corpus Christi Bay and the Nueces Bay Causeway. Land uses in this area include residential, commercial, civic, and park land uses that are centered mostly along SH 35. The Hunt Airport is located on the southwest side of Portland. West of Portland, on the north side of Nueces Bay, land uses are mostly agricultural or vacant with some single-family homes and ranchettes.

Along the Nueces River, to the west of its confluence with the Nueces Bay, land uses are mostly residential and vacant. The area is characterized by a moderate degree of urban encroachment upon the 100-year floodplain (riparian zone). The Nueces River State Park provides an area for picnics and field sports along the river on the west side of IH 37.

The Port of Corpus Christi manages port commerce along the Inner Harbor of the CCSC which is south of Nueces Bay and northwest of the City of Corpus Christi CBD. The Port includes dock-side storage areas, open storage and fabrication sites, cargo terminals, refrigerated warehouse space, direct transportation support from three major rail carriers, and several State and Federal highways. The Port of Corpus Christi has renovated its Cargo Docks 1 and 2 into a multi-purpose cruise terminal/meeting and banquet facility (Port of Corpus Christi, 2001). Also located along the Inner Harbor are numerous heavy industry land uses. Along this industrial corridor, there are several refinery plants including the Koch Services, Citgo, and Valero plants. Included in this industrial zone is the Equistar Pipeline Operations, Valley Solvents and Chemicals, the Interstate Grain Port Terminal, ADM Growmark (grain elevators), and the Centex Cement Company. Also, in and around the Inner Harbor there are numerous small and large companies associated with equipment and supplies for vessels, shipping and receiving of dry bulk materials, construction materials and other goods, pipeline manufacturing, and a wide variety of other goods and services related to waterborne commerce (USACE, 2002).

North of the Inner Harbor along the Nueces Bay Causeway is a narrow strip of land known as Corpus Christi Beach that divides Corpus Christi Bay from Nueces Bay. In this area, there are a variety of land uses, including apartments, condos, restaurants, souvenir shops, and industrial uses. The USS *Lexington* (aircraft carrier) is permanently docked here and houses a historical naval museum.

3.11.4.1 Transportation

Surface transportation in the vicinity of Corpus Christi Bay is provided by a network of primary, secondary, and local roads.

IH 37 connects Corpus Christi and San Antonio by a distance of 140 miles. In Corpus Christi, IH 37 connects the Annaville, Calallen, Five Points, and Tuloso-Midway neighborhoods on the city's northwest side with the rest of the city. U.S. Highway 77 (US 77) connects Kingsville and Corpus Christi and is the most direct route to and from the Rio Grande Valley on the Mexican border. US 181 runs north from IH 37 near the Corpus Christi bayfront. It crosses the Harbor Bridge, Corpus Christi Beach and the Nueces Bay Causeway towards Portland. After passing through Portland, it veers northwest through several small towns of San Patricio County. SH 35 runs from US 181 north of Portland to Aransas Pass and Rockport. SH 361 runs east from SH 35 to Ingleside, Aransas Pass, Harbor Island, and the north ferry landing to Port Aransas. It then heads south down Mustang Island to Park Road 22 at the southern edge of Corpus Christi. Park Road 22 begins at the southeastern end of SH 358, known locally as South Padre Island Drive, and continues to the entrance of Padre Island National Seashore. SH 358 runs from west of the Crosstown Expressway (SH 286) to the Corpus Christi Naval Air Station on the city's southeast side. The Crosstown Expressway (SH 286) connects IH 37 with South Padre Island Drive (SH 358). Shoreline Boulevard/Ocean Drive runs along the Corpus Christi bayfront from north of IH 37 to the Corpus Christi Naval Air Station (Heines and Williams, 2001).

The Corpus Christi International Airport supports five airlines and a mix of jets and turbo-prop commercial planes providing air service to other major Texas city airports. The airport is located south of SH 44 on the west side of town. Construction has already begun on a 40- to 50-year master plan to upgrade the airport's facilities, an eventual cost of $70 to $80 million. The upgrade will eventually mean an additional 30 gates, more cargo planes, a new 10,000-foot runway, and 1,400 acres added to the airport (Heines and Williams, 2001).

Rail transportation is integral to the operations of the Port of Corpus Christi, and numerous industrial sites that are located within the Inner Harbor and surrounding the Corpus Christi Bay. The Port of Corpus Christi owns and manages 26 miles of rail lines within the Inner Harbor area known as the Corpus Christi Terminal Railroad, Inc. (CCTR). All of the Port of Corpus Christi docks that are located within the Inner Harbor are served by the CCTR. The Union Pacific Railroad (UPRR) provides direct rail access to all of the industrial sites located south of the CCSC in the Inner Harbor area. Two other railroads, the Burlington Northern Santa Fe Railway (BNSF) and the Texas-Mexican Railway, also provide service to the Inner Harbor area. In addition, the UPRR provides rail access to industrial sites located along the northern shoreline of the Corpus Christi Bay (Babin, 2002; Port of Corpus Christi, 2002).

3.11.4.2 Community Services

Fire protection within the vicinity of the study area is handled by a combination of municipal and volunteer fire departments (VFD). Fire departments serving the project study area include the City of Corpus Christi Fire Department, the City of Port Aransas VFD, the Ingleside VFD, and the Ingleside-On-The-Bay VFD.

Fire protection within the city limits of Corpus Christi is handled by the Corpus Christi Fire Department, which serves approximately 300,000 residents. This fire department has 15 stations and has a service area that covers approximately 139 square miles of land, 169 square miles of water, and 12 linear miles of beach along the Gulf of Mexico. The fire stations are located throughout the City and along North Padre Island to Calallen (City of Corpus Christi, 2001a).

The City of Port Aransas VFD provides fire protection and other emergency services to 10,000 people within a 10-square-mile area surrounding the city limits of Port Aransas. This VFD includes 22 volunteer fire fighters and has one fire station and seven fire trucks (Hatzenbuehler, 2002).

The Ingleside VFD provides service to 9,388 people within an 11-square-mile area surrounding the city limits of Ingleside. This VFD includes 49 volunteer fire fighters and has one fire station and nine fire trucks (Marroquin, 2002).

The Ingleside-On-The-Bay VFD provides service to 1,500 people within a 25-square-mile service area (Texas Emergency Services, 2001). This VFD includes approximately five volunteer fire fighters and has one fire station and one fire truck (Hosea, 2002).

The Insurance Services Office, Inc. (ISO) is the entity that evaluates the performance of fire departments throughout the U.S. The ISO rankings are determined through the examination of four primary factors: the city's alerting system (e.g., 911 service and fire alarm systems), the fire department, and the existing water system. In Texas, the *Fire Suppression Rating Schedule* has been modified to include the following fire prevention activities: fire prevention code information, fire investigation, public fire safety education, construction code enforcement, attendance at Texas A&M's Fireman Training School, the number of certified volunteer firefighters available, and membership in the State Fire Marshall's Association or Texas Commission on Fire Protection. On the *Fire Suppression Rating Schedule* scale of 1 to 10, (1 being best) the ISO gives the City of Corpus Christi Fire Department a rating of 4, the Port Aransas Fire Department a rating of 6, the Ingleside Volunteer Fire Department a rating of 5, and the Ingleside-on-the-Bay Volunteer Fire Department a rating of 5 (Bradley, 2002).

Law enforcement within the vicinity of the study area is served by both state and local services. The Texas Highway Patrol, a service of the Texas Department of Public Safety's Traffic Law Enforcement Division, maintains a district office in Corpus Christi. The Nueces County Sheriff's office and the Texas Highway Patrol serve the highways in unincorporated areas of Nueces County. In San Patricio County, the Texas Highway Patrol and the San Patricio County Sheriff's office serve highways in unincorporated areas of that county. Within the incorporated areas of the two counties, the cities of Corpus Christi, Port Aransas, Ingleside, Aransas Pass, and Portland all provide police protection.

In Nueces County, the 911 EMS Service is provided by Metrocom, which is located at the Corpus Christi Police Department. Metrocom dispatches EMS service through the Nueces County Sheriff's Department in unincorporated areas of the county and through the Corpus Christi Police Department for areas within the Corpus Christi city limits (Villarreal, 2001). In San Patricio County, 911 EMS service is covered by the Tri-County EMS for both incorporated and unincorporated areas of the county. The 911 service is dispatched through city police departments and the San Patricio County Sheriff's Department. Tri-County EMS has three stations that are located in Ingleside, Odem, and Portland. The City of Corpus Christi is covered for 911 Emergency Service for emergency medical, police and fire protection (Michaels, 2001).

Within Nueces and San Patricio counties, a variety of entities provide electric utility, natural gas, water, wastewater, and solid waste disposal services. These services are summarized in Table 3.11-12.

TABLE 3.11-12

PUBLIC SERVICES AND UTILITIES FOR VICINITY OF STUDY AREA, 2002

	Electric Utility Service	Natural Gas Service	Water	Waste Water	Solid Waste Disposal Service
City of Corpus Christi	Central Power and Light Co	City of Corpus Christi	City of Corpus Christi	City of Corpus Christi	City of Corpus Christi
City of Port Aransas	Central Power and Light Co	Reliant Energy (Entex, Inc.)	City of Aransas Pass	City of Aransas Pass	City of Aransas Pass
Unincorporated Nueces County	Nueces Electric Co-op	City of Corpus Christi	City of Corpus Christi	City of Corpus Christi	Nueces County (C.C. Disposal)
City of Aransas Pass	Central Power and Light Co	Reliant Energy (Entex, Inc.)	City of Aransas Pass	City of Aransas Pass	City of Aransas Pass
City of Ingleside	Central Power and Light Co.	Reliant Energy (Entex, Inc.)	City of Ingleside	City of Ingleside	BFI
City of Ingleside-by-the-Bay	Central Power and Light Co.	Reliant Energy (Entex, Inc.)	City of Ingleside	Septic System	BFI
City of Portland	Central Power and Light Co.	Reliant Energy (Entex, Inc.)	City of Portland	City of Portland	City of Portland
Unincorporated San Patricio County	Central Power and Light Co., and REA	Reliant Energy (Entex, Inc.)	Municipal Utility Districts, and private wells.	Municipal Utility Districts, and septic systems	Various private contractors.

3.11.4.3 Aesthetics

The term aesthetics deals with the subjective perception of natural beauty in a landscape by attempting to define and measure an area's scenic qualities. Consideration of the visual environment includes a determination of aesthetic values (where the major potential effect of a project on the resource is considered visual) and recreational values (where the location of a proposed project could potentially affect the scenic enjoyment of the area). Aesthetic values considered in this study, which combine to give an area its aesthetic identity, include:

- topographical variation (hills, valleys, etc.)
- prominence of water in the landscape (rivers, lakes, etc.)
- vegetation variety (woodlands, meadows, etc.)
- diversity of scenic elements
- degree of human development or alteration
- overall uniqueness of the scenic environment compared to the larger region

The study area consists of a variety of terrain characterized by varying levels of aesthetic quality. The topography of the area is mostly flat to gently rolling, with very few outstanding elevational changes. However, the study area consists mostly of open-water areas, including Corpus Christi Bay, Nueces Bay, the southern section of Redfish Bay, the northern section of the Laguna Madre, and the Lower Nueces River. Landscapes with water as a major element are generally considered visually pleasing, and this is the case for recreational land adjacent to these water features. However, the study area has also seen widespread urban development which can detract or add, depending on the type and scale, to the overall aesthetic quality. The study area includes a variety of land uses, including downtown business areas, shoreline residential development (single-family homes, condominiums, apartments), commercial development, public and private marinas, parkland, relatively undisturbed natural areas, fishing and tourism related businesses, hotels, military installations, civic uses, transportation systems (highways and railways), port facilities, and heavy industry areas. Generally, these areas are considered to be visually pleasing, with the exception of industrial and port facilities located along the Inner Harbor (CCSC) and other industrial facilities located along the north shore of Corpus Christi Bay and the western shore of Redfish Bay. However, generally speaking, the area is distinguished in aesthetic quality from other adjacent areas within the region that lack the vast water bodies of the study area and many of the outdoor recreational amenities. The landscape exhibits a generally moderate to high level of impact from human activities. No designated scenic views or scenic roadways were identified from the literature review or from field reconnaissance of the study area. However, areas along North Padre Island and Mustang Island have been identified by both TPWD and TxDOT as the Great Texas Coastal Birding Trail (TPWD, 2001).

3.11.4.4 Future Development and Development Restrictions

Urban development within the City of Corpus Christi is expected to continue to grow at a moderate pace in the near future, with most growth occurring within the south, southwestern, and northwestern portions of the city (Payne, 2001). The City of Corpus Christi has an ongoing Comprehensive Planning program that provides the public and private sectors with guidelines for future development within the city limits and the extra-territorial jurisdiction (ETJ). The Comprehensive Planning program includes the adoption of policy statements, Area Development Plans (ADP), the Capital Improvement Program (CIP), Master Service Plans, and Specific Area Plans (City of Corpus Christi, 2001b).

The following is a list of land use guidelines/restrictions and proposed land development projects potentially affecting development within the vicinity of the study area:

- Dune Protection and Beach Access Plan and Dune Protection and Beach Access Regulations – Mustang Island
- JFK Causeway Recreation Area Master Plan Study – includes the causeway and other publicly owned land, such as portions of SH 53 and SH 361, Packery Channel, and the Gulf Beach
- The Village Master Plan – partnership between the GLO and the City of Corpus Christi for design standards and guidelines for State owned lands on the island side of the JFK Causeway
- Corpus Christi International Airport Master Plan – additional 10,000-foot runway proposed
- Packery Channel Project – includes a public marina, a public park and promenade, an RV park, and related commercial (tourism and boating related) development

The City of Port Aransas is currently in the process of updating its comprehensive plan. Future development is likely to occur in southern Port Aransas along SH 361. In the long-term, more tourism-related development is likely to occur along the south side of the city, especially if the Packery Channel development occurs (Hallbrook, 2001).

The City of Portland adopted a Comprehensive Plan in 1998, which will serve as a guide for future development. Future residential growth is expected to occur to the east of downtown Portland, and along the Corpus Christi Bay shoreline. Future industrial development is expected to occur on the north side of Portland, along SH 181 (Boren, 2001).

The Port of Corpus Christi owns numerous large tracts of land along the Inner Harbor, along the northern shoreline of Corpus Christi Bay, on Harbor Island, and along the western shoreline of Redfish Bay. These parcels of land are available for industrial development. Also, the Port of Corpus Christi is proposing a container terminal to be located along the northern shoreline of Corpus Christi Bay, adjacent to La Quinta Channel, on a 1,100-acre tract known as the La Quinta Tract (La Rue, 2001).

3.11.5 Environmental Justice

In compliance with Executive Order (EO) 12898 – Federal Action to Address Environmental Justice (EJ) in Minority Populations and Low-Income Populations, an analysis has been performed to determine whether the proposed project would have a disproportionate adverse impact on minority or low-income population groups within the study area. The EO requires that minority and low-income populations do not receive disproportionately high adverse human health or environmental impacts and requires that representatives of minority or low-income populations, who could be affected by the project, be involved in the community participation and public involvement process.

The data used in this study to determine the potential for disproportionate impacts to low-income and/or minority populations within the project study area and within the region and the State are presented in tables 3.11-3 and 3.11-13. The information is based on 1990 U.S. Bureau of the Census (USBOC) state, county, and census tract level data for ethnicity and income.

In terms of ethnicity, the population living within the project study area census tracts is characterized by some differences, on average, from that of the State, Nueces County, and San Patricio County. The percentage of African-Americans within the study area (3.8 percent), on average, is higher than Nueces County (1.3 percent), lower than San Patricio County (4.2 percent), and substantially lower than the State (11.6 percent). The percentage of Hispanics within the study area (31.9 percent), on average, is substantially lower than San Patricio County (51.9 percent) and Nueces County (50.4 percent), but higher than the State (25.5 percent). Also, the percentage of other races within the study area (1.4 percent), on average, is slightly higher than both San Patricio County (1.1 percent) and Nueces County (0.7 percent), and lower than the State (2.2 percent). However, there are several individual census tracts within the study area where percentages of ethnic minorities are substantially higher than Nueces County, San Patricio County, or the State. These include the following census tracts in Nueces County: 3, 4, 5, 6, 12, and 29. These also include census tract 109 in San Patricio County.

On average, the percentage of people living below the poverty line within the study area census tracts (17.1 percent) is lower than that of San Patricio County (20.4 percent), Nueces County (25 percent), and the State (18.1 percent). However, there are several individual census tracts within the study area where percentages of people living below the poverty line are substantially higher than Nueces County, San Patricio County, or the State. These include the following census tracts in Nueces County: 4, 5, 6, and 12. These also include census tract 102 in San Patricio County.

TABLE 3.11-13

DETAILED 1990 POPULATION CHARACTERISTICS BY PROJECT AREA CENSUS TRACTS

Census Tract	Population	Number White	% White	Number African American	% African American	Hispanic Origin	% Hispanic	Number Other	% Other	Number Below Poverty	% Below Poverty
Nueces County											
3	1,618	751	46.4%	233	14.4%	623	38.5%	11	0.7%	313	19.3%
4	2,503	72	2.9%	1,260	50.3%	1,171	46.8%	0	0.0%	1,710	68.3%
5	2,433	118	4.8%	1,237	50.8%	1,070	44.0%	8	0.3%	1,041	42.8%
6	8,012	1,626	20.3%	691	8.6%	5,503	68.7%	192	2.4%	2,552	31.9%
7	3,902	1,800	46.1%	31	0.8%	2,029	52.0%	42	1.1%	906	23.2%
12	4,342	1,168	26.9%	217	5.0%	2,835	65.3%	122	2.8%	1,714	39.5%
14	4,726	3,197	67.6%	8	0.2%	1,463	31.0%	58	1.2%	564	11.9%
21	7,180	4,391	61.2%	113	1.6%	2,624	36.5%	52	0.7%	1,046	14.6%
25	4,374	3,499	80.0%	32	0.7%	804	18.4%	39	0.9%	406	9.3%
26	7,520	4,987	66.3%	114	1.5%	2,316	30.8%	103	1.4%	1,316	17.5%
27.01	5,087	3,974	78.1%	90	1.8%	953	18.7%	70	1.4%	493	9.7%
29	1,827	1,232	67.4%	230	12.6%	276	15.1%	89	4.9%	88	4.8%
30	8,121	5,802	71.4%	260	3.2%	1,804	22.2%	255	3.1%	1,561	19.2%
31	8,688	6,786	78.1%	191	2.2%	1,428	16.4%	283	3.3%	1,110	12.8%
35	2,371	1,148	48.4%	0	0.0%	1,223	51.6%	0	0.0%	400	16.9%
36.01	5,779	128	2.2%	128	2.2%	1,455	25.2%	30	0.5%	503	8.7%
36.02	6,359	4,583	72.1%	0	0.0%	1,751	27.5%	25	0.4%	559	8.8%
36.03	2,356	1,555	66.0%	15	0.6%	772	32.8%	14	0.6%	414	17.6%
37	3,136	1,928	61.5%	0	0.0%	1,196	38.1%	12	0.4%	405	12.9%
50	1,344	633	47.1%	17	1.3%	678	50.4%	16	1.2%	343	25.5%
51.01	2,750	2,505	91.1%	32	1.2%	166	6.0%	47	1.7%	149	5.4%
51.02	2,207	2,090	94.7%	0	0.0%	84	3.8%	33	1.5%	349	15.8%

TABLE 3.11-13 (Concluded)

Census Tract	Population	Number White	% White	Number African American	% African American	Hispanic Origin	% Hispanic	Number Other	% Other	Number Below Poverty	% Below Poverty
51.03	84	84	100.0%	0	0.0%	0	0.0%	0	0.0%	6	7.1%
58.01	3,954	3,239	81.9%	48	1.2%	616	15.6%	51	1.3%	210	5.3%
58.02	4,251	2,080	48.9%	7	0.2%	2,153	50.6%	11	0.3%	602	14.2%
Total/Avg.	104,924	59,376	56.6%	4,954	4.7%	34,993	33.4%	1,563	1.5%	18,760	17.9%
San Patricio County											
102	7,187	4,371	60.8%	252	3.5%	2,538	35.3%	26	0.4%	2,596	36.1%
103	6,656	4,822	72.4%	43	0.6%	1,758	26.4%	33	0.5%	1,009	15.2%
106.01	5,382	3,536	65.7%	0	0.0%	1,747	32.5%	99	1.8%	669	12.4%
106.03	1,045	925	88.5%	0	0.0%	116	11.1%	4	0.4%	11	1.1%
106.04	3,107	2,605	83.8%	26	0.8%	458	14.7%	18	0.6%	73	2.3%
107	1,894	1,357	71.6%	0	0.0%	537	28.4%	0	0.0%	380	20.1%
109	4,430	1,937	43.7%	0	0.0%	2,486	56.1%	7	0.2%	785	17.7%
Total/Avg.	186,025	111,490	59.9%	5,973	3.2%	57,959	31.2%	2,527	1.4%	30,894	16.6%
Total/Avg Both Counties	290,949	170,866	58.7%	10,927	3.8%	92,952	31.9%	4,090	1.4%	49,654	17.1%

Source: USBOC, 1990.

4.0 ENVIRONMENTAL CONSEQUENCES

4.1 WATER QUALITY

4.1.1 Water Exchange and Inflows

Under the No-Action alternative, water exchange and inflows would continue as they are described in Section 3.2.1.

The preferred alternative would have minimal impacts on water exchange and inflows. A study was conducted by the Texas Water Development Board (TWDB) which demonstrated changes in tidal amplitude of 0.06 feet (<0.72 inch) or less (Matsumoto et al., 2001) as projected for 106 sites around the project area. Based on the recommendations of the Hydrodynamic and Salinity Modeling Workgroup, the Cumulative Impact Workgroup, and the RACT, the study included the opening of Packery Channel and modifications to the JFK Causeway.

4.1.2 Salinity

Under the No-Action alternative, salinity would continue to be as is described in Section 3.2.2.

Like changes in tidal amplitude, the changes in salinity with the preferred alternative would also be minimal relative to existing conditions (Matsumoto et al., 2001), especially for an estuarine system. During normal to dry periods, the change in monthly average salinity would be as follows:

- Nueces Bay – from an increase of 0.11 ppt to a decrease of 0.33 ppt
- Corpus Christi Bay – from an increase of 0.38 ppt to a decrease of 0.41 ppt
- Upper Laguna Madre – from an increase of 0.04 ppt to a decrease of 0.28 ppt

During wet periods, the change in monthly average salinity would be as follows:

- Nueces Bay – from an increase of 0.09 ppt to a decrease of 3.22 ppt
- Corpus Christi Bay – from an increase of 0.12 ppt to a decrease of 4.25 ppt
- Upper Laguna Madre – from no increases to a decrease of up to 4.12 ppt.

As an examination of Matsumoto et al. (2001) will demonstrate, the larger decreases noted for the wet periods only occurred for a few months after an extremely wet period when salinities in Nueces Bay were reduced to around 1 ppt and were limited to portions of the bay.

4.1.3 Water and Elutriate Chemistry

Under the No-Action alternative, there would be no construction dredging; therefore, there would be no new work material for placement. While no turbidity or possibility for the release of undesired chemicals would occur, because there would be no placement, no chance for the decrease in long-term turbidity would result from the development of seagrass beds and wetlands in the BU sites where none exist now. The use of the new work material from the preferred alternative for BU sites would allow the creation of approximately 935 acres of unvegetated and vegetated shallow water habitat, including seagrass beds, with a long-term concomitant decrease in turbidity.

Under the No-Action alternative, the effects of maintenance material disposal on water quality would be as it is presently, as described in Section 3.2.3. There should be very little change with the preferred alternative. While there will be more maintenance material, the source of the maintenance material will not change and the method of placement will not change. There is the possibility of contamination of the maintenance material by a spill or other event, as there is now, but deepening and widening the channel and adding barge lanes should increase safety and decrease the probability of a spill. Additionally, the USACE routinely tests the elutriates prepared from maintenance material according to ITM and Green Book protocols before dredging to ensure that there are no causes for concern. As noted in Section 3.2.3, Tier I and Tier II evaluations indicated that past testing of maintenance material elutriates with chemical analyses and water column bioassays has indicated no cause for concern.

The No-Action alternative may or may not affect DO concentrations in the water column at PAs (Brown and Clark, 1968; Pearce, 1972; Hopkins, 1972; May, 1973; Windom, 1972; Wakeman, 1974). May (1973) found that although the water column DO did not change, there was a temporary decrease in DO at the water/sediment interface in the areas of mud flow. He also found little apparent difference in the immediate oxygen demand between recently deposited sediments from dredged material placement and other sediments. May (1973), Jones and Lee (1978), Peddicord (1979), and Lee (1976) agree that high total oxygen demand, as measured in the laboratory, does not necessarily lead to oxygen depletion upon placement since only a small part of the oxygen demand is exerted at placement. This would apply to both the No-Action and preferred alternatives.

The most obvious impact of the No-Action alternative to the estuarine water column is turbidity associated with maintenance dredging and placement, which has been shown to reduce primary production in laboratory studies (Sherk, 1971). Field studies, however, have shown essentially no biological impacts from turbidity (Odum and Wilson, 1962; May, 1973). May (1973) found that on a still day, the turbidity plume from an open-bay PA was detectable from an aircraft only a little more than 1 mile down current. On days when winds caused natural turbidity in an estuarine system, the plume was not detectable more than a few hundred yards down current from active disposal in an open-bay PA. Use of deflectors to direct the material toward the bottom and the use of deeper water for the open bay sites should reduce turbidity and any associated impacts. However, significant detrimental environmental effects have not been noted in past construction and maintenance operations and are not expected with the preferred alternative.

4.1.4 Brown Tide

Under the No-Action alternative, brown tide conditions would continue as described in Section 3.2.4. No changes in brown tide conditions are expected from the preferred alternative.

4.1.5 Ballast Water

The most likely existing foreign and domestic sources of ballast water that may potentially be discharged into Corpus Christi are from liquid and bulk vessels from foreign and domestic last ports of call coming to Corpus Christi to load cargo. The largest potential foreign sources are from within Mexico (15.4 percent), the West Indies/Caribbean group (1.8 percent), the Northern South America/Caribbean group (1.6 percent) and the Central America group (1.1 percent). The largest potential domestic sources of ballast water are from the states of Texas (37 percent), Florida (21.1 percent), and Louisiana (5.7 percent). About 20 percent of the Texas calls originated from the lightering zones in the open Gulf of Mexico. Compared with 1998 discharge estimates (13.51 mcy), potential ballast water discharge volume from foreign and domestic sources in year 2026 (15.67 mcy) increase for the No-Action alternative by 16 percent (Carangelo, 2001).

There are no significant existing container ship calls at Corpus Christi and that condition would likely continue under the No-Action alternative.

Under the preferred alternative, an estimated 3.8 percent decrease in all liquid and bulk vessel calls is anticipated with the CCSCCIP. Because of the efficiencies to be realized with the deepened channel, vessel trips in the Inner Harbor will decrease 3.8 percent between 2006–2056 with and without the preferred alternative (see economic appendix for details). Focusing on the liquid and bulk ships that come into port in ballast to take on cargo and compared with 1998 estimates, potential ballast water discharge volume for liquid and bulk ships in year 2026 (15.20 mcy) would increase 12.5 percent for the preferred alternative which is a 3 percent decrease from the No-Action alternative.

Container vessels represent a new shipping modality for Corpus Christi with identified trading regions including Europe, Central America, the Caribbean, and Latin America and the domestic Gulf of Mexico ports of call might also be contacted en route to Corpus Christi. The majority of these regions or ports currently, and are expected to in the future, trade directly or indirectly with Corpus Christi via the liquid and bulk vessel calls. No significant change in the existing mix of the ports or world regions that may potentially be sources of ballast water that could potentially be discharged into Corpus Christi is attributed to the preferred alternative. An estimated 1.57 mcy of ballast water could potentially be discharged annually from future container ship use of the proposed La Quinta Trade Gateway.

The combined estimate for year 2026 bulk and tanker vessels and future container vessels indicates 16.74 mcy of ballast water may potentially be discharged annually into Corpus Christi (Carangelo, 2001). Although this represents a potential 6.8 percent increase over the No-Action alternative, some container ships may require ballast discharge, but many do not (Hebert Engineering, 1999). Therefore, the preferred alternative is unlikely to present any significant increase or decrease in ballast water introductions compared with the No-Action alternative.

4.2 SEDIMENT QUALITY

4.2.1 Surficial Sediments

The quality of surficial sediments from the project area is discussed in Section 3.3.1. These are the surficial sediments that will be dredged during project construction. The discussion in Section 3.3.1 indicates no cause for concern with the construction material, except from the Inner Harbor, which will be placed in a UCPA. The CW and the RACT have determined that the construction material from the other reaches of the CCSC are of sufficient quality to be used for beneficial uses, except for the fine material from the upper bay which will continue to go into open-bay, unconfined placement.

4.2.2 Maintenance Material

The existing maintenance material was described in Section 3.3.2. The quantity and quality of this material would not be expected to change with the No-Action alternative. Additionally, it would not be expected to change with the preferred alternative. While slightly more maintenance material is estimated with the preferred alternative, the source of the maintenance material will not change and the method of placement will not change. As noted above, project actions should increase safety and decrease the probability of a spill. The USACE also routinely tests the maintenance material according to ITM and Green Book protocols before dredging to ensure that there are no causes for concern. As noted in Section 3.3.2, past testing of maintenance material with chemical analyses, whole mud bioassays, and bioaccumulation studies has indicated no cause for concern.

4.3 COMMUNITY TYPES

4.3.1 Submerged Aquatic Vegetation/Seagrasses

SAV is an important component in the Corpus Christi Bay estuary complex. As noted below, project impacts can be both negative (e.g., removal of seagrass beds) and positive (e.g., creation of SAV habitat).

The No-Action alternative would not directly impact SAV since there will be no dredging of new work material; however, it would not provide any net benefits to SAV since it would not provide a new 50-year DMM/BU Plan, with projects for SAV habitat creation and protection. Dredged maintenance material from the existing channels would continue to be placed in existing PAs, which includes confined, partially confined, and open-bay placement areas and would have minimal positive or negative impacts on SAV.

Continued industrial expansion coupled with increased ship traffic expected under the No-Action alternative increases the probability for collisions and hazardous materials spills, which could negatively impact SAV communities.

In general, SAV in this area can occur in shallow areas in water depths less than –4 feet MLT. The Mitigation and RACT workgroups determined that the –4-foot MLT bathymetric contour would be used to determine the worst-case scenario of impact to unvegetated bottom, that is potential SAV habitat, and seagrass vegetated habitat within the footprint of the proposed channel. The results of the survey indicate that bay bottom with water depths less than –4 feet MLT comprise approximately 45 acres that would be impacted by the preferred alternative.

Of the 45 acres, only 5 acres of patchy SAV, dominated by shoalgrass and lesser amount of manateegrass, would be directly impacted by the project. In lieu of actual surveys of the coverage of seagrass, the potential impacts to SAV, based on aereal coverage of seagrasses, field verification and water depth, are conservative and worst case. The impacts to SAV are associated with a spit on the north end of PA 13 and are due to the dredging of the La Quinta Channel extension. The construction of BU Site GH west of PA 13 could also impact up to 4 acres of SAV habitat; however, this impact will be avoided by the plan to separate Site GH from PA 13 by several hundred feet. Net positive impacts to SAV at Site GH would result from the creation of approximately 200 acres of shallow-water habitat suitable for colonization by SAV. The planting of 15 acres of seagrass within Site GH will be conducted as mitigation for the direct loss to the 5 acres of SAV during project construction.

The construction of other BU sites would have no direct negative impacts to existing SAV beds other than possibly SAV beds in Red Fish Cove which could experience some short-term, minimal effects from turbidity associated with channel dredging and the placement of dredged material for BU Site I. However, Site I would create approximately 163 acres of suitable SAV habitat and create approximately 15 acres of marsh habitat. Site P, primarily a wavebreak structure, should protect approximately 45 acres of existing SAV.

Altogether, the BU sites would result in the creation of approximately 935 acres of new habitat suitable for colonization by SAV, creation of approximately 26 acres of marsh, and the protection of approximately 45 acres of existing seagrass habitat. Other SAV beds in the area are either distant enough or protected from dredging activities by islands or levees and would not be impacted by dredging or placement activities.

The changes in salinity (seasonally and locally decreased by up to 4 ppt in wet periods and less than 1 percent during normal-to-dry periods) and tidal range (increased 0.04–0.06 feet) predicted in the TWDB simulation (Matsumoto et al., 2001) could cause some slight adjustment in the distribution of SAV. Although impossible to quantify, this change could cause a slight increase in the areal extent of SAV. However, the predicted changes in salinity and tidal range are very small and well within the tolerances and natural ranges of the common SAV species (Stutzenbaker, 1999). In fact, these values are much smaller than the effects of seasonal tides, so it is unlikely that they will cause an appreciable change in SAV distribution.

Potential indirect impacts could be caused by reduced photosynthetically active radiation conditions associated with increased total suspended solids; however, these would be short-term and localized, so impacts should be minimal. These impacts could be further minimized if dredging in close proximity to existing beds is scheduled to avoid seasonally high growth periods.

4.3.2 Coastal Wetlands

4.3.2.1 Salt Marshes/Estuarine Shrublands/Sand Flats/Mud Flats/Algal Mats

A shoreline erosion study (PIE, 2001a) that investigated the potential impacts on shoreline erosion from the preferred alternative was conducted for the PCCA at the request of the RACT. The potential impacts of the No-Action and the preferred alternatives were investigated for several factors that could potentially affect shoreline erosion.

The expected industrial expansion coupled with increased ship traffic for the No-Action alternative would raise the potential for collisions and hazardous materials spills, which could negatively impact coastal wetland communities. This potential would be reduced with the preferred alternative.

None of these habitats occurs within the footprint of the preferred alternative. However, dredging activities associated with the deepening and widening of the channel, maintenance dredging, and operation of the improved ship channel could have impacts on these habitats in the project area. A Section 404(b)(1) Evaluation is located in Appendix A which evaluates wetland impacts according to the Clean Water Act.

PIE (2001a) considered the differences in impacts on shoreline erosion between existing conditions and the preferred alternative for several factors including tidally induced current velocity, sea level rise, pressure field effects (draw-down), wind waves, vessel wakes, and channel morphology. PIE (2001a) concluded that, currently, the main factors contributing to shoreline erosion in this area were wind-generated waves and sea level rise.

Neither the existing or proposed conditions had consistently positive or negative impacts on shoreline erosion. However, the study concluded that overall, the CCSCCIP would slightly increase shoreline erosion, although compared with existing erosion, the effect would probably not be detectable (PIE, 2001a). The study found that, at the proposed La Quinta Channel extension, although there would be changes to the dynamics of the shoreline (due only to changes in the channel morphology), there may not be any net resultant shoreline erosion since the rates of accretion tend to offset the shoreline retreat. The greatest impacts would occur on the shorelines facing the channels, which support little, if any, vegetation. The impacts are discussed in detail in PIE (2001a).

The proposed BU sites would protect some areas of existing shoreline vegetation from erosion as well as result in creating 26 acres of marsh and protecting approximately 45 acres of seagrass habitat. None of the BU sites should negatively impact salt marshes or estuarine shrublands, tidal flats, or algal mats, but most would create and/or protect these habitats, primarily salt marshes and flats.

4.3.3 Open Water/Reef Habitat

These habitats and impacts on them are described in Section 3.4.3 and discussed in Sections 4.1 and 4.4.1.2. Impacts to water quality are expected to be minimal. No significant impacts are expected for recreational and commercial fisheries. Temporary and local impacts may occur during construction and maintenance dredging.

4.3.4 Coastal Shore Areas/Beaches/Sand Dunes

The current channel enters the Gulf of Mexico, separating San Jose Island to the north from Mustang Island to the south. The channel extends into the Gulf, protected on both northern and southern sides by rock jetties. The presence of the jetties impacts the shoreline by blocking the predominant north-to-south longshore drift. There is no beach nourishment program in place, and none has been identified or requested. Occasionally, the partially confined PA 2 adjacent to the channel on San Jose Island is used as a placement area for sandy maintenance material from a portion of the Lower Bay and can be directed to overflow onto the beach area just north of the jetty. A pipeline dredge is used to clear maintenance material from the Lower Bay on those infrequent occurrences when the rest of the Entrance Channel does not need dredging. PIE (2001b) concluded that, currently, the main factors contributing to shoreline erosion in this area were wind-generated waves and sea level rise.

The preferred alternative would deepen and extend the channel into the Gulf of Mexico with no change to the width of the channel at the jetties (i.e., outlet to the Gulf); however, the channel would be widened by 100 feet on the north side near the Inner Basin to allow a greater turning radius into the Redfish Bay portion of the channel. Beach nourishment is not part of the proposed BU program, so the preferred alternative does not differ from the current practice in this regard. Wind-generated waves and sea level rise would not change as a result of the preferred alternative. The amount of sediment that could pass seaward due to the extension of the channel will not increase significantly. However, deepening of the channel may result in an approximately 5 percent increase in the trapping efficiency of the channel translating into a sediment loss of 3,000 to 5,000 cubic yards per year from the longshore drift system (PIE, 2001b). This impact is expected to be insignificant to the adjacent shoreline. The preferred alternative may increase the peak velocities in the Lower Bay reach of the CCSC, indicating a marginal increase in tidal flux causing an increase in the sediment input from the ocean to the bay. Shoreline erosion or accretion due to the preferred alternative will not be significantly or noticeably impacted according to PIE (2001b).

4.4 FISH AND WILDLIFE RESOURCES

4.4.1 Finfish and Shellfish

Under the No-Action alternative, finfish and shellfish communities will continue as described in Section 3.5.1.

One impact that would increase during project construction is water column turbidity, but it would be local. Several field studies of turbidity from TSS associated with dredging operations have concluded that dredging had no substantial effects on nekton (Flemer et al., 1968; Ritchie, 1970; Stickney, 1972; Wright, 1978); however, other studies have shown that elevated turbidities can suffocate and reduce growth rates in adult and juvenile nekton and reduce viability of eggs (Moore, 1977; Stern and Stickle, 1978). Detrimental effects were generally recognized at TSS concentrations greater than 500 milligrams per liter (mg/l) and for durations of continuous exposure ranging from several hours to a few days. Turbidities exceeding 500 mg/l have been observed around maintenance dredging and placement operations (EH&A, 1980), and such turbidities may affect some aquatic organisms. For example, Clark and Wilbur (2000) include a figure that shows some mortality to estuarine and anadromous fish eggs and larvae at concentrations of 500 mg/l for durations as short as 24 hours. Adult estuarine and anadromous fish exhibited no effects, even sublethal, with one exception, at concentrations ≤500 mg/l for up to 16 days. In a study in Corpus Christi Bay, Schubel et al. (1978) reported TSS values greater than 300 mg/l but only in a relatively small area near the bottom. They also stated that TSS in Corpus Christi Bay from maintenance dredging is not greater than that from shrimping and affect the bay for much shorter time periods. May (1973) found that TSS was reduced by 92 percent within 100 feet of the discharge point, by 98 percent at 200 feet, and that concentrations above 100 mg/l were seldom found beyond 400 feet from the placement point. Turbidities can be expected to return to near ambient conditions within a few hours after dredging ceases or moves out of a given area.

The benthos at the proposed BU sites, which would have been used as a food source by local predators, would be temporarily lost due to burial, but the area of the BU sites is small compared with the entire project area and overall productivity recovers very quickly. Notwithstanding the potential harm to some individual organisms, compared with the existing condition, no significant impact on nekton populations is anticipated from the construction and maintenance dredging and placement operations with the preferred alternative.

The preferred alternative represents a small increase in habitat for those nekton species common in deeper offshore waters, which periodically invade the bay through the deep channel corridor (Breuer, 1962). Channel deepening and widening would also result in a slight increase in the availability of feeding and nursery area for demersal fish (Breuer, 1972).

The effects of maintenance dredging for the preferred alternative would generally be the same as those discussed for the No-Action alternative. Maintenance material would be primarily silt or sandy silt, which settles less readily and causes more turbidity than construction material which would be largely clay and sand. The overall effect would be reflective of the current maintenance dredging with the addition of the volume of the La Quinta extension and widening of the Corpus Christi Ship Channel.

In the unlikely event of an oil spill, however low the probability (see Section 2.2.2 for discussion of spill analysis), adult crustaceans such as shrimp, crabs, and adult finfish are probably mobile enough to avoid most areas of high oil concentrations. Their behavior, however, may be affected by some of the aromatic constituents of oil and become lethally disoriented. Larval and juvenile finfish and shellfish tend to be more susceptible to oil than adults. Juveniles could be affected extensively by an oil spill during their period of active immigration. Serious impacts to shrimp could also affect the commercial shrimping industry in the area, particularly the Laguna Madre if the oil spill is severe and widespread.

Although potentially severe damage could result from an oil spill, the chances of one occurring actually decrease with a wider and more efficient channel that increases navigation safety. This is from the use of fewer, more-heavily-ladened vessels instead of numerous smaller vessels to import the projected crude oil needs of existing and planned refineries. Since oil spills are a function of ship traffic, modern hull designs, and probability for accidents, the fewer trips made with the preferred alternative would decrease the threat of spills.

4.4.2 Recreational and Commercial Fisheries

Under the No-Action alternative, recreational and commercial fisheries will continue as described in Section 3.5.1.1.

Temporary and minor adverse effects on recreational and commercial fisheries may result from altering or removing productive fishing grounds and interfering with fishing activity. However, the evaluation of effects on the aquatic communities of the region (Section 4.4.1.3) concluded that no significant impacts to food sources for nekton were likely. Therefore, reductions of nekton standing crops would not be expected from the preferred channel expansion plans. In particular, major species of the nekton assemblage, including the sciaenid fishes and penaeid shrimp, should not suffer any significant losses in standing crop. Recreational and commercial fishing would, therefore, not be expected to suffer from reductions in the numbers of important species.

Dredging associated with the construction of the preferred alternative would result in temporary adverse effects on bay bait shrimping by displacing the bait shrimp along the channel, possibly interfering with trawling. Shrimpers may move their efforts, but less productive shrimping in other portions of the channel may result. Thus, loss of revenues to both bait shrimpers and dealers may occur. However, this would be similar to what occurs during maintenance of the channels under the No-Action alternative, with the exception of the extension into the Gulf and the La Quinta extension. Dredging associated with the maintenance of the preferred alternative would essentially be the same as the No-Action alternative.

The temporary adverse effects on bait shrimping resulting from construction dredging will be countered by the fact that an expanded channel is expected to result in a decrease in oceangoing ship traffic through the CCSC, due to the use of more-heavily-ladened vessels carrying the projected future throughputs. A decrease in oceangoing ship traffic will result in less interference to all recreational and commercial fishing activity taking place in the CCSC, particularly bay bait shrimping.

Repeated dredging and placement operations may temporarily reduce the quality of recreational and commercial fisheries in the vicinity of dredging operations. This may result from decreased water quality and increased turbidity during dredging and loss of attractiveness to game fish in the area resulting from loss of benthic animals. This is not a permanent condition; the quality of fishing in the vicinity of the channel and the placement areas should steadily improve after dredging is completed and would likely be similar to maintenance dredging under the No-Action alternative.

The direct effects of construction dredging on bay recreational fishing will again be similar to existing maintenance dredging except for the BU sites and the La Quinta Channel extension. The impact will be temporary, potentially resulting in local disturbances to both boat and wade-bank fishing, particularly along the edges of the channels. After initial construction, disturbed boat and wade-bank fishing areas along the CCSC and the La Quinta Channel extension should return to preconstruction conditions. However, recreational fishing at these locations, while locally important, does not constitute a significant portion of the overall recreational fishing effort in the study area. The additional habitat created by construction in the BU sites should provide additional recreational fishing opportunities. Construction activity in this portion of the channel should not significantly affect overall fishing in the general project area.

Construction dredging in and near the Aransas Pass inlet can potentially interfere with recreational fishing activity which is often concentrated there. The physical activity of dredging and the resulting local turbidity increases would combine to temporarily decrease the success rate and aesthetics of fishing in this area. However, impacts are expected to be similar to existing routine maintenance dredging operations.

The placement of dredged material in the designated offshore placement site may result in a localized effect on shrimp trawling and bottom fishing, as well as a slight disturbance to sport fishing for pelagic species. The topographic relief created by offshore placement in BU Site ZZ will result in the temporary loss of 1.83 square miles of Gulf bottom during construction of BU Site ZZ. However, NOAA charts indicate a sunken vessel exists in the site, which may inhibit shrimping there due to the possibility of hangs. In addition, the size of the area is small when compared with the total remaining similar bottom habitat available for fishing and shrimping. Creation of the topographic relief features at BU Site ZZ and Site MN should provide more diversity of habitat, which has the potential to become a fish haven. The placement of maintenance material in EPA-designated PA 1 may result in an isolated effect on shrimp trawling and bottom fishing, as well as a slight disturbance to sport fishing for bottom fishes. However, this effect should be similar to the No-Action alternative.

4.4.3 Aquatic Communities

Under the No-Action alternative, aquatic communities will continue as described in Section 3.5.1.2.

Benthic organisms will be buried and epibenthic nekton may be excluded from the immediate area of the open-bay PAs 14A – 17B by the deposition or flow of material across the bay bottom. The majority of these PAs have been used for construction and maintenance dredged materials placement for at least 25 years, and many for a longer period. Because of the prior use history, changes in sediment texture, and frequency of maintenance dredging, the PAs may not be similar to undisturbed areas of equivalent depth (Ray and Clarke, 1999). Ray and Clarke (1999), comparing PAs 15A – 17B with reference sites located on the opposite side of the CCSC from the PAs, also found evidence for long-term impacts from dredged material placement but found that the differences were rather subtle, and might be attributable to changes in depth (PAs were shallower) and grain size (PAs' sediments were coarser). They note that PA and reference areas had similar benthic assemblages but that the PAs "have a greater proportion of surpulid polychaetes and less echinoderm biomass than reference areas." Confined PAs that have become emergent as a result of prior use constitute a permanent loss of aquatic habitat at that location. Except for the use of construction and maintenance materials for habitat creation, protection, and enhancement as a consequence of construction of the BU sites, only existing open-water, unconfined- or confined-in-bay, and upland sites are proposed for use in the preferred alternative. Consequently, new permanent loss of aquatic habitat is avoided or minimized.

Turbidity in estuarine and coastal waters is generally credited with having a complex set of impacts on a wide array of organisms (Thompson, 1973; Hirsch et al., 1978; Stern and Stickle, 1978; EH&A, 1978). Suspended material can play both beneficial and detrimental roles in aquatic environments. Turbidity from TSS tends to interfere with light penetration and thus reduce photosynthetic activity by phytoplankton and seagrasses. Such reductions in primary productivity would be localized around the immediate area of the maintenance dredge operations in the CCSC and at the offshore and open-bay placement sites, and would be limited to the duration of the plume at a given site. Conversely, the decrease in primary production, presumably from decreased available light, has been found to be offset by increased nutrient content (Morton, 1977). In past studies of the impacts of dredged material placement from turbidity and nutrient release, the effects are both localized and temporary (May, 1973; Odum and

Wilson, 1962; Brannon et al., 1978). Thus, due to the reproductive capacity and natural variation in phytoplankton populations, the impacts of dredged maintenance material placement anywhere within the project area are not expected to be significant.

Dredging represents two problems for aquatic communities: excavation and placement. Excavation removes organisms, but organisms can rapidly recolonize a hole (Montagna et al., 1998). Approximately 352 acres of deep-water bay bottom will be lost to construction of barge lanes (7 acres) and channel widening (352 acres). Placement of dredged material may cause ecological damage to benthos in three ways: 1) physical disturbance to benthic ecosystems; 2) mobilization of sediment contaminants, making them more bio-available; and 3) increasing the amount of suspended sediment in the water column (Montagna et al., 1998). Organisms that are buried must vertically migrate or die (Maurer et al., 1986). Although vertical migration is possible, most organisms do not survive (Maurer et al., 1986). Studies show that open-water placement in Mobile Bay, Alabama, resulted in reduced benthic biomass, reduced redox potential discontinuity depth, and altered sediment relief. However, effects were confined to within 1,500 meters of the discharge point, and benthos recovered within 12 weeks (Clarke and Miller-Way, 1992). In a study of open-bay PAs 14A – 17B, Ray and Clarke (1999) found that "although dredged material placement initially had substantial impacts on placement area sediments and infauna, the deposited materials were worked into the existing sediment and community recovery was complete within a year of the dredging operation." An example of the impact and recovery can be found at Ray and Clarke's Plot E, which had a pre-dredging biomass of 41 g/m^2. After dredging, the biomass dropped to 5 g/m^2 and then rose back to 41 g/m^2, while the reference area remained constant, near 79 g/m^2.

Repeated dredging in one place may prevent benthic communities from full development (Dankers and Zuidema, 1995). Excavation destroys the community that previously existed but creates new habitat for colonization (Montagna et al., 1998). Excavation can actually maintain high rates of macrobenthos productivity (Rhoads et al., 1978). By repeatedly creating new habitat via disturbance, new recruits continually settle and grow. However, these new recruits are always opportunistic, small, surface-dwelling organisms with high growth rates and densities. Large, deep-dwelling organisms that grow slower and live longer are lost to the area of repeated excavation. In this way, excavation may not cause a decrease in production, but rather a large shift in community structure (Montagna et al., 1998).

Placement of construction and maintenance material in the proposed offshore placement site would bury those benthic organisms incapable of escaping or burrowing up through the dredged material. Burial of benthic organisms will occur during initial construction placement but the material is virgin ocean bottom, similar to that which presently exists in the BU site and recolonization should be rapid. Benthic community structure and abundance will eventually return to pre-placement levels since these sites will be used once only for placement of construction material. Additionally, the BUW and the RACT determined that creation of the topographic relief feature would be beneficial overall. The offshore maintenance PA (PA 1) is a currently used, EPA-designated site and future maintenance impacts should be similar to existing impacts. Potential beneficial effects of the suspended material associated with dredging operations include a resuspension of nutrients, absorption of contaminants in the water column, and addition of a protective cover allowing certain nekton to avoid predation (Stern and Stickle, 1978). As with the various potential detrimental effects, the importance of each of these latter effects would vary among groups and with the physiochemical parameters existing at the time and location of dredging and placement operations.

Effects of elevated turbidities on the adult stages of various filter-feeding organisms such as oysters, copepods and other species include depression of pumping and filtering rates and clogging of filtering mechanisms (Stern and Stickle, 1978). These effects are pronounced when TSS range from 100 mg/l to 1,000 mg/l and higher, but are apparently reversible once turbidities return to ambient levels.

A few scattered oyster reefs exist in Corpus Christi Bay as described in Section 3.4.3 and most of the reefs are dead. The nearest is Long Reef, which is approximately 3,000 feet away from PA 13 and 4,000 feet away from PA 15. No live oysters occur on Long Reef, but it is a valuable hard-structure resource. PA 13 is a UCPA and the effluent is returned to La Quinta Channel. Although PA 15 is an unconfined, open-water site, it is located in deeper water and is presently used frequently for maintenance dredging. Furthermore, the discharge point is submerged to minimize the spread of dredged material. There are some additional scattered reefs in the vicinity of PA 18, but this site is not presently in use and will not be used with the preferred alternative. Therefore, adverse impacts to oyster resources are not expected to occur as a result of construction or maintenance dredging and placement operations.

In the unlikely event of an oil spill, benthic fauna may be killed, but phytoplankton may be adversely or favorably affected by oil spills. It is unlikely that an oil spill in the Corpus Christi area would result in significant, long-term impact to either phytoplankton, zooplankton, or benthic communities since these organisms have the ability to recover rapidly from a spill due primarily to their rapid rate of reproduction and to the widespread distribution of dominant species. Additionally, as noted above, the chances of a spill occurring actually decrease with the more efficient channel in the proposed project.

4.4.4 Essential Fish Habitat

Under the No-Action alternative, EFH will continue as described in Section 3.5.1.3.

EFH for adult and juvenile white shrimp, brown shrimp, red drum, Spanish mackerel, Gulf stone crab, juvenile pink shrimp, and gray snapper occur in the project area including estuarine emergent wetlands, estuarine mud, sand, sand and shell substrates, SAV, and estuarine water column. However, there is no shell substrate in the areas to be dredged for the preferred alternative. Only a few, scattered, mostly dead oyster reefs exist in Corpus Christi Bay and the nearest is Long Reef, which is approximately 3,000 feet from PA 13, a UCPA from which the discharge is returned to La Quinta Channel. The placement of the maintenance material will bury bay bottom presently used as open-water, unconfined PAs. On the other hand, construction of the preferred alternative will have more beneficial than detrimental impacts since, for example, the proposed BU sites are strategically placed to prevent shoreline erosion and preserve and create seagrasses.

Approximately 5 acres of seagrasses and 40 acres of shallow-bay bottom will be lost to the preferred alternative dredging operations. For mitigation, approximately 15 acres of seagrass will be planted at Site GH and 40 acres of shallow-bay bottom will be created. The BU sites will create approximately 935 acres of habitat suitable for recolonization by submerged aquatic vegetation and 26 acres of marsh creation. BU Sites MN and ZZ will create 1,590 acres of offshore topographic relief for marine habitat as well. However, creation of the breakwaters and fringe levees to protect the BU site and existing special habitats will cause the permanent loss of 1,782 acre-feet of water column and 108 acres of existing bay bottom.

Juvenile brown shrimp and white shrimp will be temporarily and locally impacted by the loss of seagrasses and open-bay bottom, but will benefit by the creation of 935 acres of unvegetated and vegetated shallow water and marsh. Red drum are found throughout the project area in all life stages and will be temporarily and locally impacted from dredging and placement activities and permanently excluded from the lost water column, but will benefit from the creation of BU sites in the bay and offshore. Juvenile Spanish mackerel nurseries may be impacted temporarily and locally by dredging activities, but will benefit by a greater number of nursery sites created by the BU plan and adults will benefit from the offshore sites. Adult stone crabs may be impacted temporarily and locally by turbidity, but should not be permanently impacted by the preferred alternative dredging activities. They may, however, benefit from the creation of the stone breakwaters. Postlarvae and juveniles of pink shrimp will incur temporary and localized impacts in estuarine areas, but will benefit from the creation of BU sites. Adults inhabiting offshore waters near the project may be impacted by temporary turbidity, but will benefit from the creation of Sites MN and ZZ providing topographic relief. All life stages of gray snapper occur throughout the project area and may be temporarily and locally impacted from dredging activities, but will benefit from the creation of bay and offshore BU sites.

4.4.5 Wildlife Resources

The No-Action alternative would result in no immediate direct impacts to the terrestrial wildlife species or wildlife habitats at or near the proposed study area. Some of the habitats may change over time independent of the project. Commercial development and continued dredging and placement of dredged material occurring in the area could result in increased sedimentation and altered hydrology, which could have an impact on the aquatic community and, thus the food source of many coastal birds. The number of vessels in the area would decrease due to the preferred alternative, thereby decreasing the possibility of accidental oil or chemical spill in the area.

4.4.5.1 Dredging/Construction Activities

While dredging activities from the proposed project are unlikely to have a direct impact on terrestrial wildlife species, they may have an indirect impact. Such activities may cause temporary, local impacts to aquatic communities and habitats, including increased turbidity, which in turn may indirectly impact birds in the immediate vicinity of the activities by potentially reducing the availability of the food supply. These impacts are local and temporary and are not expected to be significant considering the size of the bay and the mobility of birds. The slightly increased possibility of accidental spills of oil, chemicals, or other hazardous materials during construction dredging activities also poses a threat to the aquatic community and, thus, the food source of many coastal birds in the area. Phytoplankton and zooplankton assemblages, which make up the foundation of the aquatic food chain, could be affected by a spill. While adult shrimp, crabs and fish are mobile enough to avoid areas of high concentrations of pollutants, larval and juvenile finfish and shellfish are more susceptible. Decreased marine traffic would reduce the potential for accidents and spills, and is otherwise not expected to have a direct effect on aquatic habitat. These effects would be short-term, however.

The noise of equipment and increased human activity during dredging activities may disturb some local wildlife, particularly birds, especially during the breeding season. Such impacts, however, should be temporary and without significant long-term implications. Salinity effects are not anticipated. Most infaunal organisms in the area are relatively tolerant of salinity fluctuations and would probably remain unaffected by any salinity changes related to dredging activities.

Dredging activities for the channel improvement would occur within 1,500 feet of several rookeries, most of which are infrequently used by a small number of birds. Table 4.4-1 provides information on nesting activities at these rookeries. Pelican Island, located just south of the CCSC, is a major brown pelican nesting area (see Section 4.5.2). Apart from the brown pelican, several species of heron, egret, tern, and gull also nest there. The Point of Mustang rookery occurs just to the east of Pelican Island. However, this rookery has not been active since 1994, when 30 pairs of least terns and 56 pairs of black skimmers were recorded. The Corpus Christi Channel rookery lies just to the west of Pelican Island. Seven pairs of great blue herons, 8 pairs of gull-billed terns, 160 pairs of least terns, and 60 pairs of black skimmers nested at this rookery in 2000. No birds have nested at the West Harbor Island rookery just north of Point of Mustang on the north side of the CCSC since 1994 when 42 pairs of least terns were recorded (GLO, 2000; FWS, 2001; TXBCD, 2001).

Rookeries occur on two placement areas adjacent to La Quinta Channel: Ingleside Point (Berry Island) and La Quinta (Table 4.4-1). Eight great blue heron nests, 2 great egret nests, 5 gull-billed tern nests, 15 least tern nests, and 170 black skimmer nests were recorded at these two rookeries in 1999. Least terns have not nested at the Castors Cut rookery since 1990, when 5 nests were recorded (FWS, 2001; TXBCD, 2001). A least tern colony is located at Tule Lake just south of and adjacent to the Tule Lake turning basin (TXBCD, 2001). However, this rookery has been used just twice since 1973: 14 nests were recorded in 1983 and 6 nests in 1993 (FWS, 2001).

The dredged material would be deposited in several areas as DMM/BU sites. At several sites, these beneficial use areas will be bordered by levees. Construction of these sites and levees would have similar impacts to the dredging activities in that they would be unlikely to have a direct impact on terrestrial wildlife species but may have an indirect impact. Temporary impacts to aquatic communities and habitat from increased sedimentation and turbidity would be expected. This in turn may impact birds in the area by potentially reducing the availability of their local food supply temporarily. This impact may be more noticeable at sites located near known bird rookeries. For example, sites R and S would be located adjacent to and on the south side of the Corpus Christi Channel rookery, while sites CQ and GH would be located to the south of the Ingleside Point rookery and to the west of the La Quinta rookery, respectively. Noise and increased human activity during construction may temporarily impact terrestrial wildlife in areas adjacent to the BU sites. These impacts are expected to be minor and short term.

TABLE 4.4-1

NUMBER OF NESTS OF COLONIAL WATERBIRDS
AT SELECTED ROOKERIES IN THE STUDY AREA

Rookery / ID	Common Name	Scientific Name	1995	1996	1997	1998	1999	2000
Tule Lake / 614-142	Least tern	*Sterna antillarum*						
La Quinta Spoil Islands / 614-160 (PA 13)	Great blue heron	*Ardea herodias*	1			8	7	
	Great egret	*Ardea alba*					2	
	American oystercatcher	*Haematopus palliatus*				2		
West Harbor Island / 614-181	Least tern	*Sterna antillarum*						
Ingleside Point/Berry Island / 614-182	Great blue heron	*Ardea herodias*			5		1	
	Gull-billed tern	*Sterna nilotica*			3		5	
	Least tern	*Sterna antillarum*			56		15	
	Black skimmer	*Rynchops niger*			95	70	170	
Point of Mustang / 614-183	Least tern	*Sterna antillarum*						
	Black skimmer	*Rynchops niger*						
Pelican Island / 614-184	Brown pelican	*Pelecanus occidentalis*	1,500	900	1,350	1,375	1,100	873
	Great blue heron	*Ardea herodias*	58	30	103	62	50	31
	Great Egret	*Ardea alba*	26	50	130	25	116	33
	Snowy egret	*Egretta thula*	66	30	130	59	84	40
	Little blue heron	*Egretta caerulea*	13	20	7	36	33	
	Tricolored heron	*Egretta tricolor*	378	150	550	343	261	301
	Reddish egret	*Egretta rufescens*	124	30	115	48	34	10
	Cattle egret	*Bubulcus ibis*	1,000	120	234	109	165	70
	Black-crowned night-heron	*Nycticorax nycticorax*	130	50	200	82	86	36
	White ibis	*Eudocimus albus*	68	40	81	75	311	140
	White-faced ibis	*Plegadis chihi*	309	15	123	63	47	53
	Roseate spoonbill	*Ajaia ajaja*	110	100	66	48	62	100
	Laughing gull	*Larus atricilla*	11,400		9,310	8,000	5,700	4,600
	Gull-billed tern	*Sterna nilotica*	4	5			8	3
	Caspian tern	*Sterna caspia*		1			18	
	Royal tern	*Sterna maxima*	20	10			218	660
	Sandwich tern	*Sterna sandvicensis*	10	5			108	780
	Forster's tern	*Sterna forsteri*						
	Least tern	*Sterna antillarum*					1	2
	Black skimmer	*Rynchops niger*	200	100	30	70	56	140
Corpus Christi Channel Spoil / 614-185 (PA 9, PA 10)	Great blue heron	*Ardea herodias*	10			1		7
	Gull-billed tern	*Sterna nilotica*						8
	Least tern	*Sterna antillarum*					110	160
	Black skimmer	*Rynchops niger*			75			60
Castors Cut / 614-203	Least tern	*Sterna antillarum*						

Source: Texas Colonial Waterbird Database (FWS, 2001).

4.4.5.2 Operational Activities

Once the initial dredging activities associated with the project have been completed, little further impact is anticipated. Maintenance dredging activities would have similar temporary impacts as the initial dredging, but on a much smaller scale and for a shorter term. A decrease in the number of vessel trips in the project area for the with-project conditions as compared with the without-project conditions would reduce the potential for erosion of some of the PAs with rookeries. Decreased vessel traffic would also reduce the potential for accidental chemical or oil spills. Such spills pose a threat to the aquatic community and, thus, the food source of many coastal birds in the area. Impacts from noise and human activity are unlikely to be a factor.

The BU sites would provide a substrate for seagrass beds, thus increasing the habitat for some aquatic species, which in turn could locally increase the food source for birds in the area. In addition, BU Site Pelican is expected to have a beneficial impact on the Brown Pelican. Placement of maintenance dredged materials will continue on the south side of Pelican Island for ongoing rookery island enhancement. Also, rock revetment on the northeastern corner of the island for erosion protection will be replaced. A 2,200-linear-foot hydraulically filled embankment will extend bayward from the east end of the island for shoreline erosion protection and to prevent a land bridge from forming across Pelican Island to Mustang Island to keep predators away.

4.5 THREATENED AND ENDANGERED SPECIES

A Biological Assessment (BA) has been prepared for this project for the purpose of fulfilling the USACE requirements as outlined under Section 7(c) of the Endangered Species Act of 1973 as amended and can be found in Appendix C. The BA will be reviewed by NMFS and FWS for their Biological Opinion and to ensure that all potential project impacts have been discussed and coordinated with the appropriate agencies during various workgroup meetings.

4.5.1 Flora

There are no records of occurrence in the TXBCD database for any Federally endangered, threatened or Species of Concern in areas likely to be impacted by the current ship channel including dredged material placement areas (i.e., No-Action alternative). The habitats of the endangered species in the bay area's county lists are not likely to occur in areas impacted by the current practice. Of the SOC species, only roughseed purslane habitat (dunes and brackish swales and marshes) might be affected by dredged material placement on PA 2 (San Jose Island by the jetty) which can overflow to the beach. However, this species is not known to occur at PA 2.

The TXBCD database (Element Occurrence Records on USGS quads) was reviewed and no Federally endangered, threatened or SOC species that appear in the county lists for the study area were noted in areas that may be impacted by the proposed project. The proposed project would not impact the habitats of any of the endangered species. Of the SOC species, only roughseed purslane, which occurs in dunes and brackish swales and marshes along the coast, might be in the Gulf shore beach dune habitat close enough to the dredging activities to be affected by disturbances (from dredged material placement) in this area. However, there is no difference from the potential impacts of the current practice.

4.5.2 Fauna

The No-Action alternative would result in no immediate direct impacts to any endangered species or endangered species habitat at or near the proposed project site, although some of the habitats may change over time independent of the project. Commercial development and continued dredging and placement of dredged material occurring in the area could result in increased sedimentation, which could have an impact on the brown pelican and other birds, as well as sea turtles. A decrease in the number of vessels in the area would reduce the potential for collision with any sea turtles in the area. Decreased erosion would also be expected from the decrease in boat traffic. Such increase in sedimentation or decrease in boat traffic would be less under the No-Action alternative than under the preferred alternative.

4.5.2.1 Construction Activities

A major brown pelican colony is located on Pelican Island, which is approximately 1,500 feet south of the CCSC (GLO, 2000; FWS, 2001; TXBCD, 2001). A total of 1,100 pairs of nesting brown pelicans was recorded at this rookery in 1999 and 873 pairs in 2000 (FWS, 2001; Table 4.4-1). Because of the proximity of this island to the CCSC, erosion from boat traffic may be a problem; however, the reduction in the number of vessels due to the project would lead to a decreased possibility of chemical or oil spills, diminishing the effect on the nekton community and, thus, the food source of the brown pelican. Loafing brown pelicans were encountered on Pelican Island outside of the nesting season as well as during the nesting season during PBS&J's surveys for the piping and snowy plover (PBS&J, 2001). Pelican Island is a designated PA for maintenance material only and will not receive construction material.

The white-faced ibis, a Federal SOC and State-threatened species, and the State-threatened reddish egret also nest on Pelican Island. In 1999, 47 nesting pairs of white-faced ibis and 34 pairs of reddish egret were recorded at this rookery, while in 2000, 53 pairs of white-faced ibis and 10 pairs of reddish egret were recorded (FWS, 2001; Table 4.4-1). Dredging activities in the area could indirectly impact these two species if they take place during the nesting season by potentially reducing the availability of the food supply. Noise during construction may also have an impact on the rookeries. The decreased possibility of chemical or oil spills would reduce impacts to the nekton community and, thus, the food source of the white-faced ibis and reddish egret.

PBS&J conducted a piping plover survey in the Corpus Christi Bay study area between September 2000 and April 2001 (PBS&J, 2001). The USACE and PBS&J met with the FWS and TPWD in Corpus Christi in the summer of 2000 to discuss the methods and areas of interest, relative to a piping plover and snowy plover survey. One-meter color infrared digital orthophoto quarter quadrangles of the study area were examined and potential areas of tidal elevation change were discussed. Areas within the study area, for which there was a paucity of data or where the resource agencies felt there might be impacts, were selected by the FWS and TPWD for an intensive 8-month survey. Results of the survey are in Appendix C. The piping plover and snowy plover have been recorded at several places near the CCSC, including East Flats, Harbor Island, Point of Mustang, and Pelican Island (PBS&J, 2001) (Figure 4-1). The minor changes in salinity and tidal amplitude as a result of the preferred alternative are

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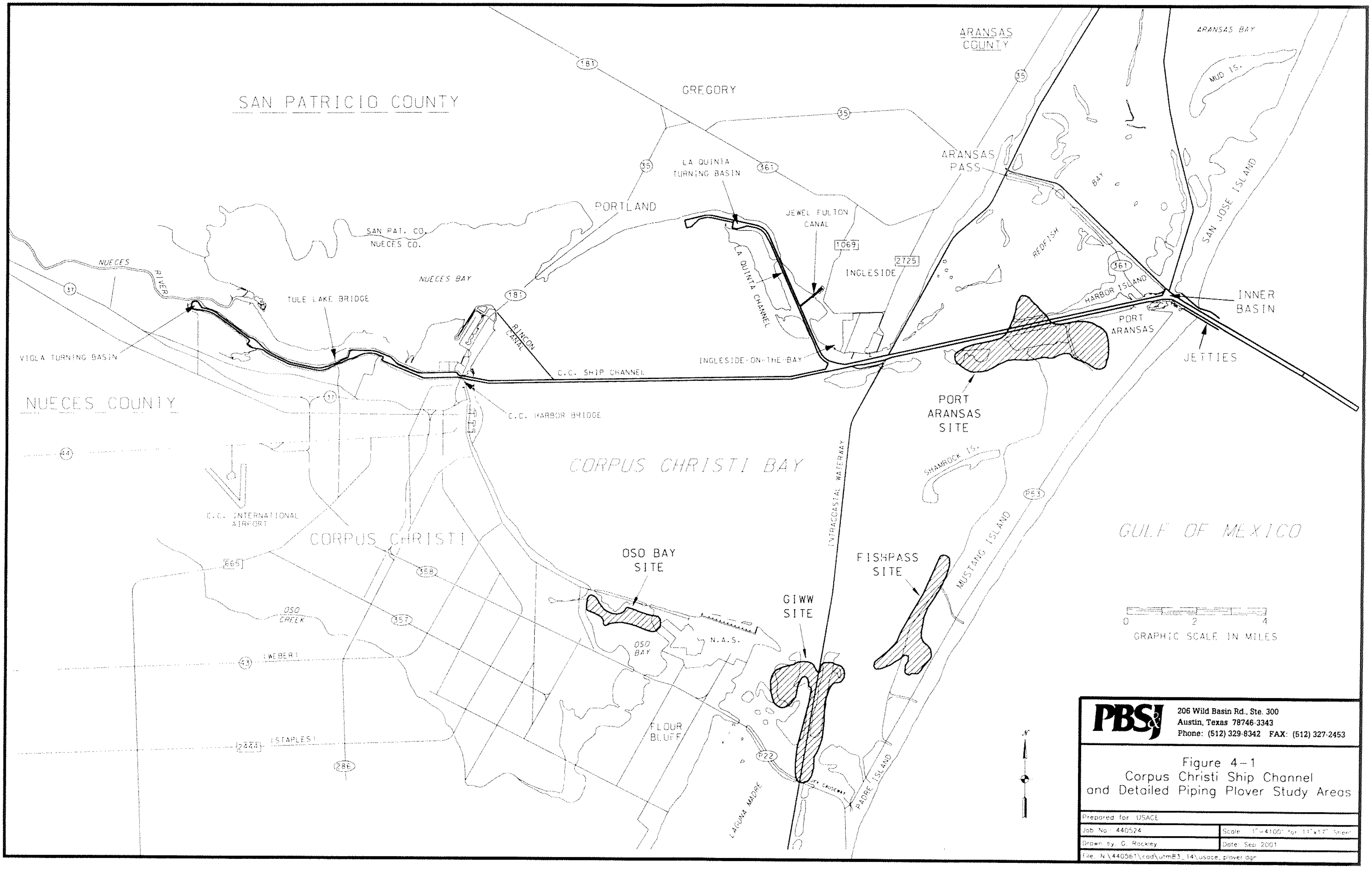
SAN PATRICIO COUNTY
GREGORY
ARANSAS COUNTY
ARANSAS BAY
MUD IS.
ARANSAS PASS
LA QUINTA TURNING BASIN
PORTLAND
JEWEL FULTON CANAL
SAN PAT. CO.
NUECES CO.
NUECES RIVER
NUECES BAY
INGLESIDE
LA QUINTA CHANNEL
REDFISH BAY
SAN JOSE ISLAND
HARBOR ISLAND
INNER BASIN
PORT ARANSAS
JETTIES
TULE LAKE BRIDGE
VIOLA TURNING BASIN
RINCON CANAL
C.C. SHIP CHANNEL
INGLESIDE-ON-THE-BAY
NUECES COUNTY
C.C. HARBOR BRIDGE
PORT ARANSAS SITE
CORPUS CHRISTI BAY
SHAMROCK IS.
INTRACOASTAL WATERWAY
C.C. INTERNATIONAL AIRPORT
CORPUS CHRISTI
MUSTANG ISLAND
GULF OF MEXICO
OSO BAY SITE
FISHPASS SITE
GIWW SITE
OSO CREEK
OSO BAY
N.A.S.
WEBER
STAPLES
FLOUR BLUFF
LAGUNA MADRE
PADRE ISLAND
0 2 4
GRAPHIC SCALE IN MILES
N
PBSJ
206 Wild Basin Rd., Ste. 300
Austin, Texas 78746-3343
Phone: (512) 329-8342 FAX: (512) 327-2453
Figure 4-1
Corpus Christi Ship Channel and Detailed Piping Plover Study Areas
Prepared for USACE
Job No: 440524
Scale 1"=4100' for 11"x17" Sheet
Drawn by: G. Rockley
Date: Sep 2001

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expected to have no impact on these two plovers. No designated critical habitat for the piping plover would be impacted and none of the above areas will receive any construction material.

Four species of sea turtle, Kemp's ridley, loggerhead, green turtle, and hawksbill have been recorded from Corpus Christi Bay (Shaver, 2000). In offshore waters, in addition to these species, leatherback sea turtles have also been recorded. Leatherback sea turtle strandings were also found in the project area (Heinly, 1990). If present in the area, sea turtles may be in danger of being sucked into the hopper during dredging in the entrance channel. Dredging activities could have an impact on these species through an increase in sedimentation and turbidity. Sedimentation may impact food sources for the turtles, and turbidity could affect primary productivity. This would be short term, however. No concerns relative to chemical compounds in new work materials were noted in sections 3.2 and 3.3. The decreased possibility of chemical or oil spills would be expected to have a positive effect on turtles both directly and indirectly through a reduced threat to their food source. A decrease in the number of vessels would result in a lower incidence of collision with sea turtles. Nesting habitat for sea turtles is confined to the Gulf beaches. Hence, nesting habitat and nesting activities are not expected to be negatively impacted by dredging.

Terrestrial reptiles such as the Gulf salt marsh snake (a Federal SOC) and the State-threatened Texas tortoise have been recorded from areas in the study area (TXBCD, 2001). No impact on these species is anticipated, however. The Texas diamondback terrapin (SOC), an inhabitant of brackish and saltwater coastal marshes, lagoons, and tidal flats, has also been recorded in the study area (TXBCD, 2001). The minor changes in salinity and tidal amplitude as a result of the project are expected to have no impact on this terrapin.

The No-Action alternative appears to have no significant detrimental effect on the listed candidate species. The PA located offshore could be beneficial to the dusky shark, sand tiger shark, night shark, and goliath grouper. The change in the bathymetry has the potential to aggregate fish, which would be a food source to these species. The TXBCD State-threatened opossum pipefish is not common in the dredged or placement areas, therefore no impacts are expected.

As noted for the No-Action alternative above, the preferred alternative appears to have no significant detrimental effect on the listed candidate species. The BU site located at the offshore placement area, could be beneficial to the dusky shark, sand tiger, night shark, and goliath grouper. The change in the bathymetry has the potential to aggregate fish, which would be a food source to these species. The deepened and widened channel area represents an increase in habitat for those nekton species common in deeper offshore waters which periodically invade the bay through the deep channel corridor (Breuer, 1962). The TXBCD State-threatened opossum pipefish has the potential to be positively impacted through the creation of emergent wetlands planted with *Spartina* in the BU sites. This fish has been reported in *Spartina* marshes and in *Sargassum* mats in the Gulf of Mexico (Hoese and Moore, 1998).

4.5.2.2 Operational Activities

Once the initial dredging activities associated with the project have been completed, little further impact is anticipated. Maintenance dredging activities would have similar temporary impacts as the existing without project practices. A decrease in the number of vessels in the area and the erosion protection features there may reduce the potential for erosion of the Pelican Island brown pelican rookery. Additionally, the proposed placement of routine maintenance material on Pelican Island, as at present, will be beneficial. Decreased boat traffic compared with future without-project traffic projections would also reduce the potential for accidental chemical or oil spills, as well as the potential for collision mortality for sea turtles. Impacts from noise and human activity are unlikely to be a factor.

Impacts to fish from operational activities would be the same as those discussed above for construction activities.

4.6 HAZARDOUS, TOXIC, AND RADIOACTIVE WASTE

4.6.1 Hazardous Material Impacts to the Existing Environment from Project Activities

The impacts from hazardous material use and handling during dredging activities associated with the preferred alternative pose a minimal risk of impacts to the environment. Typical impacts may include leaks or small spills associated with excavation and dredging equipment. However, these impacts would be minimal and typically do not pose a significant risk to the environment. The owners/operators of the pipelines located within the ship channels will be notified of the proposed dredging activities, and relocations will occur to comply with USGS regulations. The pipeline relocations have a potential for temporarily impacting the transportation of petroleum.

A review of a regulatory agency database information search, an aerial photographic review, interviews with regulatory officials, and a site reconnaissance was conducted to determine the location and status of sites regulated by the State of Texas and the EPA. This assessment identified 257 regulated properties in the study area. The environmental impacts that have resulted from these facilities vary greatly. The vast majority of these facilities do not appear to pose an environmental concern to the project. However, according to TNRCC officials, the industrial activity adjacent to the Inner Harbor of the CCSC and the La Quinta Channel has caused measurable impacts to the groundwater adjacent to these waterways.

Although the discharge of groundwater containing chromium and petroleum hydrocarbons has been documented in the Inner Harbor, all dredged materials from the Inner Harbor will go to UCPAs.

Groundwater seepage which reportedly contains carbon tetrachloride and perchloroethane has migrated and is discharging into La Quinta Channel. This discharge has potentially impacted the sediment of the ship channel. However, chemical analysis of La Quinta Channel sediments has indicated no cause for concern.

A total of 57 petroleum pipelines are reported to cross the CCSC, and six pipelines are reported to cross La Quinta Channel Extension. The proposed project could impact each of the pipelines located within the proposed dredging depth. Therefore, pipeline relocations have been made part of the project and would occur before dredging has begun.

A total of 1,568 permitted well sites are reported in the project area. Since dredging operations will be limited to existing ship channels, no impacts to oil and gas wells are expected.

4.6.2 Hazardous Material Impacts to the Project from Operation Activities

According to the regulatory agency database review, the historic utilization of the existing channels has not resulted in significant impacts to the environment. Future use of the deeper channels is not expected to result in greater impacts to the environment.

4.7 HISTORIC RESOURCES

All project impact areas have been evaluated for potential effects to historic properties. High probability areas that had not been surveyed during previous archaeological investigations, including Ricklis (1999), Highley et al. (1977), Hoyt (1990) and James and Pearson (1991), were investigated in conjunction with preparation of this FEIS (Enright et al., in preparation). The investigations reported by Enright et al. were performed to aid in the assessment of environmental consequences to historic properties for the proposed CCSCCIP and included multiple marine remote-sensing surveys and diver assessments. Scopes of work for historic properties investigations were coordinated with the Texas SHPO. Copies of agency correspondence are provided in Appendix D. Certain project impact areas were excluded from survey due to their low potential to contain significant historic properties or because of extensive prior disturbance. Such areas include landlocked portions of the Inner Harbor Reach, existing upland placement areas, previously designated and approved open-bay and offshore placement areas, and BU's MN, ZZ, L, Pelican, and the western 20 percent of BU Site GH.

Cultural resource investigations conducted in conjunction with this study have determined that proposed improvements will impact one significant historic property, the wreck of the *SS Mary* (41NU252), which is located immediately adjacent the Entrance Channel between the Port Aransas Jetties. Site 41NU252 was determined eligible for the NRHP based on SHPO concurrence with investigations by Hoyt (1990) and Pearson and Simmons (1995). One other potential NRHP property, an unidentified shipwreck (41NU264), is located immediately adjacent the Entrance Channel just beyond the end of the Port Aransas Jetties. No adverse impacts to Site 41NU264 are expected due to the fact that the channel has been naturally scoured to exceed the project depth, and no additional dredging is anticipated adjacent the wreck. No impacts are anticipated to terrestrial cultural resources.

Proposed improvements to navigation for the CCSC and La Quinta Channel include a channel extension offshore at Aransas Pass, deepening of the entire CCSC from the Entrance Channel to the Inner Harbor, widening of the CCSC across the Upper and Lower Bay reaches, and the addition of a channel extension and a turning basin at the head of the La Quinta Channel. In conjunction with improvements, dredged material will be placed in existing mid-bay PAs and in new BU sites that will be created in the bay and offshore areas. The proposed CCSC improvements (described in Section 2.2.2) include deepening the existing channel from –45 feet MLT to –52 feet MLT, plus 2 feet over-dredging allotment and 2 feet advanced maintenance, and widening the toe-to-toe measurement to 530 feet along all reaches except the Inner Harbor and Entrance channels. A 200-foot wide, 12-foot deep barge shelf additionally will be added to either side of the CCSC from the La Quinta Junction to the Harbor Bridge.

The Entrance Channel will be dredged to the –56-foot isobar which will extend the channel approximately 10,000 feet into the Gulf of Mexico. The proposed channel widening and the addition of the barge shelves will increase the impact zone width to approximately 770 feet from the inner end of the Entrance Channel to the La Quinta Junction (the Lower Bay Reach) and to approximately 1,000 feet from the La Quinta Junction to the bay end of the Inner Harbor Channel (the Upper Bay Reach). The La Quinta Channel proposed improvements include extending the existing channel 7,200 feet, at a depth of –39 feet MLT and a width of 300 feet, and the creation of a turning basin.

The placement plan for new work and dredged material (Section 2.2.2) involves using a combination of existing upland and open-water PAs, existing and new BU's in Corpus Christi Bay and the Gulf of Mexico, and the creation of one new upland BU north of La Quinta Channel, The proposed creation of BU sites in the bay and offshore areas will total approximately 935 acres of the bay bottom and 1,590 acres of the Gulf of Mexico. A variety of BU sites are proposed for use (Figure 1-3), including breakwaters, new marsh areas protected by breakwaters, a new upland natural area, the enlargement of existing bird islands, and the use of existing offshore feeder berms. Descriptions of individual BU sites are provided in Sections 1.6 and below as they apply to each channel reach.

All open-bay, offshore, and terrestrial PAs (Figure 1-2) were designated and cleared for continuous use by the CCSC 45-Foot Project (U.S. Army Engineer District, Galveston, Texas 1979). PAs are listed below in the context of the channel reach to which each applies. The footprints of existing PAs are not expected to change as a result of the CCSCCIP; therefore, no new impacts are anticipated in those areas. Existing unconfined PAs proposed for use in Corpus Christi Bay total 4,050 acres. PA 1, a 500-acre unconfined placement area, previously designated in the Gulf of Mexico, is also proposed for use by the CCSCCIP. Existing upland PAs total approximately 2,300 acres.

4.7.1 Entrance Channel

The Entrance Channel segment of the CCSCCIP is comprised of several distinct elements for which potential effects to historic properties must be evaluated. These include the existing Jetty and Outer Bar channels, the proposed Offshore Channel Extension, creation of BU sites MN and ZZ, and use of the existing PAs 1 and 2. Existing channel segments are addressed together below, since the proposed improvements are the same to both the jetty and outer bar channel segments.

4.7.1.1 Previous Investigations

Five historic properties investigations have been conducted within portions of the Entrance Channel as defined above. EH&A's 1989 survey (Hoyt, 1990) covered the immediate vicinity of the *SS Mary* wreck (Site 41NU252). That study included a remote-sensing survey, diver evaluation, and a NRHP assessment of the site. The site was recommended as eligible for the NRHP based on their work.

CEI's 1991 survey (James and Pearson, 1991) included a remote-sensing survey of the Jetty and Outer Bar channels (from Station 210+00 to Station –30+00) and diving at several anomalies. CEI recommended 7 remote-sensing targets along the Entrance Channel, in addition to the known wreck site of the *SS Mary,* for archaeological avoidance or further investigation. Those 7 targets were designated with the numbers 16, 20, 23, 24, 25, 31 and 32. A diving assessment of Target 31, conducted by CEI as part of the same project, revealed the presence of a potentially significant shipwreck, which was recorded as Site 41NU264. The other six targets were investigated by divers in 1993 (Pearson and Simmons, 1995). More extensive diver investigations of Target 31 (41NU264) and the *SS Mary* (41NU252) also were conducted during CEI's 1993 study.

In 1994, EH&A conducted additional diver investigations of Site 41NU264, believed incorrectly at the time to be the wreck of the *Utina* (Schmidt and Hoyt 1995). The site was thoroughly documented and was recommended as not eligible for the NRHP based upon the fact that better preserved examples of the *Utina* vessel type exist elsewhere. That site was recently proved by PBS&J to be misidentified. A shipwreck more closely matching the description of *Utina* has since been found south of 41NU264. The actual location of *Utina* is located well outside of the CCSCCIP impact area.

PBS&J's 2000 survey (Enright et al., in preparation) was conducted specifically for the CCSCCIP. That study included a remote-sensing survey of three areas: the proposed Outer Bar Channel Extension, the margins of the existing Outer Bar Channel, and the margins of the Inner Basin. The latter is located at the junction of the Jetty Channel and the Lower Bay Reach. PBS&J recommended four remote-sensing targets as potentially significant. Those targets were designated as anomalies M1, M2, M3 and M39. PBS&J conducted a close-order remote-sensing on the three targets that are located with the CCSCCIP impact area (M1, M2 and M3) and diver assessments of anomalies M1 and M3, both of which proved not to be archaeologically significant. Anomaly M2 is associated with the unidentified shipwreck at Site 41NU264. Anomaly M39 is associated with the suspected *Utina* wreck site and will not be affected by the CCSCCIP.

4.7.1.2 Environmental Consequences

Channel Extension

No adverse effects to historic properties are anticipated within the proposed Outer Bar Channel Extension Area. This area was surveyed by PBS&J in June 2000 (Enright et al., in preparation), and no potentially significant remote-sensing targets or historic properties were identified in this area. No adverse effects to historic properties are anticipated as a result of the channel extension.

Deepening of Existing Entrance Channel

Locations of three shipwrecks are known along the existing Entrance Channel. These vessels include Site 41NU252 (*SS Mary*), 41NU264 (unidentified vessel) and a vessel associated with Anomaly M39 (suspected location of the *Utina*; no site number yet assigned). Site 41NU252 is eligible for the NRHP. It is located along the south side of the Jetty Channel and will be adversely impacted by the CCSCCIP. Site 41NU264 is potentially eligible for the NRHP. It is located along the south side of the Outer Bar Channel, a short distance beyond the end of the jetties; however, no adverse impacts are anticipated at this site. The shipwreck at Anomaly M39 is located immediately adjacent the submerged seaward end of the southern jetty. The latter wreck is situated well clear of the Entrance Channel and will not be adversely impacted by the CCSCCIP.

The wreck of the *SS Mary* (41NU252) is located between the jetties at the base of the existing channel slope on the south side of the Jetty Channel. Although the exposed wreckage of the *SS Mary* is in very poor condition, it is eligible for designation as a State Archaeological Landmark under the criteria specified in The Antiquities Code of Texas, Section 191.091. The wreck was recommended by Hoyt (1990) as eligible for nomination to the National Register of Historic Places. Hoyt's recommendation was based on the *Mary*'s historic context, including the vessel's association with the Morgan Line steamship company owned by Charles Morgan (NRHP Criterion B: association with the lives of significant persons in the past), its service as a typical coastal steamer of the period (NRHP Criterion C: embodies the distinctive characteristics of a type, period or method of construction), and its construction by the innovative H&H Corporation (NRHP Criterion C). The THC subsequently concurred with that recommendation, thus the *Mary* is considered eligible for the NRHP.

Proposed channel deepening will adversely affect the wreck of the *Mary*. Based upon the position of the magnetic anomaly (Enright et al., in preparation), combined with positions of wreckage reported by Hoyt (1990), it appears that at least 16 feet of the *Mary's* stern should lie within the proposed dredging impact area of the CCSCCIP. Since the stern was never identified by divers, that portion of the vessel may have been impacted by the existing CCSC 45-Foot Project; however, a significant portion of the *Mary's* hull remains on the channel slope. The existing Jetty Channel depth at this location averages 52 feet MLT. On the south side of the channel, in the vicinity of the *Mary,* the channel has scoured to a depth of 55 feet MLT. Dredging to deepen the channel will impact sediments to a maximum depth of 56 feet MLT. Only minor slumping is expected before the channel slope again reaches equilibrium. Nevertheless, even minor slumping will adversely impact the *Mary* due to its proximity to the proposed new dredging.

Mitigation options for the *Mary* have been discussed in consultation with the Texas State Marine Archaeologist and the Texas SHPO (Stokes and Hoyt, 2000; Hoyt and Stokes, 2001). Data recovery is not feasible due to dangerous diving conditions, including currents in excess of 4 knots, proximity to ship traffic and near-zero visibility. The Galveston District USACE, therefore, recommends alternative mitigation measures, such as the preparation of a Texas maritime history curriculum module for use in public schools and construction of a museum display. A Memorandum of Agreement will be negotiated with the Texas SHPO, which details these alternative mitigation requirements.

A second shipwreck site (41NU264), considered potentially eligible for the NRHP, was discovered near the Outer Bar Channel by remote-sensing and diver investigations (James and Pearson, 1991; Pearson and Simmons, 1995). Site 41NU264 is located immediately adjacent the south side of the channel slightly seaward of the Aransas Pass jetties. This site was tentatively identified as the shipwreck of the *Utina* (Pearson and Simmons, 1995). Schmidt and Hoyt (1995:74-77) agreed with CEI's tentative identification of the site as the *Utina* and recommended that Site 41NU264 was not archaeologically significant based largely on the fact that several better-preserved examples of the *Utina* vessel type exist in the Sabine River. Recent information has come to light, however, which calls into question the identity of the vessel wrecked at Site 41NU264.

A more likely candidate for the *Utina* was discovered inadvertently by PBS&J during the summer of 2000 when, during a close-order magnetometer survey of Site 41NU264, another wreck was discovered at the end of the south jetty. PBS&J designated the latter wreck site as Anomaly M39. A trinomial site number has not been assigned as of this writing. Dimensions of the side-scan sonar target associated with M39 closely match the size of the *Utina*. Furthermore, the *Utina* is known from historic documents, including photography, to have stranded on the Gulf end of the south jetty (Schmidt and Hoyt, 1995), precisely where M39 is located. Site 41NU264, on the other hand, is located in deep water between the jetties on the southern margin of the ship channel. A strong case can now be made that the vessel at Site 41NU264 is not the *Utina*. Given this new information, however, Site 41NU264 must once again be considered potentially eligible for the NRHP until such time as its identity can be firmly established.

No additional research or mitigation is recommended for Site 41NU264, as the project is not expected to impact the wreck. The northern limit of wreckage, as seen on recent side-scan sonar images recorded by PBS&J, is located 14 feet south of the proposed channel toe. A recent cross-section of the existing channel in the vicinity of the site documents scouring to a depth of 65 feet MLT. No additional dredging is anticipated adjacent the wreck, since deepening of the channel will only impact sediments to a depth of 56 feet MLT.

The potential for impacts to this Site 41NU264 from erosion associated with the draw-down effects of more heavily laden ships also was evaluated using the results of a shoreline erosion study prepared by the Port of Corpus Christi for this project (Shepsis, 2001). From that study, it can be deduced that pressure field waves created by the draw-down of passing ships will play a relatively minor role in shoreline erosion, as compared to sea level rise, for example, over the next 50 years. The erosional effects of draw-down are most significant in shallow water and along steep slopes. Bottom water velocity increases as the energy from the draw-down and return waves becomes concentrated by the narrowing water column in shoal areas. Post-project bottom slopes in the vicinity of 41NU264 are not expected to differ significantly from present conditions. Ships are expected to displace more water following completion of the project due to heavier loads; however, no appreciable change in erosion rates is expected at this site. Shallow areas having relatively flat slopes, tend to experience sediment movement both toward and away from the channel (Shepsis, 2001: 2-32). Extrapolating to a flat slope in deep water, where draw-down and return wave velocities should be significantly less, the net sediment transport under such conditions is expected to result in minimal erosion of the site.

BU Site MN

BU Site MN is proposed to be approximately 440 acres. It would be located just outside of the 30-foot isobath (approximately 6,500 feet offshore) and 10,000 feet south of the project channel centerline. No shipwrecks are charted in the area of BU Site MN. Communication with the Texas State Marine Archaeologist determined that no remote-sensing survey would be required over BU Site MN because of the low potential for wrecks in the area (Murphy, 2001). No environmental consequences are anticipated for historic properties within the proposed BU Site MN (Hoyt and Stokes, 2001).

BU Site ZZ

Creation of BU Site ZZ originally was proposed as part of the Navy Homeport Project. It is proposed to be approximately 1,150 acres and is located approximately 15,300 feet southeast of the southern Aransas Pass jetty. One shipwreck is recorded within the limits of BU ZZ on NOAA Chart 11307. The AWOIS database reports this wreck (AWOIS Record 7907) as a 42-foot modern fishing vessel, lying in approximately 51 feet of water. The wreck was first reported by a Local Notice to Mariners in 1986 and is not considered a potential historic resource. A remote-sensing survey was not conducted over BU ZZ as a previous EIS, prepared by the EPA (1988), found that the use of BU ZZ will not impact sites of historical importance. No environmental consequences are anticipated for historic properties within the proposed BU Site ZZ (Hoyt and Stokes 2001).

Existing PAs

Two existing PAs (1 and 2) would be used for placement of dredged material from the Entrance Channel Reach. PA 1 is an existing offshore placement area which was previously approved for use as part of the CCSC 45-Foot Project (USACE, 1979). It covers approximately 500 acres and is located 5,300 feet southeast of the southern Aransas Pass jetty. No shipwrecks are recorded in the vicinity of PA 1, and no significant historic properties are expected to exist there (Hoyt and Stokes, 2001). A remote-sensing survey was not conducted over PA 1 as a previous Environmental Impact Statement, prepared by the EPA (1989), found that use of PA 1 would not impact sites of historical importance. PA 2 is an existing upland placement area on San Jose Island, which was approved for continuous use as part of the CCSC 45-Foot Project (USACE, 1979). No modifications of the existing PA footprints are proposed. No adverse effects are anticipated for historic properties due to the use of either PA 1 or PA 2.

4.7.2 Lower Bay

The Lower Bay Reach of the CCSCCIP is comprised of several distinct elements for which potential effects to historic properties must be evaluated. These include widening and deepening of the existing CCSC, creation of BU Sites I, R, S, L and Pelican, and use of the existing PAs 4-10. BU Site I would be located on the north side of the ship channel between Dagger Island and Pelican Island and would involve approximately 163 acres of bay bottom. BU sites R (201 acres) and S (121 acres) would be located on the south sides of existing PAs 9 and 10, respectively. BU Site L, proposed for the north side of Mustang Island east of Piper Channel, would consist of a rock revetment to serve as a marsh/ecosystem protection site. BU Pelican would consist of an armored barrier on the north and east sides of Pelican Island, to protect habitat from wind and wave erosion of PAs 7 and 8 and containment of routine placement of maintenance dredged material.

4.7.2.1 Previous Investigations

Four archaeological investigations have been conducted along the Lower Bay Reach. A remote-sensing survey conducted by CEI (James and Pearson, 1991) partially covered the CCSCCIP in the Lower Bay Reach using a 164-foot survey line interval. CEI recommended a single side-scan target (Sonar Target 40) as potentially significant. Target 40 did not have an associated magnetic anomaly and was recorded in 50 feet of water. It was investigated by archaeological divers as part of the same project;

however, divers were unable to locate an object at that location. Since Target 40 was mapped in an area which had been disturbed by dredging, no further investigation was recommended.

CEI conducted a remote-sensing survey along the GIWW across Corpus Christi Bay in 1994 (Pearson and Wells, 1995). One potentially significant target was identified at the intersection of the GIWW and the CCSC by their study. Target 1, as it was designated, was considered potentially associated with the wreck of the steamboat *Dayton* which occurred in the vicinity in 1845. CEI divers investigated Target 1 in 1996 (Pearson and James, 1997), determining that it was, instead, associated with a section of discarded dredge pipe. No further investigation of the target was recommended to follow that study.

PBS&J conducted a series of remote-sensing surveys, followed by diver investigations in 2000 and 2001 (Enright et al., in preparation). Those investigations were performed for the CCSCCIP and included, in the Lower Bay Reach, a remote-sensing survey of the area to be affected by channel widening and deepening, a remote-sensing survey of BU sites I, R and S, a close-order remote-sensing survey of 11 magnetic anomalies, and archaeological diver investigations on 7 anomalies. A total of 10 magnetic anomalies, designated M4-M13, were recommended as potentially significant following the survey along the CCSC through the Lower Bay Reach in June 2000. During the close-order survey of those 10 anomalies in December 2000, one additional potentially significant anomaly (M38) was discovered mid-way between M12 and M13. M38 also was surveyed using a close line interval at that time. Two additional anomalies (I1 and I3) were recommended as significant based on the results of BU surveys in June 2001.

Anomalies M4-M6, M8, and M10-M11 were recommended as not significant based on the results of the close-order survey. Archaeological divers investigated the remaining 7 anomalies, including M7, M9, M12, M13, M38, I1 and I3. Potentially significant archaeological remains were found at one location, Anomaly M38. All of the other anomalies have been recommended as not archaeologically significant based upon the results of diver investigations.

Anomaly M38 marks the location of a buried shipwreck which is consistent in its location, water depth, hull width and construction materials with the wreck of the steamboat *Dayton.* The *Dayton* is known from historic documents to have sunk in this vicinity in 1845 following a boiler explosion. Because of this possible associate, Anomaly M38 is recommended as potentially eligible to the NRHP.

4.7.2.2 Environmental Consequences

Channel Widening and Deepening

The location of one shipwreck has been documented in the vicinity of the CCSC along the Lower Bay Reach. Diving investigations conducted by PBS&J in 2001 at Anomaly M38 revealed suspected historic vessel remains buried beneath 6 feet of sediment. The identity of those remains has not been firmly established; however, they are consistent with the historic steamboat *Dayton* which blew up and sank in this vicinity in 1845. This site is considered potentially eligible for the NRHP. The northern edge of Anomaly M38 is located approximately 95 feet south of the projected new top of channel slope, thus the shipwreck associated with Anomaly M38 will not be adversely affected by the CCSCCIP.

BU Site I

BU Site I is proposed to be approximately 163 acres and is located on the north side of the CCSC between Dagger Island and Pelican Island. No shipwrecks are plotted in the vicinity of BU Site I. PBS&J's 2001 survey recommended avoidance or further investigation of two magnetic anomalies (I1 and I3) within Site I. Diver investigations cleared these sites as modern debris (Enright et al., in preparation). No adverse effects to historic properties are anticipated due to the creation of BU Site I.

BU Site R

BU Site R is proposed to be approximately 201 acres and is located on the south side of PA 9. PBS&J's 2001 survey of BU R did not locate any potential historic properties. No adverse effects to historic properties are anticipated due to the creation of BU Site R.

BU Site S

BU Site S is proposed to be approximately 121 acres and is located on the south side of PA 10. No shipwrecks are plotted in the vicinity of BU Site S. PBS&J's 2001 survey did not locate any potential cultural resource sites in this area. No adverse effects to historic properties are anticipated due to the creation of BU Site S.

BU Site L

The area proposed for construction of this rock revetment consists of made land. This location was not subjected to a cultural resource survey, as no disturbance of the natural bay bottom is expected. No adverse effects to historic properties are anticipated due to the creation of BU Site L.

BU Pelican

BU Pelican consists of a geotube placement atop previously deposited dredged material. The geotubes are meant to prevent material runoff from an adjacent placement area. A remote-sensing survey was deemed unnecessary as the natural bay bottom has already been covered by dredged material from the adjacent placement area. The presence of the geotubes will not impact the natural bay bottom in this area further (Hoyt and Stokes, 2001). No adverse effects to historic properties are anticipated due to the creation of BU Pelican.

Existing PAs

Seven existing PAs (4, 5, 6, 7, 8, 9 and 10) would be used for placement of dredged material from the Lower Bay Reach. These PAs were previously approved for continuous use as part of the CCSC 45-Foot Project (USACE, 1979). No modifications of the existing PA footprints are proposed, and no adverse effects are anticipated for historic properties due to their continued use.

4.7.3 Upper Bay

The Upper Bay Reach of the CCSCCIP is comprised of several distinct elements for which potential effects to historic properties must be evaluated. These include widening and deepening of the existing CCSC, creation of barge lane shelves on each side of the widened channel, creation of BU Site CQ, and use of the existing PAs 14A, 14B, 15A, 15B, 16A, 16B, 17A, and 17B (see Figure 1-2). BU Site CQ would be located south of Berry Island and west of the CCSC/La Quinta Channel junction (see Figure 1-3). Site CQ would use new work materials to create approximately 250 acres of shallow water habitat and emergent flats and 6 to 10 mounds of material placed in a northwest to southeast direction to decrease fetch.

4.7.3.1 Previous Investigations

Two archaeological investigations have been conducted along the Upper Bay Reach. A remote-sensing survey conducted by CEI (James and Pearson, 1991) partially covered the CCSCCIP in the Upper Bay Reach using a 164-foot survey line interval. CEI recommended a single side-scan target (Sonar Target 47) as potentially significant along this reach of channel. Target 47 did not have an associated magnetic anomaly and was recorded in 47 feet of water. It was investigated by archaeological divers as part of the same project; however, divers were unable to locate an object at that location. It was determined that Target 47 was a bottom scar. Target 47 was located in an area which had been disturbed by dredging. No further investigation was recommended.

PBS&J conducted a series of remote-sensing surveys, followed by diver investigations in 2000 and 2001 which included the Upper Bay Reach (Enright et al., in preparation). Those investigations were performed for the CCSCCIP and included a remote-sensing survey of the areas to be affected by channel widening and deepening and by construction of barge lane shelves along each side of the channel, a close-order remote-sensing survey of 9 magnetic anomalies, a remote-sensing survey of BU Site CQ, and archaeological diver investigations of 3 anomalies. A total of 9 magnetic anomalies, designated M14-M22, were recommended as potentially significant following the survey along the CCSC through the Upper Bay Reach in June 2000. No additional anomalies were recommended as significant based on the results of the BU Site CQ survey in June 2001. Anomalies M15-M16, M18-M20 and M22 were recommended as not significant based on the results of the close-order survey. Archaeological divers investigated the remaining 3 anomalies, including M14, M17 and M21. All three anomalies were recommended as not archaeologically significant based upon the results of diver investigations.

4.7.3.2 Environmental Consequences

Channel Widening and Deepening and Barge Lane Creation

There are no known historic properties or potentially significant remote-sensing targets located in this area. Four remote-sensing targets have been investigated by divers along the Upper Bay Reach (1 by CEI and 3 by PBS&J); however, all of those anomalies were determined not to be archaeologically significant. No adverse effects to historic properties are anticipated as a result of the proposed new dredging along this channel reach.

BU Site CQ

BU Site CQ (Figure 1-3) is proposed to be approximately 250 acres and is located to the south of Berry Island and west of the CCSC/La Quinta Channel junction. No potential historic properties are known to exist in this area, and PBS&J's 2001 remote-sensing survey did not locate any potentially significant remote-sensing targets there. No adverse effects to historic properties are anticipated due to the creation of BU Site CQ. .

Existing PAs

Eight existing, unconfined open-bay PAs (14A, 14B, 15A, 15B, 16A, 16B, 17A, and 17B) would be used for placement of maintenance material from the Upper Bay Reach. These PAs were previously approved for continuous use as part of the CCSC 45-Foot Project (USACE, 1979). No modifications of the existing PA footprints are proposed, and no adverse effects are anticipated for historic properties due to their continued use.

4.7.4 La Quinta

The La Quinta Reach is comprised of several distinct elements for which potential effects to historic properties must be evaluated. These include extending the existing channel 7,200 feet, construction of a turning basin adjacent the channel extension, creation of BU sites P, GH and E, and use of existing PA 13. Under the preferred alternative, no deepening of the existing La Quinta Channel would occur.

4.7.4.1 Previous Investigations

Two marine archaeological investigations have been conducted along the La Quinta Reach. A remote-sensing survey conducted by CEI (James and Pearson, 1991) partially covered the La Quinta Reach using a 164-foot survey line interval. CEI recommended one side-scan target (Target 53) and one magnetic anomaly (Target 84) as potentially significant along this reach of channel. Target 53 did not have an associated magnetic anomaly and was recorded in 50 feet of water. Target 84 did not have an associated sonar target and was recorded in 49 feet of water. Both targets were investigated by archaeological divers as part of the same project. Divers located only braided steel cable at both locations. No further investigations were recommended.

PBS&J conducted a series of remote-sensing surveys, followed by diver investigations in 2000 and 2001 which included the La Quinta Reach (Enright et al., in preparation). Those investigations included a remote-sensing survey of a 200-foot-wide area along each side of the channel, a remote-sensing survey of the proposed channel extension and turning basin (including the easternmost 80 percent of BU Site GH), a close-order remote-sensing survey of 14 magnetic anomalies, a remote-sensing survey of BU Site P, and archaeological diver investigations of 1 anomaly. A total of 14 magnetic anomalies, designated M24-M37, were recommended as potentially significant following the survey in June 2000. One additional anomaly (P1) was recommended as significant based on the results of the BU Site P survey in June 2001. Anomaly P1 is located in an area that will not be affected by creation of BU Site P. Anomalies M24 and M26-M37 were recommended as not significant based on the results of the close-order survey. Archaeological divers investigated the remaining anomaly, M25. Anomaly M25 was recommended as not archaeologically significant based upon the results of diver investigations.

Previous terrestrial archaeological investigations encompassing portions of BU Site E include Corbin's (1963) investigations, a survey by McDonald and Dibble (1973), and survey and excavation conducted by Ricklis (1999). Ricklis revisited all of the sites recorded by the earlier two surveys. All ten sites investigated by Ricklis were deemed ineligible for NRHP listing or SAL designation. The THC concurred with this assessment (Ricklis, 1999).

4.7.4.2 Environmental Consequences

Channel Extension and Turning Basin Creation

There are no known historic properties or potentially significant remote-sensing targets located in any of these areas. Three remote-sensing targets have been investigated by divers along the existing La Quinta Channel (2 by CEI and 1 by PBS&J); however, all of those anomalies were determined not to be archaeologically significant. Furthermore, since no modifications are planned for the existing channel under the preferred alternative, there would be no adverse effects to historic properties there, should they exist. No adverse effects to historic properties are anticipated in association with either the channel extension or turning basin construction.

BU Site GH

BU Site GH is proposed to be approximately 200 acres and is located adjacent the south side of the proposed La Quinta Channel extension and west of PA 13. PBS&J's 2000 remote-sensing survey (Enright et al., in preparation) encompassed the easternmost 80 percent of BU Site GH. PBS&J did not survey the remaining 20 percent during the 2001 survey, because it was determined that no potentially significant anomalies were recorded by the 2000 survey and because THC's shipwreck database contained no indication of a wreck in the area (Murphy, 2001). The Texas SHPO concurred that a survey of the western 20 percent was not necessary due to the low probability for historic properties in the area. No adverse effects are anticipated for historic properties due to the creation of BU Site GH.

BU Site P

BU Site P is a rock breakwater proposed to be approximately 2,400 feet long. It would be located on the east side of the La Quinta Channel adjacent Ingleside-On-The-Bay. No historic properties are known to exist in this area. PBS&J's 2001 remote-sensing survey located one potentially significant remote-sensing target, designated P1; however, that target is located in an area which will be unaffected by project-related bottom disturbances. No adverse effects to historic properties are anticipated due to the creation of BU Site P.

BU Site E

BU Site E is located on the upland bay margin, northwest of the La Quinta Channel extension. Site E would involve the creation of a 100-acre upland natural area buffer between lands to the west and the La Quinta Gateway Project. Portions of the area have been previously surveyed for terrestrial cultural resource sites, and all recorded sites have been determined not eligible for inclusion to the NRHP or as SALs. Coordination with the Texas SHPO concluded that those portions not surveyed have a low probability for the occurrence of significant archaeological sites; therefore, no further investigations are required. No adverse effect to significant historic properties are expected due to the creation of BU Site E.

Existing PAs

One existing PA (PA 13) would be used for placement of maintenance material dredged from the La Quinta Channel. PA 13 was previously approved for continuous use as part of the CCSC 45-Foot Project (USACE, 1979). No modifications of the existing PA footprints are proposed, and no adverse effects are anticipated for historic properties due to their continued use.

4.7.5 Inner Harbor

The Inner Harbor Reach is comprised of several distinct elements for which potential effects to historic properties must be evaluated. These include deepening the existing channel and use of existing confined upland PAs (IH-PA 1, IH-PA 3A, B, C, IH-PA 4, IH-PA 5, IH-PA 6 (Tule Lake), IH-PA 2 (Rincon), and IH-PA 8 (Suntide)).

4.7.5.1 Previous Investigations

Previous terrestrial archaeological investigations of the Inner Harbor area were conducted by Highley et al. (1977) for the Tule Lake Tract Project. The survey was conducted prior to disposal of fill resulting from harbor dredging activities (Highley et al., 1977). Two archaeological sites (41NU157 and 41NU158) were identified and recorded during that survey. Site 41NU157 was recommended for avoidance and was not to be covered. Site 41NU158 was recommended for intensive survey and shovel testing. It is not known whether the THC concurred with those recommendations. A later survey, conducted for a proposed dredge material site in Nueces County, overlapped a small portion of the western end of the Tule Lake survey area. The area resurveyed included previously recorded site 41NU157. Based on the reconnaissance results of the latter survey, the authors reported that no potential conflict with cultural resources was documented (Black and Highley, 1985).

PBS&J conducted a series of remote-sensing surveys, followed by diver investigations in 2000 and 2001 which included the Corpus Christi Bay portion of the Inner Harbor Reach east of the Harbor Bridge (Enright et al., in preparation). Those investigations were performed for the CCSCCIP and included a remote-sensing survey of a 200-foot-wide area along each side of the channel and a close-order remote-sensing survey of one magnetic anomaly. Anomaly M23 was recommended as potentially significant following the survey in June 2000; however, that recommendation was changed to not significant based on the results of the close-order survey. No marine remote-sensing surveys were required in the landlocked portion of this reach because the channel did not exist prior to 1934 and was not completed in it's present form until 1958. Historic navigation in this reach was not possible prior to 1934 and occurred under controlled circumstances after that date. The potential for occurrence of significant historic shipwrecks along this reach, therefore, is considered to be low. The Texas SHPO has concurred that no marine remote-sensing survey is necessary along this reach.

4.7.5.2 Environmental Consequences

Channel Deepening

There are no known historic properties or potentially significant remote-sensing targets located in this area. One remote-sensing target, Anomaly M23, was recorded by PBS&J along the bay portion of this reach, between Light Beacon 82 and the Harbor Bridge; however, a close-order survey of that anomaly suggested that it was not archaeologically significant. Deepening of the existing channel will not impact the existing exposed shoreline; therefore, a terrestrial cultural resource survey of the shoreline was not required. The Texas SHPO did not require a remote-sensing survey of the Inner Harbor Reach west of the Harbor Bridge, due to the low probability that significant submerged historic properties would be present in that area. No adverse effects to historic properties are anticipated as a result of the Inner Harbor channel deepening.

Existing PAs

Nine existing, upland confined PAs (IH-PA 1, IH-PA 3A, B, C, IH-PA 4, IH-PA 5, IH-PA 6 (Tule Lake), IH-PA 2 (Rincon), and IH-PA 8 (Suntide)) will be used for placement of new material dredged to deepen the Inner Harbor Channel. Most of these existing PAs were created prior to any legal requirement for archaeological surveys, thus they were never surveyed for cultural resources. One exception is IH-PA 6 (Tule Lake). IH-PA 6 is proposed to cover 400 acres between Tule Lake and the Viola Channel. IH-PA 6 was surveyed for cultural resources as reported by Highley et al. (1977) and by Black and Highley (1985). Several cultural resources sites were recorded by those surveys; however, none of the recorded sites are located within the boundaries of IH-PA 6. The closest cultural resource site to IH-PA 6 is 41NU157. No modification of the existing PA footprints or levees will occur as a result of the CCSCCIP, and no adverse effects to historic properties are anticipated due to their continued use.

4.8 AIR QUALITY

Under the No-Action alternative, air quality would continue as described in Section 3.9.

Impacts on air quality from the project would result during construction and follow-on maintenance dredging activities.

4.8.1 <u>Construction Dredging</u>

The combustion of diesel fuel during construction dredging operations would result in air emissions of primarily nitrogen oxides (NO_x), carbon monoxide (CO), volatile organic compounds (VOC), particulate matter (PM), and sulfur dioxides (SO_2). The amount of fuel combustion emissions would be directly related to the type and size of equipment and the amount of dredging required. The total amount of new dredged material is estimated to be about 41 mcy. Based on the construction schedule under consideration, the construction dredging would be completed in segments with the first segment completed in 2003 and the last in 2007. Emissions are estimated for each segment as summarized in Table 4.8-1.

4.8.2 Maintenance Dredging

Routine dredging would be required to maintain the channel at a depth authorized to accommodate larger vessels and tankers. Maintenance dredging would occur along different segments with each segment being relatively independent of the other. It is estimated that about 208 million cubic yards of sediment would be excavated over 50 years (i.e., an average of 4 mcy per year). The resulting emissions from this operation are estimated as shown in Table 4.8-2.

4.8.3 Expected Air Quality Impacts

Atmospheric dispersion modeling of emissions was not performed. There are dispersion modeling tools available to estimate local air quality impacts; however, these models are most accurate at estimating impacts from those facilities from which emissions occur at well-defined, stationary emission points. In the case of this project, local dispersion of emissions cannot be characterized with any degree of accuracy because they would be emitted from a variety of mobile sources that would operate intermittently. Additionally, the level of activity would be variable.

Regional dispersion models available to characterize VOC and NO_x, which are O_3 precursors and result in regional impacts, are not intended to estimate a specific project's contribution to regional O_3 concentrations. Therefore, regional dispersion models would not be useful in estimating the projects construction and operational impact on regional O3 concentrations.

It is expected that air contaminant emissions from construction dredging activities will result in minor short-term impacts on air quality in the immediate vicinity of the dredging site. Each dredging operation would be relatively independent of the other, although, there may be some overlap. In addition, these activities are considered one-time activities (i.e., the construction dredging activities would not continue past the date of completion). As a result, the impact on ambient air from construction dredging emissions would be of generally intermittent and relatively short-term duration. VOCs and nitrogen oxides can combine under the right conditions in a series of photochemical reactions to form ozone, possibly increasing ozone concentrations in the region. However, these reactions take place over a period of several hours with maximum concentrations of ozone often far downwind of the precursor sources. Due to the phased, one-time construction dredging, it is expected that there will be no long-term impacts to air quality in the area.

It is expected that air contaminant emissions from maintenance dredging activities will result in minor short-term impacts on air quality in the immediate vicinity of the dredging site. As previously noted, VOCs and nitrogen oxides can combine under the right conditions to form ozone, possibly increasing the concentration of ozone in the region. However these reactions take place over a period of several hours with maximum concentrations of ozone often far downwind of the precursor sources. The estimated emission rates for these and the other products of combustion are relatively minor and would be intermittent and of relatively short-term duration for each segment. Therefore,

TABLE 4.8-1

ANNUAL CONSTRUCTION DREDGING EMISSIONS
(TONS PER YEAR)

Activity	Completion Year	Estimated Duration (days)	PM	SO_2	NO_x	VOC	CO
La Quinta Extension and Turning Basin	2003	97	6.78	78.4	233	6.8	53.3
Entrance Channel Deepening	2004	31	2.29	26.4	78.4	2.30	17.97
Port Aransas to La Quinta Junction	2005	121	8.45	97.7	290	8.51	66.4
La Quinta Junction to Harbor Bridge Deepening and Widening	2006	224	13.6	157	466	13.7	107
Deepening of Inner Harbor	2007	49	5.02	58.0	172	5.1	39.5

TABLE 4.8-2

ANNUAL MAINTENANCE DREDGING EMISSIONS
(TONS PER YEAR)

Activity	Estimated Annual Duration (days)	PM	SO_2	NO_x	VOC	CO
Entrance Channel	5	0.39	4.52	13.42	0.39	3.07
Port Aransas to La Quinta Junction	10	0.68	7.81	23.16	0.68	5.31
La Quinta Junction to Harbor Bridge	13	0.80	9.23	27.39	0.80	6.28
Harbor Bridge to Turning Basin	4	0.45	5.20	15.42	0.45	3.53
La Quinta Channel	3	0.22	2.5	7.38	0.22	1.69
Total	35	2.53	29.3	86.77	2.55	121

emissions from the maintenance dredging are not expected to result in a serious impact to the regional air quality and they are not expected to differ significantly from present maintenance dredging.

Airshed pollutant loading determined by the magnitude of emissions expected to result from the project compared to area emissions can be used to estimate air quality impacts of the criteria pollutants. Based on available air emissions inventory information provided on the EPA's AIRData website (EPA, 2002b), the following tables (tables 4.8.3 and 4.8.4) provide a summary of emissions for the Nueces County and San Patricio County. The emissions data are available for area plus mobile source and for point source emissions, based on emissions inventory information for 1999. This emissions inventory provides a basis from which to compare the proposed project emissions.

TABLE 4.8-3

SUMMARY OF PEAK AIR EMISSIONS FROM CONSTRUCTION DREDGING ACTIVITIES COMPARED WITH NUECES AND SAN PATRICIO COUNTY EMISSIONS FOR 1999

Air Contaminant	Area and Mobile Source (tpy)	Point Source (tpy)	Total (tpy)	Estimated Peak Project Dredging Emissions (tpy)	Site Emissions % of Nueces County Emissions
NO_x	29,342	32,739	62,081	466	0.75
VOC	26,495	8,601	35,096	13.7	0.04
CO	119,655	9,465	129,120	107	0.08
SO_2	6,067	7,932	13,999	157	1.1
PM_{10}	41,227	1,748	42,975	13.6	0.03

TABLE 4.8-4

SUMMARY OF AIR EMISSIONS FROM MAINTENANCE DREDGING ACTIVITIES COMPARED WITH NUECES AND SAN PATRICIO COUNTY EMISSIONS FOR 1999

Air Contaminant	Area and Mobile Source (tpy)	Point Source (tpy)	Total (tpy)	Estimated Peak Project Dredging Emissions (tpy) *	Site Emissions % of Nueces County Emissions
NO_x	29,342	32,739	62,081	86.8	0.14
VOC	26,495	8,601	35,096	2.55	0.007
CO	119,655	9,465	129,120	121	0.09
SO_2	6,067	7,932	13,999	29.3	0.2
PM_{10}	41,227	1,748	42,975	2.53	0.006

* Assumes all maintenance dredging may occur in 1 year.

As shown on Table 4.8-3, construction dredging for the proposed project would result in an increase in emissions above those resulting from existing sources in the Nueces/San Patricio County area. Emissions of SO_2 may result in an increase of about 1.0 percent over existing area emissions. Emissions of NO_x, VOC, CO, and PM_{10} are expected to result in a less than 1 percent increase over existing emissions based on available air emissions inventory information provided on the EPA's AirData website (EPA, 2002b).

As shown on Table 4.8-4, emissions during maintenance dredging are estimated to contribute less than 1 percent to total existing emissions for these counties.

The TNRCC and EPA's air quality permitting program applies to stationary sources of air emissions, and would therefore, not apply to emissions from the dredging activities. However, emissions are expected to comply with the National Ambient Air Quality Standards and the rules and regulations of the EPA and the TNRCC promulgated in support of the State's State Implementation Plan.

4.9 NOISE

Under the No-Action alternative, noise would continue as described in Section 3.10.

Impacts to the noise environment from the proposed project would result primarily during construction and maintenance dredging activities. The noise associated with construction and maintenance activities of this project is difficult to quantify. Heavy machinery, the major source of noise in construction, would move along the project route as construction and maintenance activities proceeded; these levels would thus vary and be intermittent. However, construction normally occurs during daylight hours when occasional loud noises are more tolerable. Noise sensitive areas include residential areas at Ingleside-On-The-Bay and recreational areas in the vicinity of Port Aransas and the jetties. These areas range from 400 to 800 feet from the CCSC. None of the noise sensitive areas is expected to be exposed to the construction and maintenance dredging activities for a long duration; therefore, any extended disruption of normal activities is not expected. Provisions and specifications that require the contractor to make reasonable efforts to control construction and maintenance dredging noise will be included in all plans. Since maintenance dredging will not increase significantly in comparison with existing conditions, relative to present maintenance, noise from maintenance dredging is not expected to increase significantly with the preferred alternative.

4.10 SOCIOECONOMIC RESOURCES

The following sections address economic impacts from the construction and operations and maintenance (O&M) phases of the proposed project. The Methodology section provides details on how socioeconomic impacts were estimated based on project details, an input-output model approach, research, and interviews.

4.10.1 No-Action Alternative

Without the preferred alternative, the Corpus Christi area (Nueces and San Patricio counties) would continue on its present course of economic development and diversification, of moderate population growth, and of fairly rapid commercial, residential, and industrial land development. The PCCA would continue to function as an important port for its industrial facilities and international commerce. The PCCA would also continue to develop its industrial properties but at a slower rate than it would with the preferred alternative. The container terminal would not be built in its proposed location without the extension of the La Quinta Channel. Without the channel widening of the CCSC, safety concerns related to large vessel meetings would continue as would delays. Without the preferred alternative, the area would not take advantage of additional economic benefits related to the project in terms of an increase in the number of jobs, increased employee compensation, expanded indirect business taxes, increased value-added, and increased industrial housing development. No aesthetic or environmental justice impacts would occur with the No-Action alternative.

4.10.2 Methodology

Within the Socioeconomic Resources section, environmental consequences have been estimated through a variety of methods. One such method is qualitative analysis, which was conducted through review of government agency and private sector reports and other materials, review of local planning documents, research conducted over the internet, and through telephone discussions. Another technique includes quantitative analysis, through review of Census and economic data that pertains to the project study area. Also, a visual survey of the vicinity surrounding the proposed project area was conducted on August 16 and 17, 2001, as a source of information for land use analysis. The last technique (which is the main focus of this Methodology section) involves the use of an Input-Output Model for predicting project-related impacts to the economies of Nueces and San Patricio counties. A detailed discussion provided below outlines the approach taken by the Input-Output Model to estimate economic impacts within the two counties (Nueces and San Patricio) that encompass the project study area.

The analysis utilized a computer-based modeling program called Implan Professional (Version 2.0) (Implan). Implan uses industry and employment data from the target counties to predict indirect and induced effects from project implementation. This input-output model allows the analyst to develop a set of assumptions related to project details and predict how project-related expenditures would impact the economies of the target counties. The model predicts how dollars spent on the proposed project would affect specific industries within the regional economy as dollars are spent and re-spent locally. The results are expressed as indirect and induced impacts to employment, value-added, total output, the tax base, and employee compensation.

Indirect and induced impacts occur as goods and services are provided to the sectors that provide the goods and services directly for the industries that directly benefit from project-related expenditures. Value Added is a measurement of the value that is added to intermediate goods and services. It is equal to the total of employee compensation, proprietor income, other property income, and indirect business taxes. Total Output is a measure of the total value of purchases by intermediate and final consumers, or by intermediate outlays plus value-added. Employment impacts show the number of new jobs that would be created as a result of the project as project-related dollars are spent and re-spent within the regional economy, and new jobs are created in other industries within the target counties. Indirect business tax impacts measure the amount of local (county, city and other local taxing entities), and State sales taxes (combined) that would occur as a result of project-related expenditures.

Implan was used, along with specific proposed project-related information and a detailed set of assumptions, to predict the impacts. The details of the proposed project were analyzed to determine which portions of project-related expenditures would have an effect on the economies of the two counties. It was determined that expenditures on dredging of the CCSC and the extension of the La Quinta Channel, and O&M expenditures would have an impact on economic activity within Nueces and San Patricio counties only as a secondary effect. The secondary effects of the dredging work would occur through expenditures for fuel for the dredges and through local spending by dredge employees. The expenditures on dredge fuel and local economy expenditures by dredge employees represents a relatively small percentage (approximately 12 percent of annual construction costs, and 14 percent of annual O&M costs) of the overall construction and O&M costs. The remainder of the dredging construction costs would very likely leak out of the regional economy as the dredging contractors hired for this project (chosen through a competitive-bid process) would likely be based outside of Nueces and San Patricio counties.

However, non-dredging construction activities that are part of the proposed project are likely to be conducted by locally-based contractors and locally-based workers. These construction activities include bank stabilization, levee building, dock and pipeline modifications/relocations. Expenditures on these non-dredging construction activities represent approximately 44 percent of the proposed-project construction budget.

Employment, output, value-added, and indirect business tax impacts from the proposed La Quinta container ship terminal are considered beyond the scope of this FEIS. The proposed La Quinta container ship terminal is not part of the proposed project considered in this FEIS.

To predict project-related impacts to the economies of Nueces and San Patricio counties, research was conducted to gather detailed project-related information, and a set of assumptions was developed to further clarify the details. The assumptions involved discussions with Port of Corpus Christi personnel and other key persons, and review of relevant dredging industry information, information relating to the Nueces and San Patricio County economies, and historical USACE data (La Rue, 2001). Below is a list of key assumptions and project-related details that were used as a basis for predicting economic impacts. All dollars presented in the Socioeconomics section are presented in 2001 dollars.

- The construction phase of the proposed project would be conducted over a 5-year period (from 2003 to 2007) and would involve a total construction cost of $190 million.
- The O&M phase would occur over a 45-year period from 2008 to 2053. O&M would be conducted once every 2 years and would take 2 months of work each time. Total expenditures on O&M would be $107 million.
- All construction and O&M operations would be completed by two types of dredges: a pipeline dredge and a hopper dredge. The pipeline dredge would be used for about 90 percent of the work (for both construction and O&M) and would be used for all work except the entrance channel. The hopper dredge would perform approximately 10 percent of the work (for both construction and O&M) and would work only on dredging of the entrance channel. During both construction and O&M, the ships would work 18- to 20-hour days, with workers working in shifts.
- The pipeline dredge would employ 50 people, and these employees would make an average wage of $300 per day (including all benefits). The hopper dredge would employ 20 people, and these employees would make an average wage of $425 per day (including all benefits). All dredge employees would not need housing, since they would be housed on the ships. All dredge employees would spend an average of $1,500 per month on groceries, entertainment, clothing, and other goods and services

bought within Nueces and San Patricio counties. These expenditures would be 70 percent in Nueces County and 30 percent in San Patricio County.

- The pipeline dredge would use 10,000 gallons per day of diesel fuel. The hopper dredge would use 4,000 gallons per day of diesel fuel. The current price of this fuel is 80 cents per gallon, and the fuel would be provided by fuel barges based in the Port of Corpus Christi (Nueces County).
- Construction related to levee building, bank stabilization, dock and pipeline modifications/relocations would occur over a 5-year period and would be conducted by locally-based contractors and workers (60 percent from Nueces County and 40 percent from San Patricio County).

Based on these project-related details and assumptions, the following data were used with Implan to predict project-related impacts within Nueces and San Patricio Counties.

- During the 5-year construction phase, dredge employees would spend $1.3 million per year in Nueces County and $589,000 per year in San Patricio County on local goods and services. During the 45-year O&M phase, dredging ship employees would spend $63,500 per year in Nueces County and $30,000 per year in San Patricio County on local goods and services. These dollar amounts were applied to employee compensation (within Implan), and indirect, induced, and total impacts to the two counties were predicted.
- During the 5-year construction phase, $2.7 million would be spent annually on diesel fuel for the dredges. During the 45-year O&M phase, $231,000 would be spent annually on diesel fuel for the dredges. All fuel expenditures were applied to Implan sector #38, Natural Gas and Crude Petroleum, and applied to Nueces County only.
- During the 5-year construction phase, $16.7 million would be spent annually for the construction budget for bank stabilization (rip-rap), levee building (geotube), and dock and pipeline modifications/relocations. Approximately $3.3 million would be awarded annually to contractors that would be based in Nueces County, and approximately $2.2 million would be awarded annually to contractors that are based in San Patricio County. All non-dredging construction costs were applied to Implan industry sector #51, New Highways and Streets (which most closely represents these industries).

4.10.3 Population

Approximately 70 workers would be needed annually for the dredging portion of the proposed project. These dredge workers would have little effect on the capacity of local communities to provide adequate housing, schools, and other services. Most of these workers' essential needs would be provided on-board the dredges. An estimated 170 non-dredging construction workers would be needed annually for the proposed project. Most of the non-dredging construction workers (excludes indirect and induced employment) are likely to come from the labor force that is already living within the two counties. Inmigration to the Nueces County and San Patricio County area would be fairly minimal.

The total employment (direct, indirect, and induced) that would occur in the two counties (excluding the dredge workers) would likely cause a very small increase in population. In Nueces County, approximately 205 total jobs would be created annually during the 5-year construction period. This employment increase represents less than 0.1 percent of the year 2000 county population (pop. 313,645). During the 45-year O&M period, approximately 1 total job would be created annually in Nueces County. In San Patricio County, approximately 95 total jobs would be created annually during the 5-year construction period. This employment represents 0.1 percent of the year 2000 county population (pop. 67,138). During the 45-year O&M period, less than 1 total job would be created annually in San Patricio County.

The proposed project would produce a relatively small number of jobs during the short and long term and would not affect population growth beyond the capacity of the communities to provide adequate housing, schools, and services or otherwise adapt to growth-related social and economic changes. Also, there would be no displacement of residents or users of affected areas. There would be no project-related effects that would negatively affect community cohesion.

However, when the proposed project is completed, it is likely that new industrial development would occur within the Inner Harbor and along the north side of Corpus Christi Bay. The deeper and wider ship channels would provide an additional benefit to industry, which would likely attract new companies to locate within the Corpus Christi Bay area. New industrial development would likely include petrochemical plants, bulk grain facilities, petroleum and natural gas refineries. Also, with the extension of the La Quinta Channel, there is a strong likelihood that a container ship terminal would be built on the land adjacent to the end of the channel extension (La Rue, 2001). The impact of these new industries on population growth (mostly through in-migration) within the two counties should be considered to be substantial. Reasonable, foreseeable, future actions are discussed in Section 5.0. If new industrial facilities are built as an indirect result of the proposed project, it is likely that a substantial increase in single-family homes would occur in San Patricio County (within and near the cities of Portland, Gregory, Ingleside, and Aransas Pass) where vacant land is available for such development and is located near such available industrial sites. Also, some new housing development would likely occur within the City of Corpus Christi (especially on the west side, along the IH 37 corridor). This increase in new residents within the two counties would also substantially increase the demand for commercial development, schools, roads, and other services.

4.10.3.1 Life, Health, and Safety

The channel widening aspect of the proposed project would provide relief of safety concerns and the associated vessel delays for ships traveling through the CCSC. Currently, the Port Aransas-Corpus Christi Pilots limit vessel meetings to combined beam width of 251 feet in the 400-foot reach. Additional criteria are that meetings are not permitted between vessels with combined loaded drafts in excess of 80 feet, and that vessels should have 3 feet of underkeel clearance. The proposed project to widen the CCSC to 530 feet and to deepen it to 52 feet would easily accommodate the vessels that are forecasted to use the CCSC, in a safe manner, and with minimal delays.

4.10.4 Employment

All dredging construction work would be performed over a 5-year period, from 2003 to 2007. Approximately 70 full-time dredge workers would be needed for the duration of this construction period. Of these 70 workers, approximately 50 full-time workers would be necessary for operations of a pipeline dredge (or cutter head dredge), and approximately 20 full-time workers would be needed for the operations of a hopper dredge. Indirect and induced employment would occur within the two counties as dredge workers spend some of their disposable income locally and as operation of the dredges would necessitate expenditures on fuel that would be purchased from firms located in Nueces County (based in the Inner Harbor).

Within Nueces County, annual dredging worker expenditures would be approximately $1.2 million, and annual fuel expenditures would be approximately $2.6 million. From these local expenditures, indirect and induced job creation would result in approximately 40 new jobs annually, or 200 labor-years of employment during the 5-year construction period. Total employee compensation in Nueces County would be an estimated $1,021,000 annually, or $5,105,000 during the 5-year period. In San Patricio County, annual dredging worker expenditures would be approximately $589,000. From these local expenditures, indirect and induced job creation would result in approximately 5 new jobs annually, or approximately 20 labor-years of employment during the 5-year construction period. Total employee compensation in San Patricio County would be an estimated $71,500 annually, or $357,500 during the 5-year period.

Non-dredging construction jobs would likely be filled by locally-based construction companies and workers. During the 5-year construction period, approximately 175 full-time workers would be required to complete this work (within the two counties), and construction expenditures would be approximately $16.6 million (or $83 million for the 5-year period). In Nueces County, these construction expenditures would create approximately 165 total jobs (includes direct, indirect, and induced jobs) annually, or approximately 825 total labor-years of employment during the 5-year period. Total employee compensation in Nueces County would be an estimated $4.1 million annually, or $20.5 million during the 5-year period. In San Patricio County, these construction expenditures would create approximately 90 total jobs (includes direct, indirect, and induced jobs) annually, or approximately 450 total labor-years of employment during the 5-year period. Total employee compensation in San Patricio County would be an estimated $2.7 million annually, or $13.5 million during the 5-year period.

Dredging O&M activities would occur approximately every 2 years and would last for approximately 2 months, during the 45-year O&M phase. During these 2-month periods, approximately 70 full-time dredge workers would be required. It is likely that the dredging companies and workers hired for this work would not come from the two counties.

Within Nueces County, annual O&M dredge worker expenditures would be approximately $63,500 and annual fuel expenditures would be approximately $230,800. From these local expenditures, indirect and induced job creation would result in approximately 1 new job annually, or approximately 45 labor-years of employment during the 45-year O&M period. Total employee compensation in Nueces County would be an estimated $17,300 annually, or $778,500 during the 45-year period. In San Patricio County, annual O&M worker expenditures would be approximately $30,000. From these local expenditures, indirect and induced job creation would result in less than one job annually, or approximately 10 labor-years of employment during the 45-year O&M period. Total employee compensation in San Patricio County would be an estimated $3,600 annually, or $162,000 during the 45-year period.

The industries that would benefit directly (in terms of employment) from the proposed project during the construction and O&M phases would be dredging contractors and other construction contractors that would be involved in non-dredging activities. Indirect and induced jobs created within the two counties would occur primarily in the following industries: Natural Gas and Crude Petroleum, Eating and Drinking, Miscellaneous Retail, Hospitals, Food Stores, Real Estate, Wholesale Trade, General Merchandise Stores, Auto Dealers and Service Stations, Banking, and Doctors and Dentists.

When the proposed project is completed, it is likely that new industrial development would occur within the Inner Harbor and along the north side of Corpus Christi Bay. The deeper and wider ship channels would provide an additional benefit to industry, which would likely attract new companies to locate within the Corpus Christi area. With the new channels in place, it would be more likely that new petrochemical plants, bulk grain facilities, petroleum and natural gas refineries would be built within the area. Also, with the extension of La Quinta Channel, it is very likely that a proposed container ship terminal would be built (La Rue, 2001). The impact of these new industries on employment within the two counties is unknown but would likely be substantial. This increase in employment may substantially increase the rate of inmigration, the demand for housing, schools, and other services within the two counties.

In summary, the proposed project would create approximately 370 total new jobs (direct, indirect, and induced employment) annually, or 1,850 labor-years of employment during the 5-year construction period. However, at least 70 of these would likely be filled by workers from outside the two-county area. During the O&M phase of the proposed project, approximately 71 total new jobs would be created annually, or approximately 3,195 labor-years of employment throughout the O&M phase. However, 70 of these total jobs would likely be filled by workers from outside the two counties.

Within Nueces County, all construction activities associated with the proposed project would create approximately 205 total jobs (direct, indirect, and induced jobs) annually, or 1,025 labor-years of employment during the 5-year construction period. This would represent a 0.1 percent impact on Nueces County annual employment. Employment associated with dredging during the 45-year O&M period would create approximately 1 job annually, or 45 labor-years of employment during the 45-year O&M period. This would represent a less than 0.1 percent impact on Nueces County employment.

Within San Patricio County, all construction activities associated with the proposed project would create approximately 95 total jobs (includes direct, indirect, and induced) annually, or 475 labor-years of employment during the 5-year construction period. This would represent a 0.6 percent impact on San Patricio County annual employment. Employment associated with dredging during the 45-year O&M period would create less than 1 total job annually, or approximately 10 labor-years of employment during the 45-year O&M period. This would represent a less than 0.1 percent impact on San Patricio County employment.

4.10.5 Economy

Economic effects to the Nueces County and San Patricio County economies would be moderate at the least, and substantial at best. Much of the construction budget would likely leak from the local economy, as construction dollars spent on dredging work would likely go to dredging companies that are located outside of the local economy. However, it is anticipated that most of the non-dredging subcontractor work would be done locally, dredge workers would spend some of their disposable income locally, and dredge fuel would be purchased locally. Based on these assumptions, the following economic effects would accrue within Nueces and San Patricio counties.

In Nueces County, dredge employee expenditures and fuel expenditures would result in a total output (direct, indirect, and induced) effect of approximately $5.9 million on the county economy, or a $29.5 million effect for the 5-year construction period. These same expenditures would result in a total value-added effect of approximately $3.2 million on the county economy, or a $16 million effect for the 5-year construction period.

In San Patricio County, dredge employee expenditures would result in a total output effect of approximately $555,000 on the county economy annually, or a $2.8 million effect for the 5-year construction period. These expenditures would result in a total value-added effect of approximately $142,000 on the county economy, or a $710,000 effect for the 5-year construction period.

Within Nueces County, annual O&M dredge worker expenditures would result in a total output effect of approximately $76,000 on the county economy annually, or a $3.4 million effect for the 45-year O&M period. These expenditures would result in a total value-added effect of approximately $32,500 on the county economy annually, or a $1.5 million effect for the 45-year construction period.

Within San Patricio County, annual O&M dredge worker expenditures would result in a total output effect of approximately $3,600 on the county economy annually, or a $162,000 effect for the 45-year O&M period. These expenditures would result in a total value-effect of approximately $7,200 on the county economy, or a $324,000 effect for the 45-year construction period.

In Nueces County, during the 5-year construction period non-dredging construction expenditures would result in a total output effect of approximately $15.3 million on the county economy annually, or a $76.5 million effect for the 5-year construction period. These expenditures would result in a total value-added effect of approximately $7.0 million on the county economy, or a $35.0 million effect for the 5-year construction period. In San Patricio County, during the 5-year construction period construction expenditures would result in a total output effect of approximately $8.1 million on the county economy annually, or a $40.5 million effect for the 5-year construction period. These expenditures would result in a total value-added effect of approximately $3.3 million on the county economy, or a $16.5 million effect for the 5-year construction period.

4.10.5.1 Historical Perspective/Community Growth

Within Nueces and San Patricio counties, the social and economic effects accruing from the proposed project would simply contribute to the current development trends that have historically affected the regional economy. The increase in jobs, economic output, and the tax base would be fairly moderate and consistent with historical growth trends. The Port of Corpus Christi and its associated industries and international commerce currently serve an important role for the Corpus Christi area economy. These industries provide jobs, income, and a tax base for the area, and the effects reverberate within other industries such as housing, retail services, and wholesale trade. The proposed project would likely provide a boost to the development of industrial sites along the Inner Harbor and in San Patricio

County, near the cities of Portland, Ingleside, and Aransas Pass. Larger ships would be able to navigate the CCSC; providing cost savings for commercial vessels. In short, the Port of Corpus Christi would become a more attractive location for companies involved in industry and international commerce to conduct their business. This goal would be consistent with a steady historical trend towards increased reliance on these industries and these types of development within the region.

4.10.5.2 Tax Base

Within Nueces County, all construction activities associated with the proposed project would result in a total (direct, indirect, and induced effects) indirect business tax impact effect of approximately $745,000 on the county economy annually, or a $3.7 million effect for the 5-year construction period. During the O&M period, dredging-related expenditures would result in a total indirect business tax effect of approximately $3,000 on the county economy annually, or a $135,000 effect for the 45-year O&M period.

Within San Patricio County, all construction activities associated with the proposed project would result in a total indirect business tax impact effect of approximately $151,000 on the county economy annually, or a $755,000 effect for the 5-year construction period. During the O&M period, dredging-related expenditures would result in a total indirect business tax effect of approximately $700 on the county economy annually, or a $31,500 effect for the 45-year O&M period.

4.10.6 Land Use

The proposed project would have a very minimal impact on land use. Neither the CCSC channel improvements nor the La Quinta Channel extension would affect any shoreline land uses. All channel improvements would occur in open-water locations. The only land use implications for the proposed project relate to proposed DMM/BU sites (see sections 1.6 and 2.2.2) and indirect future land development that may occur as a result of the proposed project.

The BU sites would be created from dredged material in seven open-water locations near the Entrance Channel, and in Corpus Christi Bay and Redfish bays (see Figure 1-3). These BU areas would vary in their design but would generally consist of shallow water aquatic habitat areas surrounded by wave breaks created from construction material. The BU sites are located in areas of open water that would not create significant conflicts with recreational or commercial boating or other uses. The BU sites would positively impact the commercial and recreational boating and fishing industries or other uses, as they would create habitat for fledgling fish and other aquatic species leading to an increase in their populations. Each BU site is discussed briefly below in the Aesthetics section, and in more detail in Section 1.6.

The greatest long-term land use consequence of the proposed project would likely be a change in future land uses that would occur in response to the improvements to the CCSC and the extension of the La Quinta Channel. These future land uses are not considered part of the proposed project but would be far less likely to occur without it. The PCCA currently owns property along the Inner Harbor, along the north side of the Corpus Christi Bay, Harbor Island, San Jose Island, and along the western shoreline of Redfish Bay that is available for development for industrial sites. When the proposed project is completed, the PCCA would have the deepest and widest ship channel along the Gulf of Mexico coast, providing a large incentive for new industrial development at all of the PCCA properties, based on navigation cost savings. Future industrial development may include oil and gas refineries, petrochemical plants, bulk grain facilities, offshore oil-platform construction companies, and/or a container terminal (La Rue, 2001). The long-term land use effects of these industrial facilities are largely unknown (and beyond the scope of this report); however, they would likely lead to a substantial increase in demand for new housing development, new roads, commercial services, schools, and other services within the two-county area. Below is a brief discussion of the possible land use implications of the proposed container terminal.

The PCCA has outlined, in its "La Quinta Gateway Preliminary Master Plan," a proposal for a container terminal to be located on an 1,100-acre tract of land known as the La Quinta property, and located adjacent to the proposed La Quinta Channel extension. The proposed container terminal site is bordered by the Sherwin Alumina plant to the east, and SH 361 to the north, and is between the cities of Portland (to the west) and Ingleside (to the east). The proposed project includes a containerized cargo marine terminal, consisting of a 295-acre marine terminal, 3,800 linear feet of wharf, nine gantry cranes, a 75-acre intermodal rail terminal, and a 127-acre buffer zone. The container terminal project would also require expanded road and rail capacity within the general area. Indirect consequences of the proposed container terminal would be an increase in demand for new housing development, new roads, commercial services, schools, and other services mostly within San Patricio County (within Portland, Gregory, Ingleside, and Aransas Pass) and, to a lesser extent, in Nueces County (PCCA, 2001b).

4.10.6.1 Aesthetics

The proposed project would have a minimal effect on the overall visual quality within the study area. There would be no significant effect to the appearance of the shorelines that are adjacent to the proposed channel improvements. Existing PAs, as discussed in Section 2.2.2, utilized for maintenance dredged material will not affect the visual quality of the study area. The only aspects of the proposed project that would affect the visual quality of the study area would be the BU areas.

BU Site GH consists of an armored levee and shallow water habitat. The shoreline areas that are closest to this BU site are existing industrial sites and areas that are slated for future industrial development. The BU site would also be visible from the Northshore Golf Course and other subdivisions along the southeastern shore of the City of Portland.

BU Site CQ would consist of a shallow lagoon area bordered on three sides by a rock breakwater. This feature would be visible looking southwest from homes and the marina located along the shoreline of Ingleside-On-The-Bay, but would not block views of other portions of the Corpus Christi Bay.

BU Site P would be a rock breakwater, visible from homes facing south along the Ingleside-On-The-Bay shoreline.

BU Site I consists of a triangular-shaped lagoon area (mix of open water, shallow water, and high marsh habitat), bordered on two sides by a breakwater/shore protection berm in Redfish Bay.

This feature would be directly visible from the Ingleside shoreline, which consists of industrial land uses in this area.

BU sites R and S consist of C-shaped armored wave breaks on the perimeter of shallow lagoon areas. These beneficial use areas would not be visible from the Ingleside-On-The-Bay shoreline but possibly would be visible from much more distant shorelines along the western shore of Mustang Island.

BU Site Pelican consists of a geotube breakwater and shoreline armor. This site will receive periodic maintenance material to maintain the existing rookery island. No impact to the visual quality of the area is expected.

BU Site L would consist of a shoreline protection armor on the south shore of the channel near Port Aransas to protect existing shoreline and habitat. This site will be visible from the channel and industrial sites at Harbor Island, as well as the county pier near Port Aransas.

BU Site E is an upland site northwest of the La Quinta Channel extension. It was requested by area residents as a buffer between the Northshore Golf Course and the proposed Gateway Terminal. Therefore, it will provide a benefit to the aesthetics of the area.

BU Site ZZ is completely submerged and would have no impact on the visual quality of the area.

BU site MN is completely submerged and would have no impact on the visual quality of the area.

4.10.6.2 Community Services

The proposed project would not affect the delivery of local services, including water, wastewater, or other utilities. No disruption to roads or rail transportation would result from the preferred alternative. The preferred alternative would result in no changes in traffic demand on local roads or highways and would not affect the delivery and quality of local services to the population living within the vicinity of the study area.

4.10.7 <u>Environmental Justice</u>

Within the study area, ethnicity and poverty figures are generally consistent with those of the region, with only a few notable exceptions. For example, there are seven of thirty-two census tracts within the study area, where the percentage of ethnic minorities is substantially higher than in either county or the state. Also, there are five census tracts within the study area where the percentage of the population living below the poverty line is substantially higher than for either county or the state. Therefore, the study area does have some areas that have disproportionately high percentages of ethnic minorities and persons of poverty status. However, this does not constitute a disproportionate impact under Executive Order 12898, as there are no disproportionately high and adverse human health or environmental effects that would accrue to these populations. The minority populations living within these census tracts would likely experience no adverse changes to the demographic, economic, or community cohesion characteristics within their neighborhoods as a result of the proposed project. Also, there would be no physical changes to the environment or to land use within these census tracts. Generally speaking, the population living within these census tracts would benefit from the proposed project. These benefits would be manifested mainly in a slight increase in economic output, value added, jobs, and tax base within these communities.

No low-income or minority populations have been identified to experience disproportionately high and adverse human health or environmental effects as a result of the preferred alternative.

4.11 ANY ADVERSE ENVIRONMENTAL IMPACTS WHICH CANNOT BE AVOIDED SHOULD THE PREFERRED ALTERNATIVE BE IMPLEMENTED

The preferred alternative will result in adverse impacts to the benthos and fish of Corpus Christi Bay from dredging and placement of dredged material at the BU sites. Five acres of seagrass will also be impacted during construction. However, the BUW and the RACT determined that the BU sites will potentially provide higher value habitat; the impacted seagrasses will be mitigated by the creation of 15 acres of new seagrass area. Shoreline protection will provide benefits to existing marsh and seagrass habitats.

4.12 ANY IRREVERSIBLE OR IRRETRIEVABLE COMMITMENTS OF RESOURCES INVOLVED IN THE IMPLEMENTATION OF THE RECOMMENDED PLAN

The labor, capital, and material resources expended in the planning and construction of this project are irreversible and irretrievable commitments of human, economic, and natural resources. The loss of 5 acres of seagrass from extending the La Quinta Channel is irreversible; however, this loss will be compensated in a mitigation plan prepared and accepted by the RACT. Deep-water bay bottom loss due to deepening and widening the channel, construction of barge lanes, and extension of La Quinta will be irretrievably lost.

4.13 RELATIONSHIP BETWEEN LOCAL SHORT-TERM USES OF MAN'S ENVIRONMENT AND THE MAINTENANCE AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY

The preferred alternative would eliminate approximately 45 acres of shallow-water bay bottom including 5 acres of seagrass during construction of the channel and approximately 40 acres of bay bottom. Productivity of the sites removed during construction would be permanently lost from the ecosystem, while much of the bottom buried during construction of the BU sites will recover or be transformed into more productive seagrass habitat. The 5 acres of seagrass lost during construction will be mitigated by the construction and planting of 15 acres of seagrasses in BU Site GH. However, there will be a time lag before the BU sites become established and ecologically functional. There will be a temporary loss of productivity during that interim period. Creation of the BU site will, over the long-term, provide substantial long-term gains in productivity of the Corpus Christi Bay system.

4.14 MITIGATION

The Mitigation Workgroup (MW) was formed to assess the unavoidable direct impacts to productive estuarine habitats due to the preferred alternative and to propose the mitigation for those unavoidable impacts. Based on the conclusions of the RACT and MW, the USACE determined that impacts to seagrass and bottom shallower than –4 feet MLT (potential seagrass habitat) would be mitigated.

Impacts to estuarine habitats are estimated to be 45 acres of bottom shallower than –4 feet MLT. All potential direct impacts would be due to the proposed La Quinta Channel extension and a minimal area (less than 0.05 acre) on the western shoulder of PA 10. Eight of the 45 acres are located along the south side of the extension near PA 13. The balance, 37 acres, is located farther west along the north side of the channel extension and the new turning basin. An estimated 5 acres of seagrass vegetation are included in the total 45-acre estimate. The seagrass vegetation is predominantly shoalgrass and occurs within an 8-acre area located on the south side of the extension near PA 13. No impacts to bay bottom shallower than –4 feet MLT were identified at any other location within the proposed deepening, widening, and channel extension project or the proposed barge shelf.

Of the 45 acres of shallow-water habitat (>–4.0 feet MLT) that will be removed during project construction, 5 acres consist of seagrass habitat and 40 acres consist of shallow, unvegetated bay-bottom habitat. According to ER 1105-2-100, wetland resources must be fully mitigated to meet the administration's goal of no net loss of wetlands. Also, the significance of the resource shall be established based on monetary and non-monetary values. Seagrass is a significant resource based on non-monetary criteria, such as scarcity on a national or regional scale and institutional and public recognition of the ecological and aesthetic attributes.

While it may be argued that seagrass and shallow, nonvegetated bay-bottom habitat is not considered a wetland habitat, the FWS (1979) determined that wetland and subtidal aquatic habitat (seagrass) must be considered together in an ecological system. Furthermore, the FWS has a strong interest in preserving seagrass habitat because their policy designates this habitat as Resource Category 2 which is high value habitat for estuarine and marine species that is relatively scarce on a national scale or in the ecoregion. Their mitigation policy for this resource category is no net loss of in-kind habitat value.

In addition to resource agency recognition of seagrass habitat as a significant resource, the public has repeatedly expressed a strong desire to maintain and expand seagrass beds in the Corpus Christi Bay system. Evidence of this was provided by the Coastal Bend Bays & Estuaries Program (CBBEP) which has noted the public's desire for providing more of this valuable resource during their coordination efforts under the National Estuarine Program. More recent evidence was provided by the project non-Federal sponsor, which also recorded high public interest in protecting and expanding this resource during numerous project public meetings.

Seagrass habitat is important to the estuarine ecosystem in the project area, because the Corpus Christi Bay system is located in a region of relatively low rainfall, high evapotranspiration, and has limited freshwater inflow. As a result of these limitations, there are few areas of emergent marsh (traditional wetland habitat) that can serve as nursery habitat and food source for many estuarine and marine species. Seagrass beds generally serve this purpose, but are restricted to shallow, clear, protected waters. Corpus Christi Bay, especially in the project area, does not provide optimal seagrass habitat because it is a relatively deep bay subject to high southeast winds for much of the year that create turbid conditions along the south facing shorelines. Therefore, seagrass beds are a relatively scarce resource in this area that should be preserved to the extent practicable. If preservation is not possible, loss of this resource should be fully mitigated.

The proposed La Quinta Channel Extension has been aligned to avoid most of the seagrass beds, leaving only 5 acres of loss to be mitigated in-kind. The 40 acres of shallow, nonvegetated bay-bottom habitat does not have as high a habitat value and can be mitigated out-of-kind, if necessary.

Based on requirements for in-kind mitigation for seagrass losses, the project area has little to offer for traditional mitigation in-kind. There are three possible options available: (1) buy nearby, privately-owned upland shoreline, scrape it down to the same elevation as the existing habitat, and transplant seagrass in the site; (2) scrape down upland habitat in the nearby fully confined PA 13 to the same elevation as the existing habitat and transplant seagrass in the site; or (3) transplant seagrass into the nearby BU Site GH being constructed with new work material dredged from the La Quinta Channel extension.

During coordination with the RACT and MW, the USACE determined that the third option was the most feasible for this project. The first option was not feasible because of the cost of the waterfront land and site preparation. The site consists of a high bluff facing the bay and would require removal of about 712,000 cy of material. More importantly, there is no assurance that landowners would be willing sellers since waterfront property possesses a high commercial or residential development value. Even though there is no land acquisition fee associated with the second option, it is even less viable since all of the capacity remaining in the fully confined PA 13 is needed for maintaining the La Quinta Channel throughout the 50-year life of the project.

The RACT and MW, which include the non-Federal sponsor and USACE, concluded the best mitigation plan would be to transplant seagrass into BU Site GH that would provide the necessary protected, shallow-water habitat. The USACE, in close coordination with the RACT and MW, determined that because it will take time for the transplanted seagrass to develop the same density and provide habitat values equivalent to natural seagrass beds, a ratio of 3:1 would be used for mitigation. This is a common ratio used by the resource agencies in other mitigation actions. This equates to transplanting a 15-acre seagrass bed inside BU Site GH as compensation for 5 acres of seagrass lost to project construction. To ensure success of the mitigation plan, the USACE, in close coordination, with the RACT and MW, prepared a seagrass monitoring plan with success criteria to use in evaluating the progress in seagrass development. This plan is described below.

MITIGATIVE PROCEDURES/CONDITIONS FOR SEAGRASS TRANSPLANTING EFFORTS

1. After final construction of beneficial use Site GH and following a sediment conditioning time of at least 90 days, an appropriate location for the mitigation will be selected within the eastern portion Site GH, and the mitigation area will be planted with shoal grass (*Halodule wrightii*). Prior to mitigation site selection or planting, a survey will be performed in the candidate mitigation site area to determine the topographic condition and elevation of the deposited material. If excessive relief is encountered then planting will occur after a subsequent survey indicates that the topographic relief, elevation and sediment stability is conducive to shoal grass transplant survival. Prior to conducting planting, the USACE (the Federal sponsor) will coordinate the results of the survey(s) and sediment stability appraisal(s) with the USACE, FWS, TPWD, NMFS and the non-Federal sponsor.

   If the topographic and elevation survey or sediment stability appraisal is determined to be unsuitable for seagrass growth, then the proper course of action will be taken after coordination has taken place. Agency recommendations may include allowing for additional site conditioning time prior to conducting a full scale planting of the site, relocation of the planting effort within the candidate mitigation area, grading of the area, or even conducting a pilot planting effort.

2. Transplant source areas will be identified and applicable permits obtained from the TPWD and/or GLO and/or private landowners. Staking of the approved transplant harvest areas will be in accordance with applicable permits.

3. Shoalgrass planting may be conducted between mid-March and mid-June, or between mid-September and mid-October. Plantings outside of these times will need to be coordinated between the USACE, FWS, TPWD, NMFS and non-Federal sponsor at least two weeks prior to commencement of those plantings. The transplanting technique will be coordinated with the USACE, NMFS, FWS, TPWD and the non-Federal sponsor when the specific location and configuration of the mitigation site is being established. Initial shoalgrass planting shall be completed within one year of completion of the mitigation site or during the first suitable planting time following determination that site is conducive to transplant survival. The location of the mitigation site will be marked by PVC pipe.

4. A planting unit will consist of live shoalgrass material contained in a 3-inch-diameter plug. No more than three 3-inch plugs of source material per square yard will be obtained from the designated transplant source areas. Incidental damage to source areas will be avoided. Alternate harvest techniques may be considered but they will require prior coordination with USACE, NMFS, FWS, TPWD and the non-Federal sponsor and, as necessary, permitted through TPWD and/or GLO and/or private landowners.

5. A transplant survival survey of the planted site will be conducted between 60 and 90 days after completion of the initial planting effort. Using acceptable survey methods, a minimum of 15 percent of all transplant units will be surveyed for the initial transplant survival survey. A written report detailing the survival results shall be submitted to the USACE within 30 days of survey completion. The report will be distributed by the USACE to the NMFS, TPWD, FWS and non-Federal sponsor. If at least 50 percent survival is not achieved, then the resource agencies shall be consulted to determine if the site should be modified prior to initiating a replanting

effort. If it is determined that site modifications are not necessary and that the site should be replanted, then replanting shall commence within 30 days (or within the next suitable planting period) once the agency-coordinated decision to replant the site has been made.

6. At least six transects will be established for the purposes of pre-construction, pre-plant plant elevation, or existing-bed condition surveys, and for post-planting monitoring surveys. The ends of each transect will be marked by PVC pipe. More transects may be established depending on the size or shape of the site selected, the transplanting plan and/or planting schedule. A minimum of two transects outside of the mitigation site in nearby seagrass beds and a minimum of four transects which cross the mitigation site is to be established and surveyed. The number and configuration of transects within the planting area will be coordinated with the USACE, NMFS, FWS, and TPWD and non-Federal sponsor after the size and configuration of the mitigation site has been established.

7. All transects located within the mitigation site shall be surveyed post-planting, at 6 months, 1 year, 2 years, and 3 years to determine success of mitigation. To determine success, three samples will be taken at 10-foot intervals along the transects; one on the interval and one three feet to each side of the interval. Seagrass will be identified to species. Coverage of seagrasses will be to species and will be calculated by using the frequency of occurrence of live seagrass at each sample along the transect. In addition to the percentage of vegetative cover, the monitoring surveys at all transects will note water depths (elevation) and any unusual sediment variations or other deposits.

8. If 2 years following planting the mitigation site is not as least 70 percent covered with shoalgrass, an additional planting effort will be made and those areas of the site not vegetated will be replanted to original specifications. The occurrence of manatee grass, if any, can be included in meeting the 70 percent coverage requirement.

9. The mitigation effort will be considered successful if the mitigation site is 70 percent covered by shoalgrass and/or manatee grass within three years following shoalgrass planting and if at least 48 percent of the total vegetative coverage is shoalgrass. If the mitigation is determined to be unsuccessful at the end of the three-year monitoring period, the Federal sponsor will be required to consult with the USACE, NMFS, FWS, TPWD and the non-Federal sponsor in order to determine if corrective measures are warranted. If it is apparent that the site is unlikely to support seagrass vegetation then a determination may be made to re-locate the mitigation project.

10. Some seagrasses currently exist nearby the proposed beneficial use Site GH. The survey of the transects established outside the mitigation area will be performed prior to constructing Site GH. The survey shall use a survey method similar to that used for the transects within the mitigation area and will also obtain information on the areal extent of the existing grassbeds. One purpose of the survey in the nearby seagrass beds is to obtain data to aid in the selection of the planting area within the mitigation site. This survey will be repeated within 30 days of completing construction of those portions of Site GH that could reasonably affect the existing nearby seagrass beds. If the survey results show that impacts have occurred to the existing seagrass beds, then the results will be provided within 30 days of completion of the survey to the USACE, TPWD, FWS and NMFS and the non-Federal sponsor. These agencies will

be consulted in order to determine an appropriate course of action to restore and/or mitigate the impacts.

11. The Federal sponsor will prepare monitoring reports detailing all required surveys. These monitoring reports will be submitted to the FWS, TPWD, and NMFS and non-Federal sponsor within 60 days of survey completion.

The mitigation plan also provides compensation for the loss of 40 acres of shallow, nonvegetated bay-bottom habitat in the 200-acre BU Site GH. Since this habitat is not considered to have as high a value as seagrass habitat, a ratio of 1:1 was used for compensation. This mitigation will be considered complete once the 40 acres of the 200-acre BU Site GH is constructed. There is no additional cost to construct the BU site that can be attributed to this mitigation plan since the BU site was designed to contain the remaining material from the proposed channel extension after completing upland BU Site E and stockpiling stiff clay material for future use in raising the levees in PA 13.

ER 1105-2-100 also requires that an incremental cost analysis of all recommended mitigation plans be performed to display variation in costs and identify and describe the least cost plan so that rational decisions regarding mitigation can be made. However, since only one feasible plan (as described above) is available that meets all mitigation requirements and is acceptable to the USACE, in close coordination with the RACT and MW, an incremental cost analysis is not possible. An alternative to the structured incremental cost analysis for seagrass mitigation that will provide a cost comparison for justifying the recommended plan is to calculate the costs for Options 1 and 2 and compare them to the cost for Option 3. This comparison is presented in Table 4.14-1. A cost analysis for mitigating shallow, nonvegetated bay bottom is not needed since there is no cost associated with designating this mitigation as part of BU Site GH.

TABLE 4.14-1
COST COMPARISON OF THREE OPTIONS TO MITIGATE THE
LOSS OF SEAGRASS DUE TO PROJECT CONSTRUCTION

Cost Factors (in dollars)	Option 1	Option 2	Option 3
Acquire Land	225,000	0	0
Acquisition Fees	12,000	0	0
Scrape Down/Prepare Site	5,340,000	2,040,400	0
Survey Elevations	58,000	58,000	0
Shoreline Protection	490,000	490,000	0
Transplant Seagrass on 15 Acres	67,500	67,500	67,500
Monitor Site for 3 Years	50,000	50,000	50,000
Total Cost	6,242,500	2,705,500	117,500

As shown in Table 4.14-1, Option 3 is the most economical mitigation plan of the three possible mitigation plans identified in the area. Options 1 and 2 have higher costs due to cost of acquiring privately owned land (Option 1) and the amount of material that must by removed to create a seagrass habitat. Option 2 has no acquisition fee since it would be constructed inside PA 13, which is owned by the non-Federal sponsor through a State land patent. Another cost identified for Options 1 and 2, but not included in Option 3, is shoreline protection needed to provide a sheltered environment for seagrass growth. Seagrass transplanted into BU Site GH in Option 3 will be protected by a geotube/riprap barrier incorporated into the BU site design. The monitoring cost identified for all three options include only surveys to document seagrass survival and does not include any retransplanting costs, if needed. Therefore, Option 3 is the most economical and acceptable plan for mitigating the loss of seagrass during project construction.

Most of the in-bay BU sites will be protected from erosion by breakwaters and islands and should also be further stabilized by natural colonization by seagrasses, *Spartina*, and other estuarine organisms. The existing open-water, unconfined PAs are dispersive and the remainder are UCPAs, releasing no dredged material back into the environment, except small amounts as suspended solids. The offshore sites are dispersive, but BU Site MN and the topographic relief feature at BU Site ZZ are designed to provide variable elevation bottom structure providing in-place mitigation for lost bottom habitat.

Nonmotile organisms occurring in the sediments in the areas to be dredged will be placed in PAs or BU sites and will likely be buried. Benthos at the BU sites, existing open-water PAs, and the offshore sites will be buried during placement. However, the BU sites are designed to create more diverse habitat than presently exists in the deep-water, open-bay areas, providing in-place mitigation, and benthos at all open-water sites should rapidly recover to pre-placement conditions (Ray and Clarke, 1999).

4.15 ENERGY AND NATURAL OR DEPLETABLE RESOURCE REQUIREMENTS AND CONSERVATION POTENTIAL OF VARIOUS ALTERNATIVES AND MITIGATION MEASURES

NEPA regulations in 40 CFR 1502.16 (e) and (f) requires a discussion of project energy requirements and natural or depletable resource requirements, along with conservation potential of alternatives and mitigation measures in an EIS.

Under the No-Action alternative, the energy requirements for maintaining the channel will continue as before. However, the navigation requirements for energy (fuel) to transport commercial products will increase in the future as commerce increases and more one-way traffic increases congestion and navigation time into and out of the port. Air quality impacts are likely to increase with an increase in navigation traffic congestion and travel time along the channel.

The recommended alternative is expected to reduce energy (fuel) requirements for transporting products on a ton/mile basis by deepening and widening the channel. Ships can be more heavily loaded with cargo and two-way traffic in the channel will decrease congestion and reduce transit time into and out of the port.

Energy (fuel) will be required to construct the improved channel, but this is a short-term impact. Energy to maintain the improved channel is expected to increase slightly with the small increase in shoal material expected for the larger channel. This increase in fuel requirement is expected to be more than offset by fuel savings in ship traffic in the larger channel and should help reduce air quality impacts slightly over the No-Action alternative.

Increased efficiency in moving petroleum and other petroleum-based commodities to the local refineries is expected to help conserve natural or depletable resources in the future. The reduced energy requirements will result in lower (or at least a smaller increase in) transportation costs in the future, which reduces overall production costs for the consumer.

5.0 CUMULATIVE IMPACTS

5.1 INTRODUCTION

Cumulative impact has been defined by the President's Council on Environmental Quality (CEQ) as "the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or persons undertakes such action." Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time. Impacts include both direct effects, which are caused by an action and occur at the same time and place as the action, and indirect effects, which are also caused by the action and occur later in time and are farther removed in distance, but which are still reasonably foreseeable. Ecological effects refer to effects on natural resources and on the components, structures, and functioning of affected ecosystems, whether direct, indirect, or cumulative.

In assessing cumulative impact, consideration is given to (1) the degree to which the proposed action affects public health or safety, (2) unique characteristics of the geographic area, (3) the degree to which the effects on the quality of the human environment are likely to be highly controversial, (4) the degree to which the possible effects on the human environment are highly uncertain or involve unique or unknown risks, and (5) whether the action is related to other actions with individually insignificant, but cumulatively significant impacts, on the environment.

Cumulative effects can result from many different activities including the addition of materials to the environment from multiple sources, repeated removal of materials or organisms from the environment, and repeated environmental changes over large areas and long periods. More complicated cumulative effects occur when stresses of different types combine to produce a single effect or suite of effects. Large, contiguous habitats can be fragmented, making it difficult for organisms to locate and maintain populations between disjunctive habitat fragments. Cumulative impacts may also occur when the timings of perturbations are so close that the effects of one are not dissipated before the next occurs, or when the timings of perturbations are so close in space that their effects overlap.

The CAW developed a scope of work encompassing 36 parameters for 9 past, present, and reasonably foreseeable future projects (base projects) viewed as pertinent to the future condition of Corpus Christi Bay and the surrounding area. Parameters to be addressed include biological, physical, chemical, socioeconomic, and cultural attributes. The methodology described below was developed with the guidance and agreement of the CAW and the RACT.

5.1.1 Cumulative Impact Assessment Methodology

This discussion describes the application of the cumulative impact assessment methodology to the preferred alternative. Projects evaluated in the preferred alternative assessment include the following:

Reasonably foreseeable future actions:

- Packery Channel
- JFK Causeway
- Joe Fulton International Trade Corridor
- La Quinta Gateway Project
- The Coastal Bend Regional Water Plan update as required by Senate Bill 1
- Kiewit Offshore Services Project

Past or present actions:

- Corpus Christi Ship Channel 45-foot Project
- Rincon Channel Federal Assumption of Maintenance
- Gulf Coast Strategic Homeport Navel Station Ingleside – Corpus Christi, Texas
- Mine Warfare Center of Excellence – Corpus Christi Bay, Texas
- Jewel Fulton Channel Federal Assumption of Maintenance

The CAW agreed that the following projects or documents were not in the foreseeable future or did not have any documents available. Impacts from these projects were not addressed due to the lack of available information.

- Multipurpose Deepwater Port and Crude Oil Distribution System at Port Aransas Safeharbor Project
- Baker's Port
- State of Texas Regional Water Plan for Region L
- Harbor Island Master Plan
- Rerouting of GIWW from Ingleside across Corpus Christi Bay (Feasibility Report due 2003)
- Modifications to GIWW between Ingleside and Rockport (Feasibility Report due 2003)

The study area for the cumulative impact assessment was limited to the north portion of Upper Laguna Madre, Corpus Christi Bay, Nueces Bay, Redfish Bay, and offshore waters from Aransas Pass to Packery Pass.

Direct impacts that could be quantified in acreage were considered for habitat assessment when information was available. Habitats for cumulative impact assessment were identified from reports developed for the above proposed projects and include SAV, wetlands, estuarine sand flats/mud flats/algal mats, open water, reef habitat, coastal shore areas/beaches/sand dunes. In addition to habitats, impacts to specific resource categories were addressed in a more qualitative manner based on information provided by documents reviewed for each project. These were described as biological attributes (bay bottom habitat, terrestrial habitat, plankton, benthos, finfish, shellfish, mammals, reptiles/amphibians, threatened and endangered species, and EFH), physical environment (air quality/noise, topography/bathymetry, sediment quality, water quality, freshwater inflow, circulation, and tides), and cultural/socioeconomic attributes (recreation, commercial and recreational fisheries, ship accidents/spills, oil/gas production on submerged lands, cultural resources, public health, safety, and parks/beaches).

5.1.2 Evaluation Criteria

Cumulative effects were determined by reviewing impacts as described in the project documents and determined from recent habitat information obtained from Section 3.0. Acreage of each habitat in the study was determined from this assessment, if available.

5.1.2.1 Individual Project Evaluation

Individual project documents were reviewed for impacts to selected habitats based on the evaluation criteria described above. No attempt was made to verify or update published documents, nor were the disposal practices proposed in reviewed documents verified for current ongoing projects. In addition, no field data were collected to verify project impacts described in reviewed documents. Mitigation outlined in individual project documents may be in place or proposed. This analysis recognizes that some of the projects assessed are undergoing revisions that may alter their environmental impact. This analysis relied only on existing published documents. If acreage was available, it was summed for each habitat to obtain a cumulative acreage impact. It should be noted that because of the diverse mix of documents that were reviewed for cumulative impacts and because of the fact that not all documents used the same definitions or even the same categories of resources, it was sometimes necessary to lump or modify categories so that the quantities in this section may not be exactly comparable with those presented in sections 3 and 4 of this FEIS. However, every attempt has been made to make this section internally consistent, so that all projects included in Cumulative Impacts are evaluated comparably.

5.1.2.2 Resource Impact Evaluation

Biological/ecological, physical/chemical, and cultural/socioeconomic resource impacts were evaluated based on individual project reviews. In Table 5.1-1, a quantitative assessment of biological/ecological resources was prepared. A qualitative discussion of biological/ecological, physical/chemical resources, and cultural/socioeconomic resources were presented using information published in reviewed documents. The following is a brief description of the evaluated projects.

5.2 REASONABLY FORESEEABLE FUTURE ACTIONS

5.2.1 Packery Channel

Packery Channel is a potential environmental enhancement project that would provide a dredged channel across Padre Island between the Upper Laguna Madre and the Gulf of Mexico. The channel is located roughly north-northeast of the JFK Causeway, which crosses the Laguna Madre between the City of Corpus Christi and North Padre Island. The existing channel is largely the result of the modern dredging of a historically shallow cut between the historical pass and Laguna Madre.

In addition to opening Packery Channel to the Gulf, the project will add two rock jetties at the Gulf end of the Channel and deepen and widen the existing channel and Inner Basin. The project also

TABLE 5.1-1
CUMULATIVE IMPACTS

Project	Kiewit Offshore Services	Packery Channel	Raising Kennedy Causeway	Joe Fulton International Trade Corridor	La Quinta Gateway Project	Rincon Channel Federal Assumption of Maintenance	Gulf Coast Strategic Homeport Naval Station Ingleside	Mine Warfare Center of Excellence	Corpus Christi Ship Channel 52-foot Project	Total
RESOURCE IMPACTS										
Topography/Bathymetry	12,000 ft	3.5 statute miles	0.9 statute miles	NI	NI	NI	8.4 statute miles	NI	43 statute miles	55.8 statute miles
Shore/Beach/Dunes	NI	61 ac	NI	NI	1.8 ac	NI	NI	NI	NI	62.8 ac
Salt Marsh	NI	17.8 ac	11.5 ac	NI	2.1 ac	NI	1.2 ac	NI	NI	32.6 ac
Flats	NI	1.9 ac	NI	NI	NI	NI	112 ac	NI	NI	113.9 ac
Open Water	NI	7.1 ac	NI	NI	32 ac	NI	NI	NI	NI	39.1 ac
Oyster Reef	NI	NI	NI	NI	NI	NI	NI	NI	NI	
Upland Wetlands	NI	NI	NI	11.2 ac	NI	NI	38.6 ac	NI	NI	49.8 ac
Shallow Bay Bottom Habitat (0 to –12 MLT)		33.3 ac	NI	NI	27.1 ac	20 ac	207 ac	18 ac	40 ac (0 to –4 MLT)/ 359 ac (–4 to –12 MLT)	345.4/359 ac
Gulf of Mexico Bottom Habitat	NI	69.1 ac	NI	NI	NI	NI	NI	NI	526 ac	595.1 ac
Terrestrial Habitat		42.2 ac	NI	45 ac	245 ac (excludes 869 ac cropland)	NI	614 ac	NI	NI	946.2 ac
Submerged Aquatic Vegetation (SAV)	NI	5.4 ac	NI	NI	2.4 ac	NI	1.1 ac	3.5 ac	5 ac	17.4 ac
Essential Fish Habitat (subtotal of salt marsh, flats, shallow bay bottom habitat, and SAV)	NI	58.4 ac	11.5 ac	NI	31.6 ac	20 ac	321.3 ac	21.5 ac	404 ac	868.3 ac
MITIGATION/BENEFITS *										
Upland Habitat	NI	NI	NI	1.1 ac	NI	5 ac	NI	NI	120 ac	126.1 ac
Bay Bottom Habitat	NI	NI	5 ac	NI	NI	NI	NI	NI	NI	5 ac
Shallow-Water Habitat	NI	NI	11 ac	5.2 ac	27.1 ac	NI	5.5 ac	NI	935 ac	983.8 ac
Submerged Aquatic Vegetation	NI	16.2 ac	NI	NI	7.2 ac	NI	1.6 ac	10 ac	15 ac	50 ac

TABLE 5.1-1 (Concluded)

Project	Kiewit Offshore Services	Packery Channel	Raising Kennedy Causeway	Joe Fulton International Trade Corridor	La Quinta Gateway Project	Rincon Channel Federal Assumption of Maintenance	Gulf Coast Strategic Homeport Naval Station Ingleside	Mine Warfare Center of Excellence	Corpus Christi Ship Channel 52-foot Project	Total
Wetlands (salt marsh, brackish, fresh)	NI	18 ac	NI	NI	5.9 ac	28 ac	42 ac	NI	26 ac	119.9 ac
Beach Nourishment	NI	91.3 ac	NI	NI	NI	NI	NI	NI	NI	91.3 ac
Dune Mitigation	NI	1.5 ac	NI	NI	NI	NI	NI	NI	NI	1.5 ac
SOCIOECONOMICS										
Environmental Justice		NI	NI	NI	NI	NI	NI	NA	NI	NI
Community Cohesion		NI	NI	NI	NI	NI	NI	NA	NI	NI
Relocations		NI	1 business	NI	NI	NI	NI	NA	NI	1 business
Demand for Housing Units		3,150	NA	NA	4,600	NA	3,700	NA	Negligible	11,450
Population Increase		5,200	NA	NA	9,000	NA	14,900	NA	Negligible	29,100
BENEFITS										
Temporary (Construction Phase)										
Employment (avg. annual)		350	1,700	100	4,250	NA	535	NA	370	7,305
Wages (avg. annual)		NA	$26.9 M	NA	$210 M	NA	NA	NA	$1.1 M	$238 M
Total Output (avg. annual) (Nueces and San Patricio counties)		NA	$114.3 M	NA	$460 M	NA	NA	NA	$23 M	$597 M
Indirect Business Tax Impact (avg. annual)		NA	NA	NA	$15 M	NA	NA	NA	$900,000	$15.9 M
Permanent										
Employment (avg. annual)		2,500	NI	90	6,400	NA	8,470	NA	71	17,530
Wages (avg. annual)		$220 M	NI	$38 M	$233.4 M	NA	$150 M	NA	$21,000	$641.4 M
Total Output (avg. annual) (Nueces and San Patricio counties)		NA	NI	$115 M	$680 M	NA	NA	NA	$85,000	$795.1 M
Indirect Business Tax Impact (avg. annual)		NA	NI	$3.7 M	$21.8 M	NA	NA	NA	$3,700	$25.5 M

NI = No impacts; NA = Not Available; M = million (dollars).

* Except for CCSCCIP, all gains in the Mitigation/Benefits section of this table are from mitigation. For CCSCCIP, the only mitigation is the 15 acres of submerged aquatic vegetation; all others are from beneficial uses. Mitigation is determined based on Habitat Suitability Indices, while others were based on ratios to direct impacts. Mitigation may be completed or proposed.

involves the establishment of six dredged material PAs, including the use of some new work material for beach nourishment to counter the effects of wave erosion, providing storm damage reduction. The City of Corpus Christi has proposed recreational development in conjunction with the project; however, recreation is not part of the Federally cost-shared project.

The length of the proposed channel from the Gulf end of the jetties to the GIWW is approximately 18,500 feet (3.5 miles). The Packery Channel alignment follows an existing channel southeast of the GIWW for approximately 2.6 miles to a basin southeast of SH 361. From this basin the proposed new channel will extend approximately 0.9 mile toward the Gulf following a historic washover channel. Packery Channel will allow recreational and small commercial boats access between the GIWW and the Gulf. Traffic will not include large commercial ships, tows, deepwater draft barges, or any floating vessel with a draft greater than 4 feet.

The proposed channel opening involves dredging a new channel from the Gulf into the existing basin area located southeast of the SH 361 bridge. Two rock jetties will extend from the shoreline southeastward approximately 1,400 feet paralleling the channel. The basin will be reconfigured and deepened to a consistent depth of –12 feet mean lower low water level (MLLW). The existing Packery Channel west of SH 361 that extends to the GIWW will be increased to 80 feet in bottom width and 7 feet in depth (USACE, 2003).

5.2.2 JFK Causeway

The JFK Causeway is located in southeast Nueces County in the City of Corpus Christi on the northern end of the Laguna Madre providing a connection between the mainland and North Padre Island. The current causeway is approximately 4 feet mean sea level (MSL) with a 3,280-foot-long bridge, which provides a clear roadway width of 54 feet, including a divided four-lane road with a concrete median barrier and a vertical clearance of 80 feet above the water surface.

The proposed project would raise the existing JFK Causeway (Park Road 22) to a minimum of 9 feet above MSL from O'Connell Street on the mainland to a point 1,740 feet east of Aquarius Drive on Padre Island. The new portion of the bridge would be 2,850 feet with a 2,550-foot water opening at the west end of the causeway. No new through lanes would be added by the project, and the existing two lanes in each direction would remain upon completion of the project. Between O'Connell Street and the Laguna Madre, the existing four-lane divided highway would be converted to an urban freeway with four main lanes and frontage roads to provide access to abutting properties. A turnaround at the western bank of the Laguna Madre would aid local traffic access. During construction, one lane in each direction would remain open to traffic. The westbound traffic lanes would be completed first to ensure safe evacuation in case of an emergency during construction. The GIWW high bridge would not be modified as part of this project since it is already well above the 9-foot minimum elevation needed for safe evacuation during storm events. (Hicks & Company, 1999)

5.2.3 Joe Fulton International Trade Corridor

The Joe Fulton International Trade Corridor (JFITC) is a proposed intermodal project to connect road, rail and marine traffic between IH 37 and US 181. The proposed project area is located along the Port of Corpus Christi Inner Harbor in Nueces County, Texas, and is located north of the City of Corpus Christi, south of Nueces Bay, and west of Corpus Christi Bay. It would result in the construction of a two-lane roadway (one 12-foot lane in each direction and 10-foot shoulders) approximately 11.8 miles in length and a railroad corridor approximately 6.0 miles in length, parallel to a portion of the proposed roadway.

The JFITC would provide improved road and rail access to existing facilities on the north side of the Inner Harbor from the Tule Lake Lift Bridge to US 181. It would also facilitate development of approximately 1,100 acres of PCCA and Driscoll Foundation land between the Lift Bridge and Carbon Plant Road/IH 37. The new rail link would provide alternative service to the north bank area, eliminating the need for all rail traffic to pass over the Lift Bridge. The proposed road would provide alternative routing for industrial vehicles between US 181 and IH 37 and PCCA facilities, thus eliminating the need for traffic to traverse the downtown Corpus Christi area and the Harbor Bridge. The proposed route would provide an alternative for general traffic, including hurricane evacuation traffic from areas east of Corpus Christi Bay, independent of the Harbor Bridge and the Lift Bridge (Shiner, Moseley and Associates, 2001).

5.2.4 La Quinta Gateway Project

The proposed La Quinta Gateway project involves the construction and operation of an intermodal container terminal and associated deep draft docking facility. The project would be located on PCCA-owned property (approximately 1,114 acres) in San Patricio County, Texas, between Reynold's Metals Company to the east, SH 361 and the City of Gregory to the north, US 181 and the North Shore Country Club Estates to the northwest and west, respectively, and Corpus Christi Bay to the south. The Corpus Christi Bay portion of the site is in Nueces County, Texas, adjacent to the La Quinta channel extension. The objectives of the modern container facility are to facilitate the need for increased container terminal capacity in the rapidly growing Gulf market and provide diversification for the PCCA.

The proposed cargo facility for the La Quinta Gateway project would be constructed over three phases to include: highway access via improvements to SH 35 and US 181, rail access via the Union Pacific Railroad ROW, water access via extension of the La Quinta Channel and a new 1,500-foot turning basin, a 295-acre marine terminal with stacked container and wheeled storage areas, a 3,800-linear-foot container wharf capable of accommodating three post-Panamax containerships simultaneously, nine gantry cranes with a boom reach capable of handling loading/off-loading activities, a 75-acre intermodal rail terminal along the east edge of the La Quinta property, four 6,000-foot loading tracks, a warehousing and distribution facility, and two dredged material placement areas totaling nearly 300 acres, including a 100±acre buffer zone located along the western boundary of the site (PCCA, 1999). Approximately 819 acres of the 1,114-acre project area is in row crop production, while 295 acres is predominantly in brushland used for grazing.

5.2.5 Regional Water Plan

Senate Bill 1, passed in 1997, directed the TWDB to designate regional water planning areas, which were designated Regions A through P. Region N, the Coastal Bend Region, includes Aransas, Bee, Brooks, Duval, Goliad, Jim Wells, Kenedy, Kleberg, Live Oak, McMullen, Nueces, and San

Patricio counties. The CAW was interested in the impact of the preferred alternative on the Coastal Bend Regional Water Plan update and vice versa because of a potential substantial change in tidal amplitude and a substantial increase in population, and thus water needs, from the preferred alternative. As an examination of Sections 4.1.1 and 4.10 will reveal, changes in tidal amplitude are predicted to be minimal, as is the added need for infrastructure, since the projected increase in population with the preferred alternative is a fraction of 1 percent. Therefore, the Coastal Bend Regional Water Plan update will not be carried thorough the rest of the analysis of cumulative impacts.

5.2.6 Kiewit Offshore Services Project

Kiewit Offshore Services, located north of the intersection of La Quinta Channel and Jewel Fulton Canal, plans to bring in large components of a proposed floating oil/gas platform and then tow the fabricated structure to the Gulf of Mexico. The existing depth of –45 MLT is adequate for vessel draft, however the channel width is too narrow. Kiewit Offshore Services proposes to widen 12,000 linear feet of the bottom width of the La Quinta Channel from the existing 300 feet to 400 feet. Widening would begin just north of Station 57+00, which is approximately 4,000 feet north of its intersection with the CCSC. Dredging would end at Station 174+10 on the east side of the channel and Station 180+00 on the west side of the channel. Widening of the channel would be box cut on a 1:1 side slope template, which should stabilize to approximately 2:1 or steeper. However, the bottom width of the channel can be extended about 50 feet on either side with limited relative change anticipated at the top of each slope. The approximately 800,000 cy of hydraulically dredged material would be placed on PA 13. To accommodate components of the platform, an area measuring 385 feet wide by 850 feet long would also be hydraulically dredged to a depth of –85 feet MLT from its existing depth of –45 feet MLT. Approximately 500,000 cy of material would be placed either on uplands located on Kiewit Offshore Services property or in PA 13. The channel widening is not expected to have any effect on SAV observed adjacent to the channel.

5.3 PAST OR PRESENT ACTIONS

5.3.1 Corpus Christi Ship Channel 45-Foot Project

The existing channel extends from deep water in the Gulf of Mexico through a jettied entrance channel in Aransas Pass to Harbor Island and across Corpus Christi Bay to a land-locked channel south of Nueces Bay. A branch channel to La Quinta extending from the main channel along the north shoreline of Corpus Christi Bay is included in the project. According to the USACE (1975) the Corpus Christi Ship Channel was deepened from the existing 40-foot depth to an authorized depth of 45 feet. The 40-foot dimensions were authorized by the Rivers and Harbors Act of 1958, and the 45-foot dimensions were authorized by the Rivers and Harbors Act of 1968.

The 45-foot project provides maintenance dredging of the CCSC to authorized dimensions. Maintenance dredging is required periodically to insure sufficient carrying capacity in the channels for efficient and safe movement of commercial navigation. Shoaling within the channels would seriously hamper or halt deep-draft shipping within 2 or 3 years if maintenance dredging were discontinued. The outer bar and jetty channel to Harbor Island are normally maintained by a hopper dredge, with the dredged material placed in a designated open water placement area in the Gulf of

Mexico. The remaining portions of the CCSC are maintained by hydraulic pipeline dredge and materials placed in UCPAs, confined placement areas, and open-water placement areas in Corpus Christi Bay. Materials dredged from the landlocked portion of the channel south of Nueces Bay are placed in UCPAs. Variations of these procedures could occur as a result of improvements in dredging techniques and equipment or possible emergency conditions. Resource impact evaluation of the 45-foot project was not conducted due to the proposed impacts of the CCSCCIP.

5.3.2 Rincon Canal Federal Assumption of Maintenance

The USACE proposes to assume responsibility for maintenance of the Rincon Canal and Canal A in Corpus Christi Bay and the Rincon Industrial Park (RIP), and to use the dredged material for BU sites in the project area, where possible.

The Corpus Christi Rincon Canal System (CCRCS) is composed of several connecting channels constructed between 1967 and 1974. The Rincon Canal is a channel measuring 100 feet in width, 12 feet in depth, and 14,256 feet in length, and connects the CCSC to the RIP. The canal passes under US 181/Nueces Bay Causeway east of the northern end of the RIP. The CCSC serves as a connection between the CCRSC and the GIWW. The RIP is served by Canal A (150 feet in width, 12 feet in depth, and 4,980 feet in length), and Canals B and E, all of which connect to the Rincon Canal. Rincon Canal and Canal A compose that part of the system proposed for assumption of maintenance dredging by Federal entities. The proposed BU sites are located in Nueces County along the southwestern margin of Corpus Christi Bay, adjacent to the City of Corpus Christi and the RIP, which is part of the PCCA.

The channels are currently maintained using a cutterhead pipeline dredge. No changes in historical dredging practices would be proposed as a result of this action (USACE, 2000).

5.3.3 Gulf Coast Strategic Homeport Naval Station Ingleside (Naval Station Ingleside)

The U.S. Navy proposed a strategic homeporting action for 27 battleship surface vessels at eight locations on the U.S. Gulf Coast, including Naval Station Ingleside, Texas. Very little information was available regarding the execution of this project. Of the proposed actions, only dredging of navigation channels and turning basins are known to have occurred in the region. Additionally, waterfront facilities were constructed to support the homeported vessels. The following information is taken largely from the project EIS (US Navy, 1987).

The Naval Station Ingleside project site is located in and adjacent to the CCSC, from La Quinta to Harbor Island. Approximately 8.4 miles of the CCSC was proposed to be widened from 500 to 600 feet. The CCSC was to be hydraulically dredged to a depth of –46.5 feet MLT. A 105-acre turning basin was to be dredged to a depth of –41 feet MLT in the western 42 acres and –46.5 feet MLT in the eastern 63 acres. Dredging depths include 2 feet advance maintenance and 2 feet allowable over depth.

Approximately 13.2 mcy of material was proposed to be dredged, including 5.9 mcy from the CCSC and 7.3 mcy from the turning basin. Maintenance dredging is expected to occur every 5 years with an estimated volume of 6.4 mcy of material being removed from the CCSC and 6.5 mcy of material being removed from the turning basin over the 50-year life of the project. The dredged material was proposed to be hydraulically removed and pumped to USACE-designated placement sites (EPA, 1987). Additionally, the EPA designated the Navy Homeport ODMDS, under MPRSA, for the placement of virgin and maintenance material from the Entrance Channel. The physical location of the Navy Homeport ODMDS coincides with BU Site ZZ.

5.3.4 Mine Warfare Center of Excellence

Dredging approximately 400,000 cy for the U.S. Navy facilitated the construction of a Magnetic Silencing Facility (MSF) for use by the Mine Warfare Center of Excellence at Ingleside, Texas. This MSF is required to measure the magnetic signature of the mine warfare ships for utilization in mine warfare training. Construction of an entrance channel, turning basin and slip was required for the Avenger and Osprey Class Naval Vessels.

The entrance channel measured 150 feet wide and approximately 700 feet in length and will be dredged to –17 feet MLW. The turning basin measured 500 feet by 500 feet and was dredged to –17 MLW. To allow for placement of the MSF, a corridor measuring 520 feet by 270 feet was dredged to –25 feet MLW. The MSF consists of piers and sensor tubes. Two piers 300 feet in length were constructed parallel to one another 66 feet apart to allow docking of naval vessels between them. A walkway measuring 800 feet in length connects these piers to the shoreline.

An additional small craft pier was constructed adjacent to Naval Station Ingleside and CCSC. The pier measures 600 feet in length and accommodates utility boats used to support the mine warfare exercises and existing boats assigned to the station.

The small craft pier facilities are near Naval Station Ingleside, San Patricio County, Texas. The dredging portion of the project was performed at the confluence of the Jewel Fulton Canal and La Quinta Channel west of Ingleside, Texas (EPA, 1987).

5.3.5 Jewel Fulton Canal Federal Assumption of Maintenance

The Jewel Fulton Canal is a small canal off La Quinta Channel located adjacent to Kiewit Offshore Services, Ltd. and Navy-owned property in Ingleside, Texas, which continues into Kinney Bayou. Channel improvements for this area are currently being planned.

5.4 RESULTS

5.4.1 Ecological/Biological Resources

Biological and ecological resources will experience a net negative impact from increased turbidity associated with the dredging and dredged material placement required in the majority of the projects evaluated. Temporary disturbance of bay bottom due to open bay placement and channel dredging is anticipated to provide temporary negative impacts to benthos and SAV. Loss of freshwater marsh and upland habitat due to construction is expected to reduce food and nutrient sources. Not all projects will impact freshwater marsh or upland habitat. Long-term positive impacts from the preferred alternative for the CCSCCIP are anticipated from the creation of seagrass, marsh, and shallow aquatic habitat, which will increase nursery habitat for finfish/shrimp and provide rich substrate for benthic organisms. Birds will benefit by the periodic placement of dredged material on existing upland sites due to creation of temporary unvegetated nesting substrate. However, construction operations attributed to almost all evaluated projects may disturb nesting activity. Mammals, reptiles/amphibians, and terrestrial vegetation will be negatively impacted, temporarily, by placement of material on existing upland placement sites. Threatened/endangered species are not expected to be negatively impacted; in fact, some benefit may be realized from creation of marsh and unvegetated nesting substrate on existing placement sites. Although wetland vegetation will be negatively impacted where wetlands are damaged or destroyed by project construction, marsh creation projects will benefit wetland vegetation, resulting in an overall positive cumulative impact in the general study area. Except for the CCSCCIP, all gains in the Mitigation/Benefits section of Table 5.1-1 are from mitigation. For the CCSCCIP the only mitigation is for SAV; all others are from beneficial uses.

5.4.1.1 Wetlands

The CCSCCIP preferred alternative will not impact any freshwater or brackish wetlands. Wetlands evaluated included salt marsh, freshwater, and brackish wetlands. Negative impacts (totaling 82 acres) are expected to wetland habitat from Packery Channel (17.8 acres); JFK Causeway (11.5 acres); the JFITC (11.2 acres), La Quinta Gateway Project (1.7 acres); and Naval Station Ingleside (39.8 acres). Mitigation for negative impacts associated with these projects include creation of 18 acres of wetlands for Packery Channel, 28 acres of salt marsh proposed for the Rincon Canal Project, 42 acres for Naval Station Ingleside; and 5.3 acres for La Quinta. The CCSCCIP preferred alternative will provide a BU of 26 acres of wetlands. A net gain of 44 acres for the Corpus Christi Bay area is predicted, based on the above totals.

According to studies conducted within the CCBNEP study area (that includes Aransas Bay, Corpus Christi Bay, and the Upper Laguna Madre) (White et al., 1998), marsh habitat constitutes approximately 97 percent (116,041 acres) of total vegetated wetland areas (119,425 acres) (marshes, scrub-shrub, and forested wetlands). Some of the findings in these studies reveal that salt and brackish marshes compose approximately 48 percent of the marsh system. As presented in these studies, the trend in vegetated wetlands is one of net gain from the 1950s to 1992 (including photointerpretation inconsistencies). However, loss of marsh habitat has resulted from agricultural or urban land conversion with additional loss due to dredging, filling, and draining. According to the studies, the greatest changes in habitat between the 1950s to 1979 has occurred in tidal flats due to permanent inundation. The response to permanent inundation has primarily resulted in conversion to open water or seagrass beds. Some losses included conversion to smooth cordgrass marshes along the upper reaches of the tidal flats that became more frequently flooded. According to the CCBNEP studies (White et al., 1998), some of the largest losses in tidal flats was in the Corpus Christi/Nueces Bay-Laguna Madre system.

5.4.1.2 Finfish/Shellfish

Shallow water nurseries and spawning grounds are sensitive sites within the general study area. Shrimp and finfish production would be temporarily displaced due to dredging activity and open water placement of dredged material, and periodic loss of production would occur during maintenance dredging. These areas will recover after activity has ceased, but the quality of the habitat will be reduced by repeated placement of dredged material. Dredging and placement activity will increase turbidity, which may impede gill function in finfish and shrimp not able to leave the area. Damage to marshes from placement of dredged material will reduce nursery areas available for finfish and shrimp. Potential contaminants that may be in bottom sediments will be retrained when dredging occurs, potentially exposing finfish and shrimp to contaminated materials. No contaminants in bottom sediments have been identified to date except from the Inner Harbor which will go to UCPAs. These impacts, except damage to marshes (Section 5.4.1.11), are associated with all dredging projects reviewed, as well as the CCSCCIP preferred alternative. Shallow bay bottom habitat (0 to –12 MLT) will be impacted by the following projects: Packery Channel (33.3 acres), La Quinta Gateway (27.5 acres), Rincon Channel Federal Assumption of Maintenance (20 acres), Naval Station Ingleside (207 acres), and the Mine Warfare Center of Excellence (18 acres). The CCSCCIP preferred alternative will impact 40 acres of shallow bay bottom (0 to –4 MLT) and 359 acres of bay bottom (–4 to –12 MLT). The CCSCCIP is the only project that identifies shallow bay depth differences; thus, all other impacts of shallow bay habitat are assumed at 0 to –12 MLT. BU sites for the preferred alternative will create approximately 935 acres of shallow water habitat; and the Naval Station Ingleside creates 5.5 acres. A net gain of approximately 235.7 acres of shallow water/bay bottom habitat will occur from mitigation and beneficial uses due to all projects reviewed.

As presented in Section 5.4.1.1, a net gain of 44 acres of wetland habitat is estimated. Approximately 595.1 acres of Gulf of Mexico ocean bottom are expected to be temporarily affected by the combined Packery Channel project (69.1 acres) and the CCSCCIP preferred alternative (526 acres). These temporary disturbances will be from the initial lowering of the channel bottom and resultant maintenance dredging, and beneficial use placement along beach shorelines. A small amount (7.1 acres) of Gulf bottom will be lost permanently to jetties for the Packery Channel project.

5.4.1.3 Terrestrial Habitat

Terrestrial vegetation present on any placement sites will be covered by deposition of the maintenance materials as a result of those reviewed projects requiring dredging activities. This vegetation consists mainly of opportunistic species that thrive on disturbed soils and are likely to return after the site has been dewatered. These species are not anticipated to make significant contributions as food or detritus sources. The following projects will cause a total impact of 996.2 acres to terrestrial areas: Packery Channel (42.2 acres), JFITC (45 acres), La Quinta Gateway Project (295 acres), and Naval Station Ingleside (614 acres). Approximately 819 acres of cropland potentially impacted by the La Quinta Gateway Project is not included as terrestrial habitat. Terrestrial vegetation found in the vicinity of the JFK Causeway will be destroyed during construction of the elevated bridge and causeway; however, the upland areas within the road ROW will continue to provide habitat for opportunistic species. Projects providing upland habitat include: 5 acres created for the Rincon Channel Federal Assumption of Maintenance, and a 120-acre upland site (BU Site E) west of the La Quinta Gateway Project for the CCSCCIP preferred alternative. For the Packery Channel project, dune mitigation of 1.5 acres of displaced dunes for restoring and revegetating has been proposed. A net loss of terrestrial habitat totals 877.2 acres among all of the reviewed projects.

5.4.1.4 Mammals

The general study area is not considered high quality mammal habitat; however, terrestrial species will be negatively affected by periodic placement of dredged material on upland disposal sites and construction of facilities and roads associated with the projects. Habitat which attracted them will be covered, resulting in death to any slow moving or non-motile species. Others will be displaced; however for the upland disposal sites after dewatering, the habitat will likely return. Upland placement sites are not intended to be managed for mammal habitat.

5.4.1.5 Reptiles and Amphibians

The general study area is not considered high quality reptile and amphibian habitat; however, land turtles, snakes, lizards, and others may be adversely affected by periodic placement of dredged material on upland placement sites or clearing of upland sites. Habitat which attracted them will be covered, resulting in death to nonmotile or slow-moving species remaining on the site during placement. After dewatering from a placement area, the habitat will likely return; however, placement sites are not expected to be managed for this purpose.

5.4.1.6 Threatened and Endangered Species

Refer to Section 4.5 in this FEIS for a discussion of potential impacts to threatened and endangered species from the CCSCCIP preferred alternative. No significant impacts to threatened or endangered species are anticipated as a result of the reviewed projects in the general study area, with the exception of Packery Channel. The Biological Opinion for impacts to endangered and threatened species relative to Packery Channel has been issued by FWS. Piping plover critical habitat will be affected by the dredging of Packery Channel. Approximately 1.5 acres of critical habitat will be negatively impacted by the channel and jetties. In addition, 20 acres of beach nourishment will be placed on foraging beachfront areas for piping plover, yet would be considered a temporary impact.

5.4.1.7 Benthic Habitat

Organisms present on open-bay bottom will be temporarily affected by the project due to excavation and placement of dredged materials. However, a 290.4-acre net gain will occur when considering beneficial uses creation and mitigation for bay bottom and shallow-water habitat, SAV, wetlands (salt marsh), and flats (see sections 5.4.1.1, 5.4.1.2, 5.4.1.10, and 5.4.1.11). Additional impacts associated with the loss of Gulf of Mexico ocean bottom will occur due to the opening of Packery Channel (69.1 acres: 7.1 acres permanent; 62 acres temporary) and the CCSCCIP preferred alternative (526 acres), a temporary impact. Dredging activity in association with these projects may temporarily reduce the quality of nearby benthic habitat from increased turbidity. Most organisms present in areas covered for open water placement sites will be permanently lost; however, recovery will occur after placement is completed. Recent studies in Corpus Christi Bay (Ray and Clarke, 1999) have indicated that recovery occurs at open-bay placement sites in less than 1 year. Opportunistic populations can overtake newly created benthic habitat increasing its value to foraging species.

Toxic materials may be present in roadway runoff, which will negatively affect the benthos in the immediate vicinity of the JFITC and the JFK Causeway. Piers constructed to support the causeway and bridge are expected to be colonized by animals such as barnacles, oysters, and limpets, providing habitat for crabs, shrimp, small fish, and other marine organisms. The creation of shallow-water unvegetated and vegetated habitat is expected to provide rich substrate for benthic populations to develop. Rock breakwaters associated with CCSCCIP BU sites and the jetties at Packery Channel are expected to be colonized by animals such as barnacles, oysters, and limpets, providing habitat for crabs, shrimp, small fish, and other marine organisms.

5.4.1.8 Plankton

Increased turbidity during dredging and placement will decrease light transmittance necessary for photosynthesis of phytoplankton. Increased turbidity may also negatively affect zooplankton by damaging their filtering mechanism and impeding respiration. However, these impacts are temporary and local.

Toxic materials released during dredging of the projects, construction of the JFITC or the JFK Causeway, or traffic accidents on the bridge may have an adverse effect on plankton populations. However, data are not available to provide a quantitative analysis of the potential problem.

5.4.1.9 Essential Fish Habitat

Section 305(b)(1)(A and B) of the Magnuson Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act, 16 U.S.C 1801 et seq.), as amended, requires that the Regional Fishery Management Councils submit, by October 11, 1998, amendments to their Fishery Management Plans that identify and describe EFH for species under management. The Act also requires identification of adverse impacts on EFH and the actions that should be considered to ensure that EFH is conserved and enhanced.

Based on direct impacts (868 acres) to submerged aquatic vegetation, salt marsh, shallow bay bottom habitat, and flats identified in the reviewed projects, the net gain from proposed mitigation and beneficial use areas amounts to approximately 290.4 acres, with the majority of this acreage proposed by shallow water habitat. Given the size of this bay system, and the net gains from the projects, EFH will not be adversely affected.

5.4.1.10 Submerged Aquatic Vegetation

Based on the results of the document reviews, SAV will experience an area-wide increase. Approximately 5 acres are to be negatively impacted by the CCSCCIP and mitigated at a 3:1 ratio and approximately 935 acres of potential SAV habitat will be created in the BU sites. Four projects account for approximately 12.9 acres of negative impacts to SAV in the general vicinity. These include La Quinta Gateway Project (2.9 acres), Packery Channel (5.4 acres), Naval Station Ingleside (1.1 acres), and Mine Warfare Center of Excellence (3.5 acres). Negative impacts to seagrass habitat by these projects will be mitigated with 50 acres proposed for restoration.

As presented in the CCBNEP studies by Pulich et al. (1997), the Laguna Madre system has seen many changes since the 1950s, primarily in response to salinity changes. A summary of studies identified in the CCBNEP (Pulich et al., 1997) provide seagrass data results. In the Upper Laguna Madre from 1967 to 1988, shoalgrass increased; but from 1988 to 1994, shoalgrass decreased up to 60 percent with manateegrass becoming established in the northern part. Decreases since 1990 in the Upper Laguna Madre have been attributable to brown tide which reduces water clarity. Between 1958 and 1994, there has been an indication of an expansion of shoalgrass and widgeongrass on the backside of Mustang Island (Pulich et al., 1997). According to Pulich et al. (1997), general trends have shown that seagrass dynamics are highly variable with localized changes.

5.4.1.11 Estuarine Sand Flats/Mud Flats/Algal Flats

For the purpose of this study, impacts resulting from the CCSCCIP preferred alternative to this habitat were included in the Essential Fish Habitat (Section 5.4.1.9). No negative impacts were found to estuarine sand flats/mud flats/algal flats due to the CCSCCIP preferred alternative. Of the projects reviewed, the Naval Station Ingleside project identifies potential impacts at the project site to 112 acres of low-quality sand flats, and Packery Channel construction impacts identifies 1.9 acres. No mitigation has been proposed for any of the projects reviewed for tidal flats.

5.4.1.12 Open-Water Habitat

The construction of Packery Channel will cause the loss of approximately 7.1 acres of open-water habitat for jetty construction. No additional impacts are due to the CCSCCIP preferred alternative, with the exception of an anticipated loss from the conversion of deep-bay open-water to shallow-water marsh habitat and emergent islands in the BU sites. The benefit of the BU sites outweighs the impact of the loss of open water due to the high productivity to be created in these areas.

5.4.1.13 Oyster Reef Habitat

No impacts will occur to oyster reef habitat from the CCSCCIP preferred alternative. Impacts to oyster reef habitat were not indicated by the reviewed projects.

5.4.1.14 Coastal Shore Areas/Beaches/Sand Dunes

No significant or noticeable impacts are expected from the CCSCCIP preferred alternative. Impacts to coastal shore areas/beaches/sand dunes from the reviewed projects include approximately 63.0 acres from Packery Channel and 0.7 mile of shoreline for the La Quinta Gateway project. However, these impacts from Packery Channel result from beach nourishment with placement of sands on eroding beach and in shallow Gulf waters along the beach. Dune relocation and revegetation of 5,670 cy (approximately 1.5 acres) of dunes has been proposed for the Packery Channel project.

5.4.2 Physical/Chemical Resources

Increases in both upland and submerged elevations from dredged material placement with the preferred alternative can be expected to change local circulation patterns.

5.4.2.1 Topography/Bathymetry

Projects impacting topography/bathymetry include Packery Channel (3.5 miles), JFK Causeway (0.9 mile), La Quinta Gateway Project (32 acres), and Naval Station Ingleside (8.4 miles). The CCSCCIP will impact 43 miles. Periodic placement of maintenance material on open-water placement areas will temporarily decrease water depth in those areas until currents and wave action erode the dredged material away. Surface elevation will increase due to replacement of open bay with created marshes as BU sites and with the building of structures for reviewed projects.

5.4.2.2 Noise

Noise impacts included in those projects associated with dredging will include operation and maintenance noise. This impact will be temporary, will move up and down the project area depending on the section being dredged, and is not expected to differ from current maintenance dredging for many of the projects.

5.4.2.3 Air Quality

Objectionable odors (mercaptan, hydrogen sulfide) may result from the dredging of maintenance sediments containing high concentrations of organic matter in those reviewed projects requiring dredging. Temporary and intermittent maintenance dredging activities would emit nitrogen oxides and carbon monoxide primarily. During operation, pollutants expected to be emitted include nitrogen oxides, carbon monoxide, particulates, sulfur dioxides, and hydrocarbons. No reviewed projects are anticipated to violate the NAAQS because these projects require State air permits and compliance with permits would result in no adverse cumulative impacts on air quality.

5.4.2.4 Water Quality

Contaminants originating from the Inner Harbor and contained in material displaced or dredged from the Inner Harbor to Station 1080+00 and in upper Corpus Christi Bay will be contained in UCPAs. Monitoring and management of the effluent from these sites will control the reintroduction of contaminants to the environment. All reviewed projects will comply with the requirements of NPDES during construction of the projects.

Although water quality in the general study area appears to be improving, dredging and placement operations are expected to temporarily degrade water quality in the project vicinity through increased turbidity and release of bound nutrients. This is true of all projects involving dredging and dredged material placement. No projects reviewed cited concerns with sediment contamination or nutrients, including the CCSCCIP preferred alternative.

Dredging and placement at proposed open water and upland placement areas may increase suspended solids, release contaminants and bound nutrients, and deplete oxygen. This impact is temporary and, except for turbidity, insignificant. If temporary degradation occurs, the study area should rapidly return to ambient conditions upon completion of dredging.

A slight impact to water quality may occur as a result of vehicular use of the JFITC and the elevated JFK Causeway. Stormwater runoff, which may contain oil and grease may also have minimal impacts to water quality.

5.4.2.5 Salinity

Existing salinity condition is anticipated to be maintained as a result of dredging and maintenance of the majority of projects reviewed. Possible changes in hydrodynamics from the proposed JFK Causeway and Packery Channel may cause localized changes and, therefore, will not change the salinity structure of the Upper Laguna Madre or Corpus Christi Bay, as a whole (Hicks et al., 1999).

5.4.2.6 Freshwater Inflows

No alteration to freshwater flow is anticipated from the preferred alternative or from any projects reviewed in this analysis.

5.4.2.7 Turbidity

Reviewed projects requiring dredging and open water placement of dredged material will produce increased turbidity during dredging and placement. Continued use of open water placement areas may provide a source of continuing turbidity due to erosion by currents and wave action. Turbidity will also often occur in the immediate vicinity of the cutterhead dredge near the point of open-water placement and from runoff from construction sites during highway projects. Turbidity from these sources is expected to return to concentrations below ambient soon after cessation of dredging.

5.4.2.8 Circulation/Tides

Temporary, minor changes in circulation in the vicinity of open water placement areas containing newly placed materials are expected upon construction dredging and with the maintenance dredging process. Circulation is expected to return to existing conditions when the majority of the material has eroded away. No changes in turnover and tides are expected as a result of dredging the reviewed projects. Hicks et al. (1999) predicts a small, localized effect in hydrodynamics as water is allowed to move through a 2,550-foot water opening in the proposed JFK Causeway, rather than the present exchange through Humble Channel and the GIWW only. Changes in circulation will occur with the opening of Packery Channel.

5.4.2.9 Sediment Quality

Potentially contaminated sediments from the Inner Harbor reach of the CCSCCIP will be placed in UCPAs. Monitoring and management of the effluent from these sites will control reintroduction of these contaminants to the environment. Decreased ship traffic resulting from the preferred alternative may decrease the potential for spills that may eventually contaminate sediments in the study area.

5.4.3 Cultural/Socioeconomic Resources

Cultural impacts are anticipated to be minimal as a result of the CCSCCIP preferred alternative. There is a low probability that unknown submerged archaeological sites, excluding shipwrecks, may be impacted.

Socioeconomic impacts relate mainly to an increase in population, an increase in demand for housing, and impacts to land use. These impacts would occur in Nueces and San Patricio Counties primarily in the following communities: Corpus Christi, Portland, Ingleside, Ingleside-by-the-Bay, and Aransas Pass. The population increase that would result from the projects evaluated would be approximately 29,000 (assuming complete build-out of all projects). This increase in population would provide the impetus for a local demand of approximately 11,450 housing units. One business would be relocated as a result of the construction of the Raising Kennedy Causeway project. No EJ or community cohesion impacts would result from any of the projects evaluated. Land use impacts include development of approximately 1,300 acres of vacant land in San Patricio County, expanded roadways and rail-lines on the north side of the Corpus Christi Bay and within the Inner Harbor area of Corpus Christi. The Packery Channel project would impact approximately 25 acres of currently vacant land, although approximately 20 of these acres would be converted to public parkland (including parking and other structures). Cumulative impacts related to an increase in visitor usage of parks and recreational areas was not evaluated, as these impacts were not addressed in any of the documentation prepared for any of the reviewed projects.

Socioeconomic benefits are grouped into benefits that would occur during project construction, and those that would occur after project construction is complete. The projects that were reviewed would provide an increase in annual employment of approximately 7,305 jobs (includes indirect and induced jobs), and wages for these jobs would be approximately $238 million annually. Total economic output within San Patricio and Nueces Counties would be approximately $597 million annually, and indirect business taxes for local and State government would be $15.9 million annually. After construction on all reviewed projects is complete, there would be an increase in annual employment of approximately 17,530 annual jobs, and wages for these jobs would be approximately $641.4 million annually. Total economic output within San Patricio and Nueces Counties would be approximately $795.1 million, and indirect business taxes for local and State government would be $25.5 million annually.

Secondary effects would occur as a result of the reviewed projects. Increased tourist and recreational usage of North Padre and Mustang islands is anticipated as a result of potential secondary development due to improved access resulting from the JFK Causeway. The Packery Channel Project would also increase tourist and recreational usage in the North Padre Island area. Economic development in this area is anticipated to result in increased commercial, and residential development on North Padre Island. Transportation access will be improved with new channel development projects and maintenance of existing channels. Transportation safety will be improved in all channel projects and hurricane evacuation for Padre Island will be improved due to the JFK Causeway project.

5.4.3.1 Oil and Gas Production on Submerged Lands

Current oil and gas pipelines are placed to accommodate existing channel dimensions. The majority of the reviewed project documents did not address oil and gas production; however, no change in oil and gas production is anticipated as a result of the projects evaluated for cumulative impact assessment.

5.4.3.2 Ship Accidents/Spills

A decrease in the number of vessels will occur with the CCSCCIP preferred alternative relative to the No-Action alternative and may occur due to the other channel improvement or maintenance projects reviewed, which may decrease potential for spills. The potential for accidental releases related to dredging activity will exist; however, spill prevention plans can minimize impacts. No additional impacts are anticipated.

5.4.3.3 Historic Resources

Historic and archeological resources are expected to be impacted by the CCSCCIP preferred alternative (see Section 4.7). None of the reviewed projects conflict with sites currently listed on the NRHP or are designated as SALs.

5.4.3.4 Recreation

The Corpus Christi Bay area is widely used by recreational fishermen and boaters. Turbidity associated with dredging and placement is anticipated to temporarily damage local fisheries in small portions of the general study area. Restricted areas are likely to be associated with the U.S. Navy projects (Naval Station Ingleside and Mine Warfare Center). Channel improvement projects like those reviewed provide greater access to and throughout the bay for recreational fishermen and boaters. Increased tourism would likely be a response to the opening of Packery Channel and the development of ancillary park facilities. Cumulative impacts associated with aquatic habitat are addressed in Sections 5.4.1.2, 5.4.1.7, and 5.4.1.9.

5.4.3.5 Commercial and Recreational Fisheries

Many commercially and recreationally important species of shrimp and finfish are common in the general study area, specifically, red drum, spotted sea trout, black drum, mullet, southern flounder, brown shrimp, and pink shrimp. These species may be adversely affected by degradation of open-bay bottom foraging habitat due to open-water placement, but recovery is speedy (Ray and Clarke, 1999). Refer to Section 4.2.1.2 in this FEIS for impacts to commercial and recreational fisheries with the CCSCCIP preferred alternative. Opening Packery Channel is expected to increase opportunities for recreational fisherman.

5.4.3.6 Public Health

No impacts to public health are expected from the reviewed projects.

5.4.3.7 Safety

The primary purpose of elevating the JFK Causeway to a minimum of 9 feet MSL is to enhance public safety, particularly during natural emergencies such as hurricanes. Safety impacts to other reviewed projects were not indicated except for the CCSCCIP preferred alternative, which would improve safety in the CCSC from channel widening and the addition of barge lanes.

5.4.3.8 Parks and Beaches

No impacts to parks and beaches are expected from the reviewed projects except the Packery Channel Project. Beach will be removed due to channel construction, and beach nourishment in two areas will temporarily prevent use by the public.

5.5 CONCLUSIONS

Cumulative impacts due to past, existing, and reasonably foreseeable future projects, along with the CCSCCIP preferred alternative, were found to produce a net positive cumulative impact in the CCSC area. Although some parameters would experience negative impacts, most of these impacts would be temporary and minor. Benefits realized through creation and protection of wetlands, seagrass, and marsh habitat by the preferred alternative and some other projects resulted in a net positive impact assessment.

6.0 COMPLIANCE WITH TEXAS COASTAL MANAGEMENT PROGRAM

Compliance with the Texas Coastal Management Program (CMP) is documented in Appendix E. The project was reviewed and found consistent by the Coastal Coordination Council.

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7.0 CONSISTENCY WITH OTHER STATE AND FEDERAL REGULATIONS

This FEIS has been prepared to satisfy the requirements of all applicable environmental laws and regulations and has been prepared using the CEQ's NEPA regulations (40 CFR Part 1500) and the USACE's regulation ER 200-2-2 (Environmental Quality: Policy and Procedures for Implementing NEPA, 33 CFR 230). The following sections present a summary of environmental laws, regulations, and coordination requirements applicable to this FEIS.

7.1 NATIONAL ENVIRONMENTAL POLICY ACT

This FEIS has been prepared in accordance with CEQ regulations in compliance with NEPA provisions. All impacts on terrestrial and aquatic resources have been identified, significant adverse impacts requiring mitigation have been identified, and mitigation has been proposed.

7.2 NATIONAL HISTORIC PRESERVATION ACT OF 1966

Compliance with the NHPA of 1966, as amended, requires identification of all NRHP-listed or NRHP-eligible properties in the project area and development of mitigation measures for those adversely affected in coordination with the SHPO and the Advisory Council on Historic Preservation (ACHP). As indicated in Section 4.7, this project will have no impacts on NRHP-listed properties or SALs. This FEIS has been coordinated with the Texas SHPO.

7.3 CLEAN WATER ACT

Section 404 of the Act applies to the preferred alternative and compliance will be achieved under Section 404(r). Section 404(r) provides an exemption from obtaining either State water quality certification or a 404 permit if specific requirements are met. These requirements include a discussion based on the Section 404(b)(1) Guidelines in the FEIS and submittal of that document to Congress before the proposed project is authorized. The FEIS contains the necessary evaluation (Appendix A) and will be submitted to Congress for authorization. The basis for concluding that 404(r) requirements have been met is the fact that all relevant sediment and water quality data for both new-work and maintenance material were reviewed by a team of State and Federal resource agencies (Contaminants Workgroup), including the TNRCC, and they found no cause for concern over water or sediment quality in any channel reach, except the Inner Harbor. New-work sediments were deemed suitable for use in constructing BU sites or placement in the open bay or upland confined PAs. Maintenance material will be handled according to the DMM/BU Plan. The Inner Harbor dredged material will be placed in fully confined upland PAs and the decant water returned to the Inner Harbor to avoid potential contamination of other areas.

7.4 ENDANGERED SPECIES ACT

Interagency consultation procedures under Section 7 of this act have been undertaken. A BA was prepared describing the study area, Federally listed endangered and threatened species likely to occur in the area (as provided by the FWS and NMFS), and potential impacts on these listed species (attached as Appendix C). The USACE has determined that no significant impacts to Federally listed species or designated Critical Habitat will occur as a result of the project addressed in this FEIS. Agency comments, including concurrence from FWS and the NMFS Biological Opinion, have been included as an attachment to this FEIS. The NMFS has guidelines to protect sea turtles when hopper dredges are being used. These guidelines will be followed.

7.5 FISH AND WILDLIFE COORDINATION ACT OF 1958

This act requires the FWS to prepare an official Fish and Wildlife Coordination Act Report (CAR). The Final CAR is included in this FEIS as part of the Appendix D, Coordination, and constitutes compliance with the act. All project alternatives, including the preferred alternative, have been extensively coordinated with the FWS and other State and Federal resource agencies, including an 8-month piping plover survey in the project area and FWS participation in the RACT and the Workgroups concerned with mitigation and beneficial uses.

7.6 FISHERY CONSERVATION AND MANAGEMENT ACT OF 1996

Congress enacted amendments to the Magnuson-Stevens Fishery Conservation and Management Act (PL 94-265) as amended in 1996 that established procedures for identifying Essential Fish Habitat (EFH) and required interagency coordination to further the conservation of Federally managed fisheries. Rules published by the National Marine Fisheries Service (50 CFR Sections 600.805 – 600.930) specify that any Federal agency that authorizes, funds or undertakes, or proposes to authorize, fund, or undertake an activity that could adversely affect EFH is subject to the consultation provisions of the above-mentioned act and identifies consultation requirements.

EFH consists of those habitats necessary for spawning, breeding, feeding, or growth to maturity of species managed by Regional Fishery Management Councils in a series of Fishery Management Plans. Sections 3.5.1.3 and 4.4.1.4 of the FEIS were prepared to address EFH in the project area and meet the requirements of the act.

7.7 COASTAL BARRIER IMPROVEMENT ACT OF 1990

This act is intended to protect fish and wildlife resources and habitat to prevent loss of human life and to preclude the expenditure of Federal funds that may induce development on coastal barrier islands and adjacent nearshore areas. Certain exceptions exist which allow for such expenditures. The preferred alternative is exempt from the prohibitions identified in the act.

7.8 MARINE PROTECTION, RESEARCH, AND SANCTUARIES ACT

This 1972 act requires a determination that dredged material placement in the ocean will not reasonably degrade or endanger human health, welfare, or amenities or the marine environment, ecological systems, or economic potentialities (shellfish beds, fisheries, or recreational areas). All construction material destined for the Gulf of Mexico has been evaluated using the CWA 404(b)(1) guidelines (Appendix A) and will be used beneficially, as determined by the RACT. Maintenance material proposed for placement at the existing Ocean Dredged Material Disposal Site designated by the EPA for maintenance material from the Corpus Christi Entrance Channel is subject to evaluation using the ocean dumping environmental criteria.

7.9 FEDERAL WATER PROJECT RECREATION ACT

This 1995 act requires consideration of opportunities for outdoor recreation and fish and wildlife enhancement in planning water resource projects. The beneficial uses included in the project for the construction material include uses requested by various recreational groups, environmental groups, and State and Federal regulatory agencies. All will benefit one or more of the items listed above.

7.10 EXECUTIVE ORDER 11988, FLOODPLAIN MANAGEMENT

This Executive Order (EO) directs Federal agencies to evaluate the potential effects of proposed actions on floodplains. Such actions should not be undertaken that directly or indirectly induce growth in the floodplain unless there is no practical alternative. The preferred alternative will not significantly affect the Corpus Christi Bay floodplain.

7.11 EXECUTIVE ORDER 11990, PROTECTION OF WETLANDS

This EO directs Federal agencies to avoid undertaking or assisting in new construction located in wetlands, unless no practical alternative is available. The preferred alternative has been analyzed for compliance with EO 11990. Erosion protection measures and beneficial uses should result in a net gain in wetland habitat.

7.12 TEXAS COASTAL MANAGEMENT PROGRAM

Section 6.0 and Appendix E address the compliance of the preferred alternative addressed in this FEIS with the TCMP, including a Consistency Agreement by the Coastal Coordination Council.

7.13 CEQ MEMORANDUM DATED 11 AUGUST 1980, PRIME OR UNIQUE FARMLANDS

There will be no impacts to prime and unique farmlands from the preferred alternative.

7.14 EXECUTIVE ORDER 12898, ENVIRONMENTAL JUSTICE

This EO directs Federal agencies to determine whether the preferred alternative will have a disproportionate adverse impact on minority or low-income population groups within the project area.

The preferred alternative has been analyzed for compliance with EO 12898. The preferred alternative will not significantly affect any low-income or minority population.

7.15 CLEAN AIR ACT OF 1972

This act is intended to protect and enhance the quality of the nation's air resources; to initiate and accelerate research and development to prevent and control air pollution; to provide technical and financial assistance for air pollution prevention and control programs; and to encourage and assist regional air pollution prevention and control programs. The preferred alternative is in compliance with this Act.

7.16 MARINE MAMMAL PROTECTION ACT OF 1972

This act, passed in 1972 and amended through 1997, is intended to conserve and protect marine mammals, establish a marine mammal commission, establish the International Dolphin Conservation Program, and establish a Marine Mammal Health and Stranding Response Program. The preferred alternative is in compliance with this Act.

8.0 PUBLIC INVOLVEMENT, REVIEW, AND CONSULTATION

Review and consultation of this document was performed by the USACE, PCCA, and RACT members.

8.1 PUBLIC INVOLVEMENT PROGRAM

The USACE and PCCA involved the public through outreach programs such as newsletters, public meetings, special interest group meetings, and other outreach throughout the history of this project. A proactive approach was taken to inform and involve the public, resource agencies, industry, local government, and other interested parties about the project and to identify any concerns from the aforementioned groups. Appendix D contains only a portion of the official record of communication with the public. The most pertinent documents were chosen to include in Appendix D.

In 1990, the U.S. Congress authorized the USACE to begin a reconnaissance study to investigate deepening the CCSC. Public involvement began during the reconnaissance phase on March 30, 1994, when the USACE held a public workshop to describe the study and solicit public input. In September 1994, the USACE completed the reconnaissance study. The study concluded that the benefits of channel improvements would be 2.5 times greater than the project cost. Therefore, the recommendation was made to proceed into the feasibility phase. Nine public meetings followed to update the public about the progression of the project and to solicit input. A series of newsletters was also sent to approximately 1,300 people or organizations in the area, including those who attended meetings or expressed an interest in the project or could potentially be interested in the project. In addition to the general public meetings, special-interest group meetings were also held. Other various forms of outreach utilized during this project included early regulatory agency coordination, RACT/Workgroup meetings, individual contacts, a toll-free 800 number, Spanish voice mailbox, web site posting, press releases, and comment forms.

8.2 REQUIRED COORDINATION

The Draft Feasibility Report and DEIS have been circulated to all known Federal, State, and local agencies. Interested organizations and individuals were sent notice of availability.

8.3 STATEMENT RECIPIENTS

The following list includes those who were sent a copy of these documents along with a request to review and provide comments on the documents:

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8.4 PUBLIC VIEWS AND RESPONSES

Public views and concerns expressed during this study have been considered during the preparation of this FEIS. The views and concerns were used to develop planning objectives, identify significant resources, evaluate impacts of various alternatives, identify potential beneficial uses, and identify a plan that is socially and environmentally acceptable. Important concerns expressed included the beneficial use of dredged material and recreational opportunities.

Development of alternatives is explained in the Feasibility Report. The recommended plan meets the expressed objectives, views, and concerns of the resource agencies and public. Comment letters on the DEIS, and responses to those comments, are included in Appendix D.

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9.0 LIST OF PREPARERS

The USACE Project Manager for the Corpus Christi Ship Channel – Channel Improvements Project EIS is Carl Anderson. PCCA Project Manager is David Krams.

PBS&J key personnel responsible for preparation of the EIS are listed below:

Topic/Area of Responsibility	Name/Title	Experience
U.S. Army Corps of Engineers, Galveston District		
Document Coordination & Review	Carolyn Murphy Environmental Section Chief	24 Years, Planning and Environmental Resources
Document Coordination & Review	Bob Heinly Project Engineer	11 Years, Civil Works Planning and Regulatory Branch
Document Coordination & Review	Terrell W. Roberts, Ph.D. Wildlife Biologist	18 Years, Environmental, Threatened, and Endangered Species Impact Analysis
Document Coordination & Review (Archaeological)	Janelle Stokes Archaeologist	21 Years, Cultural Resources Coordination, Archaeological Research and Surveys
Document Coordination & Review	John McManus Civil Engineer	29 Years, Civil Engineering
Document Coordination & Review	Dave McLintock Hazardous, Toxic, and Radioactive Waste, Water/ Air Quality	16 Years, Environmental Protection
Port of Corpus Christi Authority		
Document Coordination & Review	David Krams Senior Project Engineer/ Project Manager	18 Years, Engineering/Project Management
Document Coordination & Review	Paul Carangelo Environmental Project Manager	26 Years, Environmental Planning/ Project Management
PBS&J:		
Project Manager	Martin Arhelger Vice President, Project Director	27 Years, Environmental Assessment and Impact Analysis
Assistant Project Manager, Document Review (Project Description, Alternatives Analysis)	Kari Jecker Ecologist	7 Years, Natural Resources Management and Impact Analysis
Wildlife and Habitat; Endangered and Threatened Wildlife Species	Derek Green Biologist, Wildlife Specialist	20 Years, Environmental Assessment and Impact Analysis

Topic/Area of Responsibility	Name/Title	Experience
PBS&J (cont'd):		
Historical/Cultural Resources – Marine	Bob Gearhart Archeologist; Magnetometer and Side-Scan Sonar Specialist	18 Years, Marine Archaeology
Air Quality	Ruben Velasquez, P.E. Senior Engineer, Air Quality Specialist	19 Years, Air Quality Analysis
Vegetation; Endangered and Threatened Plant Species	Kathy Calnan Ecologist, Botanist	13 Years, Vegetation Analysis and Impacts
Hazardous Materials	Steve McVey Geologist, HAZMAT Specialist	8 Years, Environmental Geology
Historical/Cultural Resources – Terrestrial	Meg Cruse Archaeologist	14 Years, Archaeology
Land Use; Environmental Justice; Socioeconomics	Chris Moore Environmental Planner	6 Years, Urban and Environmental Planning
Environmental Justice	Kathie Martel Environmental Planner	3 Years, Environmental Planning and Socioeconomic Analysis
Noise	Thomas Ademski Environmental Planner	3 Years, Environmental Planning and Noise Analysis
Cumulative Impacts	Patsy Turner Ecologist, Botanist	17 Years, Environmental Assessment and Impact Analysis with Emphasis on Vegetation
Essential Fish Habitats	Lisa Vitale Marine\Aquatic Biologist	10 Years, Marine/Aquatic Biology
Traffic	Ryan Hill Air and Noise Specialist	16 Years, Transportation Planning
Technical Support	Ty Summerville Senior GIS Analyst	7 Years, CAD/GIS
Technical Support	Gray Rackley CAD/GIS Specialist	4 Years, CAD/GIS
Technical Support	David Kimmerling CAD/Graphics Specialist	18 Years, Graphics
Technical Support	Bob Bryant Lead Word Processor	13 Years, Word Processing

10.0 REFERENCES, ABBREVIATIONS, INDEX, AND GLOSSARY

10.1 REFERENCES

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10.2 LIST OF ABBREVIATIONS

ADP	Area Development Plan
AIC	Agency Information Consultants
AOU	American Ornithologists' Union
AST	aboveground storage tank
AWOIS	Automated Wreck and Obstruction Information System
BA	Biological Assessment
BEG	U.S. Bureau of Economic Development
BNSF	Burlington Northern Santa Fe Railway
BU	Beneficial Use
BUW	Beneficial Uses Workgroup
CAR	Center for Archaeological Research
CAW	Cumulative Assessment Workgroup
CBBF	Coastal Bend Bays Foundation
CBD	central business district
CCBNEP	Corpus Christi Bay National Estuary Program (now the Coastal Bend Bays & Estuaries Program (CBBEP)
CCRCS	Corpus Christi Rincon Canal System
CCSC	Corpus Christi Ship Channel
CCSCCIP	Corpus Christi Ship Channel – Channel Improvements Project
CCTR	Corpus Christi Terminal Railroad
CEQ	Council on Environmental Quality
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act (1980)
CERCLIS	EPA's Comprehensive Environmental Response, Compensation, and Liability Information System
CFR	Code of Federal Regulations
CIP	Capital Improvement Program
CLF	civilian labor force
CORRACT	RCRIS Corrective Action Database
CW	Contaminants Workgroup
dBA	A-weighted decibel
DEIS	Draft Environmental Impact Statement
DoD	Department of Defense
EA	Environmental Assessment
EFH	Essential Fish Habitat
EIS	Environmental Impact Statement
EJ	Environmental Justice

EO	Executive Order
EPA	U.S. Environmental Protection Agency
ERDC	U.S. Army Engineer Research and Development Center
ERL	Effects Range Low
ERNS	Emergency Response Notification System
ESA	Endangered Species Act (1973)
ETJ	extra-territorial jurisdiction
FEIS	Final Environmental Impact Statement
FEMA	Federal Emergency Management Agency
FINDS	Facility Index System
FMP	Fisheries Management Plan
FR	Federal Register *or* Feasibility Report
FS	Feasibility Study
FWS	U.S. Fish and Wildlife Service
GIWW	Gulf (of Mexico) Intracoastal Waterway
GLO	Texas General Land Office
GMFMC	Gulf of Mexico Fishery Management Council
HSMW	Hydrodynamic and Salinity Modeling Workgroup
HTRW	Hazardous, Toxic, Radioactive Waste
IH	Interstate Highway
ISO	Insurance Services Office, Inc.
JFITC	Joe Fulton International Trade Corridor
JFK	John F. Kennedy (Causeway)
L_{dn}	day-night sound level
LPUST	leaking petroleum underground storage tank
LQG	large quantity generator
mcy	million cubic yards
mg/kg	milligrams per kilogram
mg/l	milligrams per liter
MLT	mean low tide
mph	miles per hour
MSF	Magnetic Silencing Facility
MSFCMA	Magnuson-Stevens Fishery Conservation and Management Act
MSL	mean sea level
MW	Mitigation Workgroup
NAAQS	National Ambient Air Quality Standards
NGVD	National Geodetic Vertical Datum
NEPA	National Environmental Policy Act

NFRAP	No Further Remedial Action Planned
NIS	Non-Indigenous Invasive Species
NISA	National Invasive Species Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NPS	National Parks Service
NRCS	Natural Resources Conservation Service
NRHP	National Register of Historic Places
NWI	National Wetlands Inventory
NWPCP	National Wetlands Priority Conservation Plan
NWR	National Wildlife Refuge
OAQPS	(EPA) Office of Air Quality Planning and Standards
PA	dredged material placement area
PAH	polycyclic aromatic hydrocarbons
PCB	polychlorinated biphenyl
PCCA	Port of Corpus Christi Authority
PCE	perchloroethane
PM	particulate matter
ppb	parts per billion
ppt	parts per thousand
RACT	Regulatory Agency Coordination Team
RCRA	Response Conservation and Recovery Act
RCRA-GEN	RCRA Generators Sites
RCRIS	EPA's Resource Conservation and Recovery Information System
RIA	Regional Implementation Agreement
RIP	Rincon Industrial Park
SAL	State Archeological Landmark
SAV	submerged aquatic vegetation
SEW	Shoreline Erosion Workgroup
SH	State Highway
SHPO	State Historical Preservation Officer
SOC	Species of Concern
SQG	Sediment Quality Guidelines
SQT	Sediment Quality Triad
SWL	Solid Waste Landfill
TAAS	Texas Agricultural Statistics Service

TARL	Texas Archeological Research Laboratory
TCMP	Texas Coastal Management Program
TDH	Texas Department of Health
TDWR	Texas Department of Water Resources
THC	Texas Historical Commission
TMDL	total maximum daily load
TNRCC	Texas Natural Resource Conservation Commission
TOC	total organic carbon
TOES	Texas Organization for Endangered Species
TOS	Texas Ornithological Society
TPH	total petroleum hydrocarbons
TPWD	Texas Parks and Wildlife Department
TSD	Treatment, Storage or Disposal (TSD) database
TSDC	Texas State Data Center
TWC	Texas Workforce Commission
TWDB	Texas Water Development Board
TWQS	Texas Surface Water Quality Standards
TXBCD	Texas Biological and Conservation Data System
TxDOT	Texas Department of Transportation
μg/kg	micrograms per kilogram
μg/l	micrograms per liter
UPRR	Union Pacific Railroad
U.S.	United States
UCPA	Upland Confined Placement Area
USACE	U.S. Army Corps of Engineers
USBEA	U.S. Bureau of Economic Analysis
USBOC	U.S. Bureau of Census
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
UST	underground storage tank
VFD	volunteer fire department
VOC	volatile organic compound

10.3 INDEX

10.4 GLOSSARY

The following definitions are for the convenience of those reading this Environmental Impact Statement and do not replace definitions in State, Federal, or local laws, regulations and ordinances.

benthos – Aquatic bottom dwelling organisms which include worms, leeches, snails, flatworms, burrowing mayflies, clams.

bioaccumulation – The accumulation of contaminants in the tissues of organisms through any route, including respiration, ingestion, or direct contact with contaminated water, sediment, or dredged material.

biomass – The mass of living material in a given area or volume of habitat.

brackish water – A mixture of fresh and salt water.

coastal zone – Coastal waters and adjacent lands that exert a measurable influence on the uses of the sea and its ecology.

contaminant – A chemical or biological substance in a form that can be incorporated into, onto, or be ingested by and that harms aquatic organisms, consumers of aquatic organisms, or users of the aquatic environment.

crustacean – A group of aquatic animals characterized by jointed legs and a hard shell which is shed periodically, e.g., shrimp, crabs, crayfish, isopods, and amphipods.

dredged material – Material excavated from waters of the United States or ocean waters. The term dredged material refers to material which has been dredged from a water body, while the term sediment refers to material in a water body prior to the dredging process.

effluent – A discharge of pollutants into the environment, partially or completely treated or in its natural state. Generally used in regard to discharges into waters.

EIS – Environmental impact statement. A document prepared on the environmental impact of actions significantly affecting the quality of the human environment and used as a tool for decision-making.

family household – A household maintained by a householder who is in a family.

floodplain – The flat, low-lying portion of a stream valley subject to periodic inundation.

groundwater – The supply of freshwater under the earth's surface in an aquifer or soil that forms the natural reservoir for man's use.

group quarters – Noninstitutional living arrangements for groups not living in conventional housing units or groups living in housing units containing ten or more unrelated people

habitat – The specific area or environment in which a particular type of plant or animal lives. An organism's habitat provides all of the basic requirements for the maintenance of life. Typical coastal habitats include beaches, marshes, rocky shores, bottom sediments, mudflats, and the water itself.

infauna – Animals which live within the sediment of the sea bottom.

isopod – A small, flattened crustacean belonging to the order Isopoda.

lagoon – A shallow body of seawater generally isolated from the ocean by a barrier island. Also the body of water enclosed within an atoll, or the water within a reverse estuary.

larva (pl. **larvae)** – An embryo that differs markedly in appearance from its parents and becomes self-sustaining before assuming the physical characteristics of its parents.

lead – A heavy metal that may be hazardous to human health if breathed or ingested.

mercury – A heavy metal, highly toxic of breathed or ingested. Mercury is residual in the environment, showing biological accumulation in all aquatic organisms, especially fish and shellfish. Chronic exposure to airborne mercury can have serious effects on the central nervous system.

non-family household – A household maintained by a householder who is not in a family.

open-water disposal – Placement of dredged material in rivers, lakes, estuaries, or oceans via pipeline or surface release from hopper dredges or barges.

organism – Any living human, plant, or animal.

particulate matter – very fine solid or liquid particles in the air or in an emission, including dust, fog, fumes, mist, smoke, and spray, etc.

PCB – Polychlorinated biphenyls, a group of organic compounds used in the manufacture of plastics. In the environment, PCBs exhibit many of the same characteristics as DDT and may, therefore, be confused with that pesticide. PCBs are highly toxic to aquatic life, they persist in the environment for long periods of time and are biologically accumulative.

"permitted" – Used by TNRCC personnel to mean 1) required to have a permit from the TNRCC or 2) having received such a permit through a process that includes a written application and a formal review by the agency.

phytoplankton – Plantlike, usually single-celled members (generally microscopic) of the plankton community.

plankton – Drifting or weakly swimming organisms suspended in water. Their horizontal position is to a large extent dependent on the mass flow of water rather than on their own swimming efforts.

runoff – The portion of rainfall, melted snow, or irrigation water that flows across ground surface and eventually is returned to streams. Runoff can pick up pollutants from the air or the land and carry them to receiving waters.

sediment – The layer of soil, sand, and minerals at the bottom of surface water that absorbs contaminants.

shoalgrass – Seagrass species (*Halodule beaudettei*); submerged perennial, restricted to shallow, saline coastal bays.

Superfund – The common name used for the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA).

surface water – Water on the earth's surface exposed to the atmosphere as rivers, lakes, streams, and oceans.

TNRCC – Texas Natural Resource Conservation Commission. On September 1, 1993, the Texas Air Control Board, Texas Water Commission, and parts of the Texas Department of Health merged and became the TNRCC.

toxic pollutant – Pollutants, or combinations of pollutants, including disease-causing agents, that after discharge and upon exposure, ingestion, inhalation, or assimilation into any organism, either directly from the environment or indirectly by ingestion through food chains, will, on the basis of information available to the Administrator of the U.S. Environmental Protection Agency, cause death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions, or physical deformations in such organisms or their offspring.

TPDES – Texas Pollutant Discharge Elimination System. The major program for regulating municipal and industrial wastewater discharges through the permitting of wastewater treatment facilities. In 1998, TNRCC took over the administration of this program in Texas, formerly the NPDES, administered by the U.S. EPA.

turbidity – An optical measure of the amount of material suspended in the water. Increasing the turbidity of the water decreases the amount of light that penetrates the water column. High levels of turbidity may be harmful to aquatic life.

wetlands – Areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support and that, under normal circumstances, do support a prevalence of vegetation typically adapted for life in saturated-soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas (40 CFR Part 230), especially areas preserved for wildlife, zooplankton (planktonic animals that supply food for fish).

VOC – Volatile organic compounds. Secondary petrochemicals, including light alcohols, acetone, trichloroethylene, perchloroethylene, dichloroethylene, benzene, vinyl chloride, toluene, and methylene chloride, which are used as solvents, degreasers, paint thinners, and fuels. Because of their volatile nature, they readily evaporate into the air, increasing the potential exposure to humans. Due to their low water solubility, environmental persistence and widespread industrial use, they are commonly found in soil and groundwater.

zooplankton – Animal members of the plankton community.

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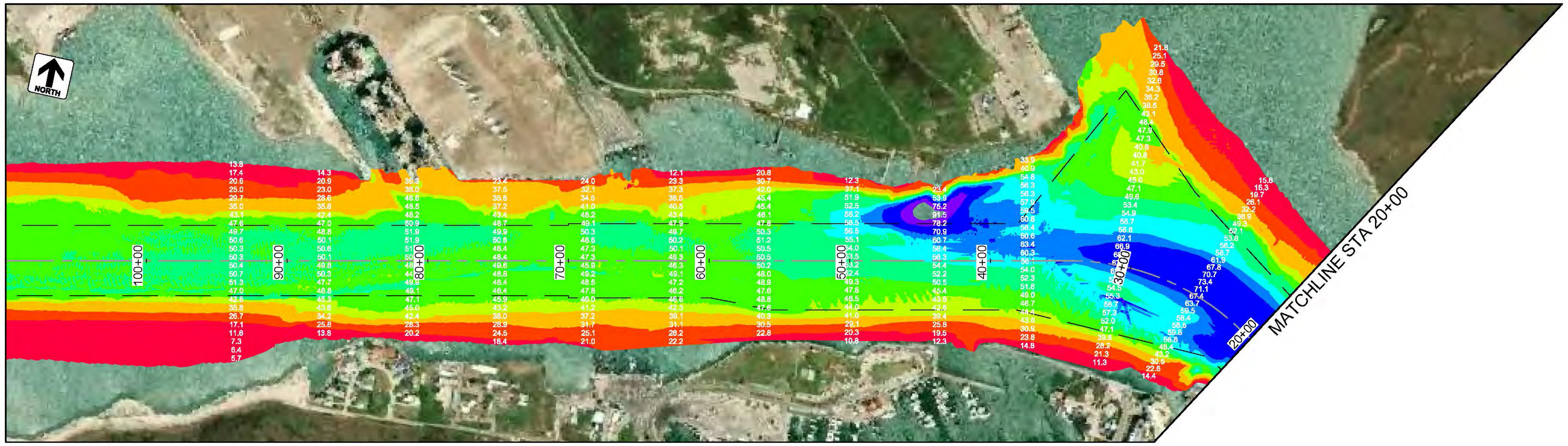
Appendix B

Fugro Geotech (Channel Bathymetry, Cross Sections, and Geotechnical Boring Logs)

CHANNEL BATHYMETRY



Elevations Table			
Number	Minimum Elevation	Maximum Elevation	Color
1	−20.000	0.000	red
2	−30.000	−20.000	orange-red
3	−40.000	−30.000	orange
4	−45.000	−40.000	yellow-green
5	−50.000	−45.000	green
6	−55.000	−50.000	aqua-green
7	−60.000	−55.000	cyan
8	−65.000	−60.000	light blue
9	−75.000	−65.000	blue
10	−85.000	−75.000	violet

SCALE:
0 250' 500' 1,000'

PCCA PROJ. #18-038A

GENERAL NOTES:

1. BATHYMETRY DATA SHOWN IS COMPRISED OF USACE SINGLE BEAM DATED JUNE 2018 AND TERRASOND MULTIBEAM DATED SEPTEMBER 2018.
2. SOUNDINGS AND ELEVATIONS SHOWN REPRESENT CONDITIONS AT THE TIME SURVEYED.
3. SOUNDINGS AND ELEVATIONS ARE IN FEET AND TENTHS AND ARE REFERENCED TO MEAN LOWER LOW WATER (MLLW) DATUM.
4. HORIZONTAL COORDINATES ARE REFERENCED TO U.S. STATE PLANE TEXAS SOUTH 4205, NAD83.
5. AERIAL IMAGERY OBTAINED FROM ESRI WORLD IMAGERY AND IS DATED 2018.

NO.	DATE	REVISION

PORT CORPUS CHRISTI

PORT OF CORPUS CHRISTI AUTHORITY

CORPUS CHRISTI SHIP CHANNEL DEEPENING PROJECT

Permit # SWE 2019-00067

SCALE: 1" = 500'	CHANNEL BATHYMETRY MAP 1	DATE: 3/7/2019
DWN. BY: JS		DWG. NO.

\\ushou1fs001\prod\Projects_PWD\Port of Corpus Christi\900 CADD\25-Sketches\BatMaps\PCCA_BatMap-Soundings.dwg 3/7/2019 3:47 PM

Elevations Table

Number	Minimum Elevation	Maximum Elevation	Color
1	-20.000	0.000	
2	-30.000	-20.000	
3	-40.000	-30.000	
4	-45.000	-40.000	
5	-50.000	-45.000	
6	-55.000	-50.000	
7	-60.000	-55.000	
8	-65.000	-60.000	
9	-75.000	-65.000	
10	-85.000	-75.000	

SCALE:
0 250' 500' 1,000'

PCCA PROJ. #18-038A

GENERAL NOTES:

1. BATHYMETRY DATA SHOWN IS COMPRISED OF USACE SINGLE BEAM DATED JUNE 2018 AND TERRASOND MULTIBEAM DATED SEPTEMBER 2018.
2. SOUNDINGS AND ELEVATIONS SHOWN REPRESENT CONDITIONS AT THE TIME SURVEYED.
3. SOUNDINGS AND ELEVATIONS ARE IN FEET AND TENTHS AND ARE REFERENCED TO MEAN LOWER LOW WATER (MLLW) DATUM.
4. HORIZONTAL COORDINATES ARE REFERENCED TO U.S. STATE PLANE TEXAS SOUTH 4205, NAD83.
5. AERIAL IMAGERY OBTAINED FROM ESRI WORLD IMAGERY AND IS DATED 2018.

NO.	DATE	REVISION

PORT CORPUS CHRISTI

PORT OF CORPUS CHRISTI AUTHORITY

CORPUS CHRISTI SHIP CHANNEL DEEPENING PROJECT

Permit # SWE 2019-00067

SCALE: 1" = 500'

DWN. BY: JS

CHANNEL BATHYMETRY MAP 2

DATE: 3/7/2019

DWG. NO. 18-031A-####

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MATCHLINE STA -448+00

MATCHLINE STA -604+00

MATCHLINE STA -604+00

Elevations Table			
Number	Minimum Elevation	Maximum Elevation	Color
1	-20.000	0.000	
2	-30.000	-20.000	
3	-40.000	-30.000	
4	-45.000	-40.000	
5	-50.000	-45.000	
6	-55.000	-50.000	
7	-60.000	-55.000	
8	-65.000	-60.000	
9	-75.000	-65.000	
10	-85.000	-75.000	

SCALE:
0 250' 500' 1,000'

PCCA PROJ. #18-038A

GENERAL NOTES:

1. BATHYMETRY DATA SHOWN IS COMPRISED OF USACE SINGLE BEAM DATED JUNE 2018 AND TERRASOND MULTIBEAM DATED SEPTEMBER 2018.
2. SOUNDINGS AND ELEVATIONS SHOWN REPRESENT CONDITIONS AT THE TIME SURVEYED.
3. SOUNDINGS AND ELEVATIONS ARE IN FEET AND TENTHS AND ARE REFERENCED TO MEAN LOWER LOW WATER (MLLW) DATUM.
4. HORIZONTAL COORDINATES ARE REFERENCED TO U.S. STATE PLANE TEXAS SOUTH 4205, NAD83.
5. AERIAL IMAGERY OBTAINED FROM ESRI WORLD IMAGERY AND IS DATED 2018.

NO.	DATE	REVISION

PORT CORPUS CHRISTI

PORT OF CORPUS CHRISTI AUTHORITY

CORPUS CHRISTI SHIP CHANNEL DEEPENING PROJECT

Permit # SWE 2019-00067

SCALE: 1" = 500'
DWN. BY: JS

CHANNEL BATHYMETRY MAP 3

DATE: 3/7/2019
DWG. NO. 18-031A-####

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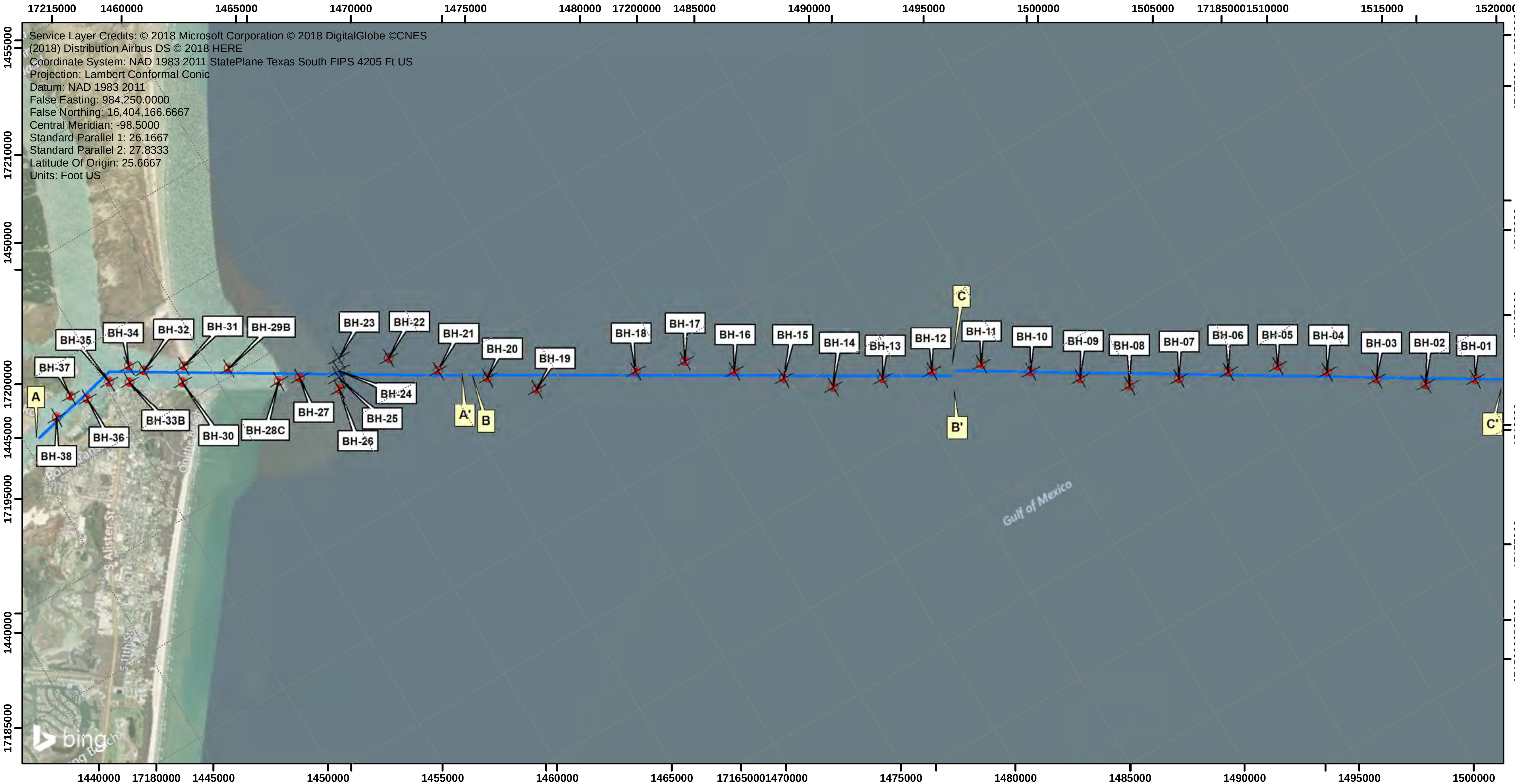
CROSS SECTIONS



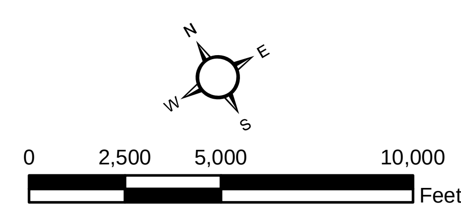
LEGEND

GEOTECHNICAL BORING

- COMPLETED
- CANCELLED
- CROSS-SECTION LINES

NOTES:

1. Boring locations are approximate.
2. As-built coordinates of exploration locations surveyed by Fugro Starfix Positioning System.

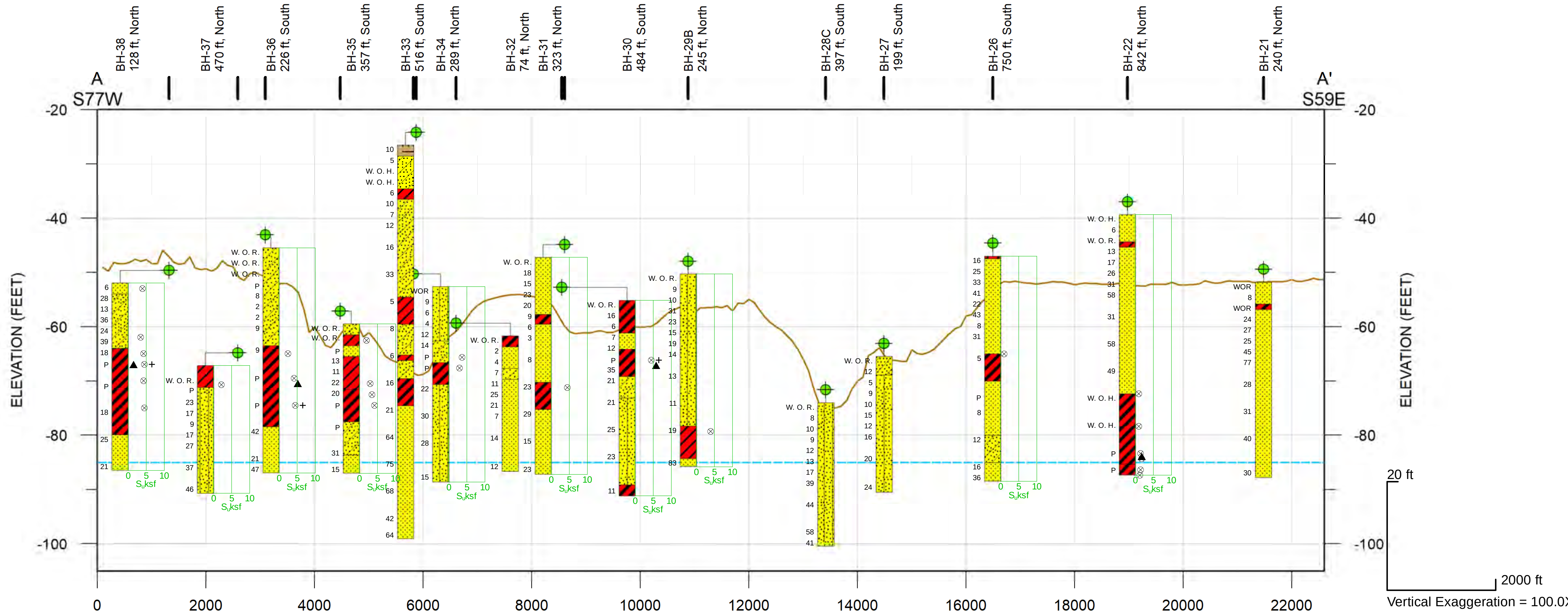


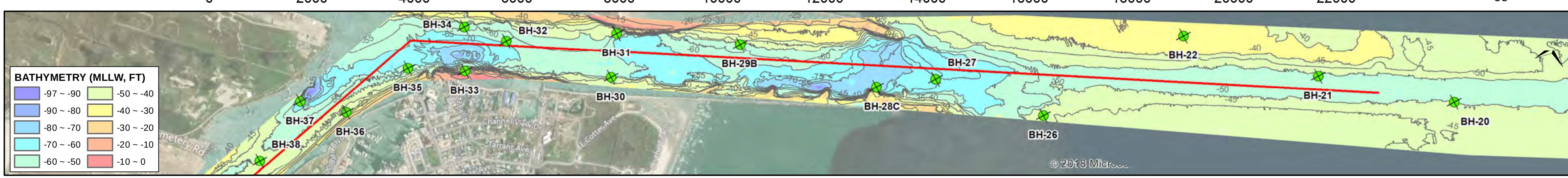
PLAN OF BORINGS

PCCA CORPUS CHRISTI CHANNEL DEEPENING PROJECT
AECOM
CORPUS CHRISTI, TEXAS

PLATE 2

R:\04100\2018 Projects\0001-0099\04.10180080 - Corpus Christi Channel Deepening\00_GIS\MXD\Plate-02_Overall Plan of Borings.mxd, 10/17/2018, k.kim





LEGEND

- Fill
- Lean CLAY (CL)
- Fat CLAY (CH)
- Poorly-Graded SAND (SP)
- Clayey SAND (SC)
- Silty SAND (SM)
- Bathymetry (MLLW, ft)
- Minimum Boring Termination Depth (85 ft, MLLW)

UNDRAINED SHEAR STRENGTH (S_u)

- ▲ Unconsolidated Undrained Triaxial
- Torvane
- Pocket Penetrometer
- \+ Soil Strength Exceeds Instrument's Maximum Measurable Strength.

TUBE AND SPT SAMPLES

P	Push thin-walled 3" tube.
20	Number of blows to produce 12" of penetration after the initial 6" of seating.
86/11"	Number of blows required to produce the indicated penetration after an initial 6" seating.
Ref/3"	50 blows produced the indicated penetration during the initial 6" interval.
W.O.H.	Weight of Hammer

NOTES:

1. As-built coordinates of exploration locations provided by Fugro Starfix Positioning System.
2. Stratigraphic contacts are approximate, and interpreted from borings. Conditions vary both along and perpendicular to the section line. The lateral extent of the top soil is not known based on the limited borings.
3. Boring data are projected onto the cross section line, therefore, stratigraphic contacts may not correspond to the descriptions (lithology, shear strength, etc.) on the logs.
4. Material descriptions are generalized. Materials may vary within the stratigraphic unit and include layers of material that differ from the general description. Refer to boring logs for detailed descriptions of the materials encountered at the exploration location.
5. See Plate 2 for location of explorations and cross section lines.

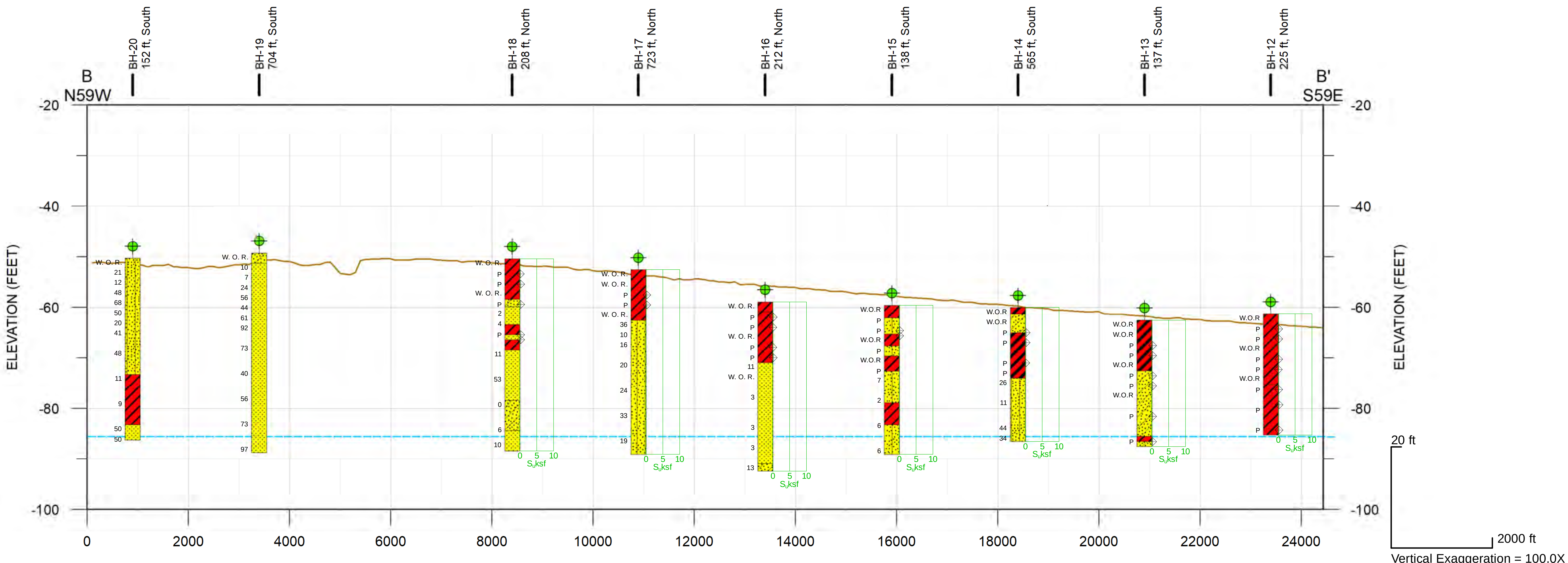
SUBSURFACE PROFILE (A-A')

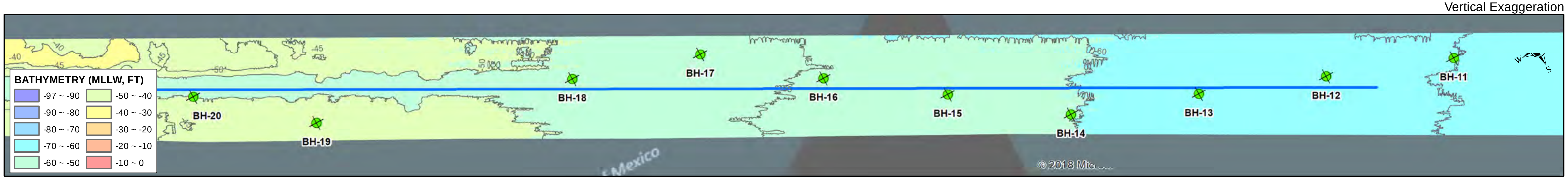
PCCA CORPUS CHRISTI CHANNEL DEEPENING PROJECT
AECOM
CORPUS CHRISTI, TEXAS

PLATE 3

R:\04100\2018 Projects\0001-0099\04.10180080 - Corpus Christi Channel Deepening\00_GIS\MXD\Xsect\Plate_03-Subsurface_Profile_A.mxd, 10/17/2018, k.kim

FUGRO





LEGEND

- Lean CLAY (CL)
- Fat CLAY (CH)
- Poorly-Graded SAND (SP)
- Clayey SAND (SC)
- Silty SAND (SM)
- Bathymetry (MLLW, ft)
- Minimum Boring Termination Depth (85 ft, MLLW)

UNDRAINED SHEAR STRENGTH (S_u)

- ▲ Unconsolidated Undrained Triaxial
- ◇ Torvane
- ⊗ Pocket Penetrometer
- + Soil Strength Exceeds Instrument's Maximum Measurable Strength.

TUBE AND SPT SAMPLES

P	Push thin-walled 3" tube.
20	Number of blows to produce 12" of penetration after the initial 6" of seating.
86/11"	Number of blows required to produce the indicated penetration after an initial 6" seating.
Ref/3"	50 blows produced the indicated penetration during the initial 6" interval.
W.O.H.	Weight of Hammer

NOTES:

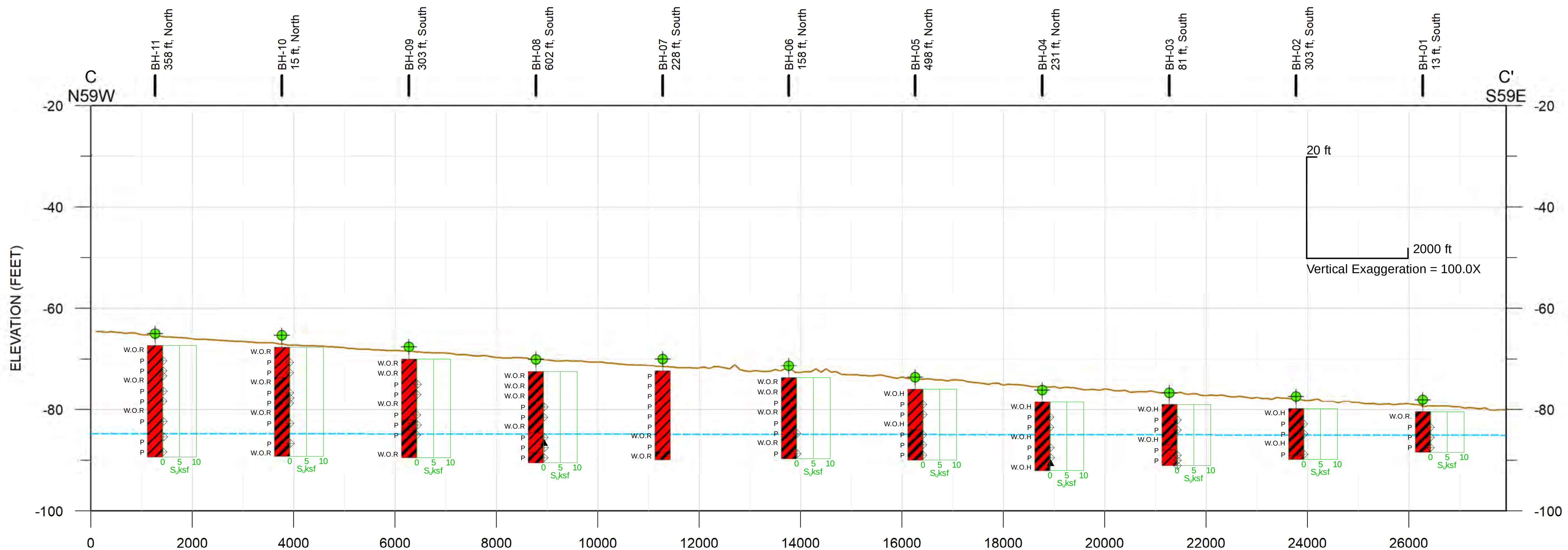
1. As-built coordinates of exploration locations provided by Fugro Starfix Positioning System.
2. Stratigraphic contacts are approximate, and interpreted from borings. Conditions vary both along and perpendicular to the section line. The lateral extent of the top soil is not known based on the limited borings.
3. Boring data are projected onto the cross section line, therefore, stratigraphic contacts may not correspond to the descriptions (lithology, shear strength, etc.) on the logs.
4. Material descriptions are generalized. Materials may vary within the stratigraphic unit and include layers of material that differ from the general description. Refer to boring logs for detailed descriptions of the materials encountered at the exploration location.
5. See Plate 2 for location of explorations and cross section lines.

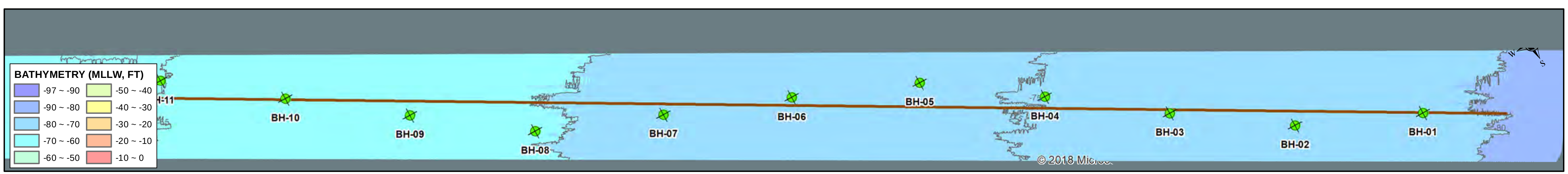
SUBSURFACE PROFILE (B-B')

PCCA CORPUS CHRISTI CHANNEL DEEPENING PROJECT

AECOM

CORPUS CHRISTI, TEXAS





LEGEND

- Lean CLAY (CL)
- Fat CLAY (CH)
- Sandy Fat CLAY (CH)
- Bathymetry (MLLW, ft)
- Minimum Boring Termination Depth (85 ft, MLLW)

UNDRAINED SHEAR STRENGTH (S_u)

- ▲ Unconsolidated Undrained Triaxial
- Torvane
- ⊗ Pocket Penetrometer
- \+ Soil Strength Exceeds Instrument's Maximum Measurable Strength.

TUBE AND SPT SAMPLES

P	Push thin-walled 3" tube.
20	Number of blows to produce 12" of penetration after the initial 6" of seating.
86/11"	Number of blows required to produce the indicated penetration after an initial 6" seating.
Ref/3"	50 blows produced the indicated penetration during the initial 6" interval.
W.O.H.	Weight of Hammer

NOTES:

1. As-built coordinates of exploration locations provided by Fugro Starfix Positioning System.
2. Stratigraphic contacts are approximate, and interpreted from borings. Conditions vary both along and perpendicular to the section line. The lateral extent of the top soil is not known based on the limited borings.
3. Boring data are projected onto the cross section line, therefore, stratigraphic contacts may not correspond to the descriptions (lithology, shear strength, etc.) on the logs.
4. Material descriptions are generalized. Materials may vary within the stratigraphic unit and include layers of material that differ from the general description. Refer to boring logs for detailed descriptions of the materials encountered at the exploration location.
5. See Plate 2 for location of explorations and cross section lines.

SUBSURFACE PROFILE (C-C')

PCCA CORPUS CHRISTI CHANNEL DEEPENING PROJECT
AECOM
CORPUS CHRISTI, TEXAS

R:\04100\2018 Projects\0001-0099\04.10180080 - Corpus Christi Channel Deepening\00_GIS\MXD\Xsect\Plate 05 Subsurface Profile_C.mxd

BORING LOGS

LOCATION: See Plate 2

COORDINATES: 1509922.214 N
17162948.141 E
(SPCS83 South Texas Zone)

MUDLINE EL.: -80.4' (MLLW)

DEPTH, FT	WATER LEVEL	SYMBOL	SAMPLES	SAMPLE TYPE	BLOWS PER FOOT	% RECOVERY / RQD	STRATUM DESCRIPTION	STRATUM ELEVATION, FT	UNIT DRY WT, PCF	PASSING NO. 200 SIEVE, %	WATER CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX (PI)	SHEAR STRENGTH (KIPS PER SQ FT)
0–1				SPT	W.O.R.		FAT CLAY (CH): very soft, gray to dark gray, wet, with traces of sand								
3				T			- gray, with sand, below 3'			90	51	51	16	35	
5				T											
7				T											
8								-88.4	81		42				

Shear strength legend: □ Penetrometer; ◇ Torvane; △ Field Vane; Unconfined ▼; Triaxial ●; Miniature Vane ▲. Scale: 0.5, 1.0, 1.5, 2.0, 2.5 kips per sq ft.

NOTES:

Depth to Mudline (ft) = 92.0
Depth to Water (ft) = 10.5
Water Depth (ft) = 81.5
Record Date&Time: 8/1/2018 5:30

DATE: August 1, 2018
TOTAL DEPTH: 8'
CAVED DEPTH: Not Applicable
DRY AUGER: Not Applicable
WET ROTARY: 0' to 8'
BACKFILL: NONE
HAMMER TYPE: Automatic Trip
LOGGER: J. Soto/A. Bull

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LOG OF BORING NO. BH-01
SHIP CHANNEL DEEPENING PROJECT
PORT OF CORPUS CHRISTI AUTHORITY
CORPUS CHRISTI, TEXAS

FUGRO

DEPTH, FT	WATER LEVEL	SYMBOL	SAMPLES	SAMPLE TYPE	BLOWS PER FOOT	% RECOVERY / RQD	LOCATION: See Plate 2 COORDINATES: 1507640.985 N 17163994.001 E (SPCS83 South Texas Zone) MUDLINE EL.: -79.8' (MLLW) STRATUM DESCRIPTION	STRATUM ELEVATION, FT	UNIT DRY WT, PCF	PASSING NO. 200 SIEVE, %	WATER CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX (PI)	SHEAR STRENGTH (KIPS PER SQ FT)
0				SPT	W.O.H		FAT CLAY (CH): very soft, gray to dark gray, wet, with sand								
				T			- with traces of sand, 1.5' to 4'			95	43	52	16	36	Torvane ◇
5				T											Torvane ◇
				SPT	W.O.H										
				T				-89.1							Torvane ◇
10							- with seam of silty sand, 9.3' to 9.6'	-89.8		78	44	28	18	10	

Shear strength legend: □ Penetrometer; ◇ Torvane; △ Field Vane; Unconfined ▼; Triaxial ●; Miniature Vane ▲. Scale: 0.5, 1.0, 1.5, 2.0, 2.5 KIPS PER SQ FT.

Depth scale: 5, 10, 15, 20, 25, 30, 35

NOTES:
Depth to Mudline (ft) = 90.1
Depth to Water (ft) = 10.2
Water Depth (ft) = 79.9
Record Date&Time: 8/1/2018 1:00

DATE: August 1, 2018
TOTAL DEPTH: 10'
CAVED DEPTH: Not Applicable
DRY AUGER: Not Applicable
WET ROTARY: 0' to 10'
BACKFILL: NONE
HAMMER TYPE: Automatic Trip
LOGGER: J. Soto

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LOG OF BORING NO. BH-02
SHIP CHANNEL DEEPENING PROJECT
PORT OF CORPUS CHRISTI AUTHORITY
CORPUS CHRISTI, TEXAS

FUGRO

LOCATION: See Plate 2

COORDINATES: 1505614.784 N
17165487.048 E
(SPCS83 South Texas Zone)

MUDLINE EL.: -79.0' (MLLW)

Depth, ft	Sample Type	Blows per Foot	Stratum Description	Stratum Elevation, ft	Unit Dry Wt, PCF	Passing No. 200 Sieve, %	Water Content, %	Liquid Limit	Plastic Limit	Plasticity Index (PI)	Shear Strength (kips per sq ft)
0–1.5	SPT	W.O.H	FAT CLAY (CH): very soft, olive gray, with fine sand								
2–4	T		- gray, with sand, with traces of shell frags, 2' to 6'				60	60	16	44	Penetrometer, Torvane
4–6	T										Penetrometer, Torvane
6–7.5	SPT	W.O.H	- gray, witg traces of sand, with traces of shell gragments below 6'	-87.0							
8–10	T		SANDY LEAN CLAY (CL): very soft, gray to dark gray, wet, with fine sand, with traces of shell fragments	-88.0		63	24	29	21	8	Penetrometer, Torvane
10–12	T		LEAN CLAY (CL): very soft, gray to dark gray, wet, with traces of sand	-91.0							Penetrometer, Torvane

Column headings: DEPTH, FT; WATER LEVEL; SYMBOL; SAMPLES; SAMPLE TYPE; BLOWS PER FOOT; % RECOVERY / RQD; STRATUM DESCRIPTION; STRATUM ELEVATION, FT; CLASSIFICATION: UNIT DRY WT, PCF; PASSING NO. 200 SIEVE, %; WATER CONTENT, %; LIQUID LIMIT; PLASTIC LIMIT; PLASTICITY INDEX (PI); SHEAR STRENGTH.

Shear strength legend: □ Penetrometer, ◇ Torvane, △ Field Vane, Unconfined ▼, Triaxial ●, Miniature Vane ▲. KIPS PER SQ FT: 0.5, 1.0, 1.5, 2.0, 2.5

Depth scale: 5, 10, 15, 20, 25, 30, 35

NOTES:
Depth to Mudline (ft) = 97.0
Depth to Water (ft) = 17.2
Water Depth (ft) = 79.8
Record Date&Time: 7/31/2018 20:30

DATE: July 31, 2018
TOTAL DEPTH: 12'
CAVED DEPTH: Not Applicable
DRY AUGER: Not Applicable
WET ROTARY: 0' to 12'
BACKFILL: NONE
HAMMER TYPE: Automatic Trip
LOGGER: A. Bull/J. Soto

R:\04100\2018 PROJECTS\0001-0099\04.10180080 - CORPUS CHRISTI CHANNEL DEEPENING\00_GIS\GINT\04.10180080.GPJ 04.10180080 PCCA CORPUS CHRISTI 2/18/2019 BH-03

LOG OF BORING NO. BH-03
SHIP CHANNEL DEEPENING PROJECT
PORT OF CORPUS CHRISTI AUTHORITY
CORPUS CHRISTI, TEXAS

LOCATION: See Plate 2

COORDINATES: 1503638.793 N
17167058.022 E
(SPCS83 South Texas Zone)

MUDLINE EL.: -78.5' (MLLW)

DEPTH, FT	SAMPLE TYPE	BLOWS PER FOOT	STRATUM DESCRIPTION	STRATUM ELEVATION, FT	UNIT DRY WT, PCF	PASSING NO. 200 SIEVE, %	WATER CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX (PI)	SHEAR STRENGTH (KIPS PER SQ FT)
	SPT	W.O.H	FAT CLAY (CH): very soft, olive gray, wet, with fine sand								
	T					93	44	53	16	37	Penetrometer, Torvane
5	T		- with traces of shell fragments, 4' to 6'								Penetrometer, Torvane
	SPT	W.O.H									
	T		- with shell fragments, 8' to 10'								Torvane
10			- with little sand below 10'			91	44	67	18	49	Penetrometer
	T										Penetrometer, Torvane
					72		52				Penetrometer, Triaxial
	SPT	W.O.H	- with shell fragments below 12'								
13.5				-92.0							

Shear strength legend: Penetrometer (□), Torvane (◇), Field Vane (△), Unconfined (▼), Triaxial (●), Miniature Vane (▲). Scale: 0.5, 1.0, 1.5, 2.0, 2.5 KIPS PER SQ FT.

Depth scale: 5, 10, 15, 20, 25, 30, 35

NOTES:
Depth to Mudline (ft) = 89.5
Depth to Water (ft) = 10.3
Water Depth (ft) = 79.2
Record Date&Time: 7/31/2018 12:45

DATE: July 31, 2018
TOTAL DEPTH: 13.5'
CAVED DEPTH: Not Applicable
DRY AUGER: Not Applicable
WET ROTARY: 0' to 13.5'
BACKFILL: NONE
HAMMER TYPE: Automatic Trip
LOGGER: A. Bull

LOG OF BORING NO. BH-04
SHIP CHANNEL DEEPENING PROJECT
PORT OF CORPUS CHRISTI AUTHORITY
CORPUS CHRISTI, TEXAS

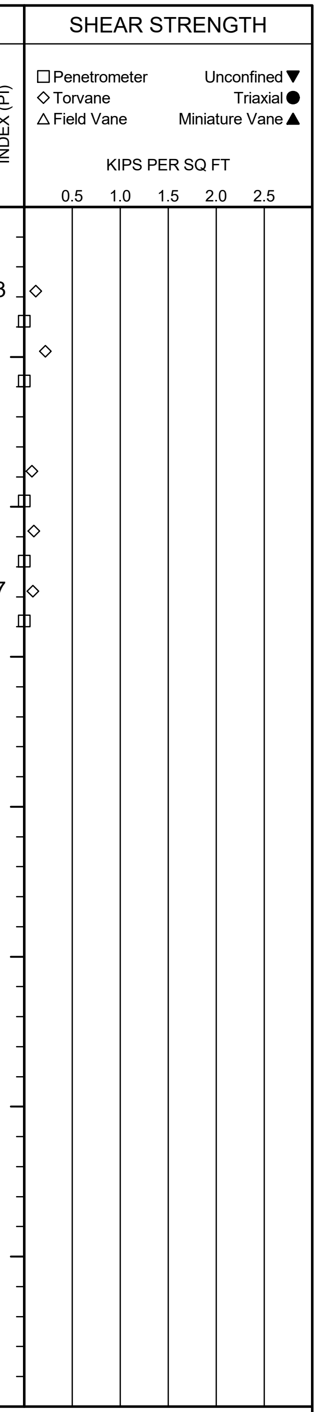
LOCATION: See Plate 2

COORDINATES: 1501638.405 N
17168587.604 E
(SPCS83 South Texas Zone)

MUDLINE EL.: -75.9' (MLLW)

DEPTH, FT	SAMPLE TYPE	BLOWS PER FOOT	STRATUM DESCRIPTION	STRATUM ELEVATION, FT	UNIT DRY WT, PCF	PASSING NO. 200 SIEVE, %	WATER CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX (PI)
0	SPT	W.O.H	LEAN CLAY (CL): very soft, gray to olive gray, wet, with sand, with traces of shell fragments							
3	T		- with gray to dark gray, 2' to 4'			89	44	49	16	33
5	T		- gray below 4' - with sand, 4' to 8'							
7	SPT	W.O.H								
8			FAT CLAY (CH): very soft, gray, wet, with silt	-83.9						
9	T		- with sand, 8' to 10'							
11	T									
13	T					94	57	52	15	37
14				-89.9						

SHEAR STRENGTH



NOTES:
Depth to Mudline (ft) = 88.0
Depth to Water (ft) = 11.4
Water Depth (ft) = 76.6
Record Date&Time: 7/31/2018 9:15

DATE: July 31, 2018
TOTAL DEPTH: 14'
CAVED DEPTH: Not Applicable
DRY AUGER: Not Applicable
WET ROTARY: 0' to 14'
BACKFILL: NONE
HAMMER TYPE: Automatic Trip
LOGGER: J. Soto/A. Bull

LOG OF BORING NO. BH-05
SHIP CHANNEL DEEPENING PROJECT
PORT OF CORPUS CHRISTI AUTHORITY
CORPUS CHRISTI, TEXAS

DEPTH, FT	SAMPLE TYPE	BLOWS PER FOOT	STRATUM DESCRIPTION	STRATUM ELEVATION, FT	UNIT DRY WT, PCF	PASSING NO. 200 SIEVE, %	WATER CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX (PI)
	SPT	W.O.R	FAT CLAY (CH): very soft, gray, wet, with sand				77	53	16	37
	SPT	W.O.R				85				
5	T									
	SPT	W.O.R	- with seam of sandy clay, gray, wet, with fine sand, 7.2' to 8.4'							
	T		- with traces of sand, 8' to 12'							
10	T					99	57	66	18	48
	SPT	W.O.R								
15	T			-89.7						
20										
25										
30										
35										

LOCATION: See Plate 2

COORDINATES: 1499331.364 N
17169596.93 E
(SPCS83 South Texas Zone)

MUDLINE EL.: -73.7' (MLLW)

SHEAR STRENGTH — KIPS PER SQ FT (0.5, 1.0, 1.5, 2.0, 2.5)
☐ Penetrometer; ◇ Torvane; △ Field Vane; Unconfined ▼; Triaxial ●; Miniature Vane ▲

NOTES:
Depth to Mudline (ft) = 84.0
Depth to Water (ft) = 10.0
Water Depth (ft) = 74.0
Record Date&Time: 7/30/2018 19:31

DATE: July 30, 2018
TOTAL DEPTH: 16'
CAVED DEPTH: Not Applicable
DRY AUGER: Not Applicable
WET ROTARY: 0' to 16'
BACKFILL: NONE
HAMMER TYPE: Automatic Trip
LOGGER: J. Soto

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LOG OF BORING NO. BH-06
SHIP CHANNEL DEEPENING PROJECT
PORT OF CORPUS CHRISTI AUTHORITY
CORPUS CHRISTI, TEXAS

DEPTH, FT	WATER LEVEL	SYMBOL	SAMPLES	SAMPLE TYPE	BLOWS PER FOOT	% RECOVERY / RQD	STRATUM DESCRIPTION	STRATUM ELEVATION, FT	UNIT DRY WT, PCF	PASSING NO. 200 SIEVE, %	WATER CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX (PI)
				T			LEAN CLAY (CL): very soft, gray							
				T										
5				T						90	51	48	16	32
				T			- with fine sand, with traces of shell fragments, 6' to 8'							
				T										
10				T			- with clay, below 10'							
				SPT	W.O.R									
15				T										
				SPT	W.O.R		FAT CLAY (CH): very soft, gray, with silt	-88.3		85	54	62	18	44
								-89.8						

LOCATION: See Plate 2

COORDINATES: 1496999.926 N
17170564.864 E
(SPCS83 South Texas Zone)

MUDLINE EL.: -72.3' (MLLW)

SHEAR STRENGTH (KIPS PER SQ FT): □ Penetrometer; ◇ Torvane; △ Field Vane; Unconfined ▼; Triaxial ●; Miniature Vane ▲. Scale 0.5, 1.0, 1.5, 2.0, 2.5

NOTES:
Depth to Mudline (ft) = 84.4
Depth to Water (ft) = 11.2
Water Depth (ft) = 73.2
Record Date&Time: 7/30/2018 10:30

DATE: July 30, 2018
TOTAL DEPTH: 17.5'
CAVED DEPTH: Not Applicable
DRY AUGER: Not Applicable
WET ROTARY: 0' to 18'
BACKFILL: NONE
HAMMER TYPE: Automatic Trip
LOGGER: A. Bull

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LOG OF BORING NO. BH-07
SHIP CHANNEL DEEPENING PROJECT
PORT OF CORPUS CHRISTI AUTHORITY
CORPUS CHRISTI, TEXAS

Report No. 04.10180080

LOCATION: See Plate 2

COORDINATES: 1494674.019 N
17171542.182 E
(SPCS83 South Texas Zone)

MUDLINE EL.: -72.4' (MLLW)

DEPTH, FT	SAMPLE TYPE	BLOWS PER FOOT	STRATUM DESCRIPTION	STRATUM ELEVATION, FT	UNIT DRY WT, PCF	PASSING NO. 200 SIEVE, %	WATER CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX (PI)
0	SPT	W.O.R	FAT CLAY (CH): very soft, olive gray, wet, with sand							
	SPT	W.O.R								
5	SPT	W.O.R								
	T		- with little sand, 6' to 14'			97	55	59	19	40
	T									
10	SPT	W.O.R								
12			LEAN CLAY (CL): very soft, olive gray, wet, with little sand	-84.4						
	T					90				
					75		51	43	15	28
15	T		- with sand below 14'							
16	T		FAT CLAY (CH): very soft, olive gray, wet, with sand and trace shell fragments	-88.4		90	48	60	17	43
18				-90.4						

SHEAR STRENGTH (KIPS PER SQ FT: 0.5, 1.0, 1.5, 2.0, 2.5)
☐ Penetrometer ◇ Torvane △ Field Vane; Unconfined ▼ Triaxial ● Miniature Vane ▲

NOTES:
Depth to Mudline (ft) = 85.6
Depth to Water (ft) = 12.1
Water Depth (ft) = 73.5
Record Date&Time: 8/1/2018 11:00

DATE: August 1, 2018
TOTAL DEPTH: 18'
CAVED DEPTH: Not Applicable
DRY AUGER: Not Applicable
WET ROTARY: 0' to 18'
BACKFILL: NONE
HAMMER TYPE: Automatic Trip
LOGGER: A. Bull

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LOG OF BORING NO. BH-08
SHIP CHANNEL DEEPENING PROJECT
PORT OF CORPUS CHRISTI AUTHORITY
CORPUS CHRISTI, TEXAS

DEPTH, FT	SAMPLE TYPE	BLOWS PER FOOT	STRATUM DESCRIPTION	STRATUM ELEVATION, FT	UNIT DRY WT, PCF	PASSING NO. 200 SIEVE, %	WATER CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX (PI)
0	SPT	W.O.R	LEAN CLAY (CL): very soft, olive gray, wet, with clean sand at the tip of SPT							
	SPT	W.O.R	- with clean sand layer, 2.8' to 3.3'			88	43	43	15	28
			- with sand , 3.3' to 12'							
5	T									
	T									
	SPT	W.O.R								
10	T				71		51	70	19	51
12	T		SANDY FAT CLAY (CH): very soft, gray, wet, with sand pocket	-82.0						
14	T		FAT CLAY (CH): very soft, olive gray, wet, with sand	-84.0						
	SPT	W.O.R	- with little sand below 18'			92	45	54	16	38
19.5				-89.5						

LOCATION: See Plate 2

COORDINATES: 1492692.496 N 17173103.771 E (SPCS83 South Texas Zone)

MUDLINE EL.: -70.0' (MLLW)

SHEAR STRENGTH, KIPS PER SQ FT (0.5, 1.0, 1.5, 2.0, 2.5) — □ Penetrometer, ◇ Torvane, △ Field Vane, Unconfined ▼, Triaxial ●, Miniature Vane ▲

NOTES:

Depth to Mudline (ft) = 82.8
Depth to Water (ft) = 11.5
Water Depth (ft) = 71.3
Record Date&Time: 8/1/2018 14:45

DATE: August 1, 2018
TOTAL DEPTH: 19.5'
CAVED DEPTH: Not Applicable
DRY AUGER: Not Applicable
WET ROTARY: 0' to 19.5'
BACKFILL: NONE
HAMMER TYPE: Automatic Trip
LOGGER: A. Bull

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LOG OF BORING NO. BH-09
SHIP CHANNEL DEEPENING PROJECT
PORT OF CORPUS CHRISTI AUTHORITY
CORPUS CHRISTI, TEXAS

Report No. 04.10180080

FUGRO

LOCATION: See Plate 2

COORDINATES: 1490716.505 N
17174674.745 E
(SPCS83 South Texas Zone)

MUDLINE EL.: -67.7' (MLLW)

DEPTH, FT	SAMPLE TYPE	BLOWS PER FOOT	STRATUM DESCRIPTION	STRATUM ELEVATION, FT	UNIT DRY WT, PCF	PASSING NO. 200 SIEVE, %	WATER CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX (PI)	SHEAR STRENGTH (KIPS PER SQ FT)
0	SPT	W.O.R	LEAN CLAY (CL): very soft, olive gray, wet, with traces of sand, - sandy clay partings, with traces of shell fragments								
	T										Torvane
			- with many shell fragments, 3.8' to 3.9'				27	39	14	25	
5	T		- with sand pockets below 4'		83						Torvane
	SPT	W.O.R	FAT CLAY (CH): very soft, olive gray, wet, with traces of sand, with shell fragments, with silt partings, - with silty sand seams, 6.2' to 6.7', - moist to wet, 8' to 12', - with traces of shell fragments, 8' to 10'	-73.7							
	T										Torvane
10	T				94	55	66	19	47		Torvane
	SPT	W.O.R	- wet, 12' to 16'								
15	T										Torvane
	T		- gray to greenish gray, with traces of sand, with traces of shell fragments								Torvane
20	SPT	W.O.R			96	51	65	18	47		
				-89.2							

Shear strength legend: Penetrometer, Torvane, Field Vane, Unconfined, Triaxial, Miniature Vane. KIPS PER SQ FT: 0.5, 1.0, 1.5, 2.0, 2.5

NOTES:
Depth to Mudline (ft) = 79.7
Depth to Water (ft) = 10.8
Water Depth (ft) = 68.9
Record Date&Time: 8/1/2018 20:55

DATE: August 1, 2018
TOTAL DEPTH: 21.5'
CAVED DEPTH: Not Applicable
DRY AUGER: Not Applicable
WET ROTARY: 0' to 21.5'
BACKFILL: NONE
HAMMER TYPE: Automatic Trip
LOGGER: J. Soto

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LOG OF BORING NO. BH-10
SHIP CHANNEL DEEPENING PROJECT
PORT OF CORPUS CHRISTI AUTHORITY
CORPUS CHRISTI, TEXAS

Report No. 04.10180080

FUGRO

LOCATION: See Plate 2

COORDINATES: 1488757.749 N
17176274.959 E
(SPCS83 South Texas Zone)

MUDLINE EL.: -67.3' (MLLW)

DEPTH, FT	SAMPLE TYPE	BLOWS PER FOOT	STRATUM DESCRIPTION	STRATUM ELEVATION, FT	UNIT DRY WT, PCF	PASSING NO. 200 SIEVE, %	WATER CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX (PI)
0	SPT	W.O.R	LEAN CLAY (CL): very soft, olive gray, wet							
	T									
5	T		- with seam of silty sand and fine sand, 3.5' to 3.7' - with sand, with silty sand seams and pockets, 4' to 6'			79	40	44	15	29
	SPT	W.O.R								
	T		- with traces of sand, 8' to 10'							
10	T									
	SPT	W.O.R								
15	T		- with seam of silty sand, 13.2' to 13.4' - greenish gray, 14' to 18' -moist to wet, with sand, 14' to 20'			84	39			
	T		- gray to greenish gray below 18' - with traces of shell fragments, 18' to 20'							
20	T		- with traces of sand below 20'							
22				-89.3						

SHEAR STRENGTH (KIPS PER SQ FT): □ Penetrometer, ◇ Torvane, △ Field Vane, Unconfined ▼, Triaxial ●, Miniature Vane ▲; scale 0.5, 1.0, 1.5, 2.0, 2.5

NOTES:
Depth to Mudline (ft) = 79.8
Depth to Water (ft) = 11.6
Water Depth (ft) = 68.2
Record Date&Time: 8/2/2018 1:35

DATE: August 2, 2018
TOTAL DEPTH: 22'
CAVED DEPTH: Not Applicable
DRY AUGER: Not Applicable
WET ROTARY: 0' to 22'
BACKFILL: NONE
HAMMER TYPE: Automatic Trip
LOGGER: J. Soto

LOG OF BORING NO. BH-11
SHIP CHANNEL DEEPENING PROJECT
PORT OF CORPUS CHRISTI AUTHORITY
CORPUS CHRISTI, TEXAS

FUGRO

LOCATION: See Plate 2

COORDINATES: 1486409.073 N
17177213.655 E
(SPCS83 South Texas Zone)

MUDLINE EL.: -61.3' (MLLW)

DEPTH, FT	SAMPLE TYPE	BLOWS PER FOOT	STRATUM DESCRIPTION	STRATUM ELEVATION, FT	UNIT DRY WT, PCF	PASSING NO. 200 SIEVE, %	WATER CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX (PI)
0	SPT	W.O.R	SANDY LEAN CLAY (CL): very soft, olive gray, wet, with sand							
3	T									
5	T					66	35	46	15	31
6.5	SPT	W.O.R	- with traces of shell fragments at 6'							
7.3			- with 2" of clean sand seam at 7.3'							
9	T									
11	T									
12.5	SPT	W.O.R								
13.5			- with 2" of clean sand seam at 13.5'	-75.3						
14			LEAN CLAY (CL): very soft, gray, wet, with sand pockets - with shell fragments at 19'							
15	T						44			
19	T					77	36	31	16	15
22-23	T		- with shell fragments, 22' to 23'							
24				-85.3						

SHEAR STRENGTH (KIPS PER SQ FT: 0.5, 1.0, 1.5, 2.0, 2.5)

□ Penetrometer ◇ Torvane △ Field Vane — Unconfined ▼ Triaxial ● Miniature Vane ▲

NOTES:
Depth to Mudline (ft) = 70.25
Depth to Water (ft) = 7.5
Water Depth (ft) = 62.75
Record Date&Time: 8/2/2018 7:45

DATE: August 2, 2018
TOTAL DEPTH: 24'
CAVED DEPTH: Not Applicable
DRY AUGER: Not Applicable
WET ROTARY: 0' to 24'
BACKFILL: NONE
HAMMER TYPE: Automatic Trip
LOGGER: A. Bull

LOG OF BORING NO. BH-12
SHIP CHANNEL DEEPENING PROJECT
PORT OF CORPUS CHRISTI AUTHORITY
CORPUS CHRISTI, TEXAS

Report No. 04.10180080

FUGRO

LOCATION: See Plate 2

COORDINATES: 1484077.637 N
17178181.587 E
(SPCS83 South Texas Zone)

MUDLINE EL.: -62.5' (MLLW)

DEPTH, FT	SAMPLE TYPE	BLOWS PER FOOT	STRATUM DESCRIPTION	STRATUM ELEVATION, FT	UNIT DRY WT, PCF	PASSING NO. 200 SIEVE, %	WATER CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX (PI)
	SPT	W.O.R	FAT CLAY (CH): very soft, olive gray, wet, with sand pockets							
	SPT	W.O.R	- with trace shell fragments, 2' to 3.5'			75				
5	T									
	T					97	46	59	16	43
	SPT	W.O.R								
10	T		CLAYEY SAND (SC): very loose, olive gray, wet, with clay pockets and traces of shell fragments	-72.5						
	T									
15	SPT	W.O.R				70	40			
	T		- gray below 18'							
20										
	T		SANDY CLAY (CL): very soft, gray, wet, with shell fragments	-85.5						
			CLAYEY SAND (SC): very loose, gray, wet, with shell fragments	-86.5						
25				-87.5						

SHEAR STRENGTH (KIPS PER SQ FT: 0.5, 1.0, 1.5, 2.0, 2.5)
□ Penetrometer, ◇ Torvane, △ Field Vane, Unconfined ▼, Triaxial ●, Miniature Vane ▲

NOTES:
Depth to Mudline (ft) = 74.2
Depth to Water (ft) = 10.5
Water Depth (ft) = 63.7
Record Date&Time: 8/2/2018 13:00

DATE: August 2, 2018
TOTAL DEPTH: 25'
CAVED DEPTH: Not Applicable
DRY AUGER: Not Applicable
WET ROTARY: 0' to 25'
BACKFILL: NONE
HAMMER TYPE: Automatic Trip
LOGGER: A. Bull

LOG OF BORING NO. BH-13
SHIP CHANNEL DEEPENING PROJECT
PORT OF CORPUS CHRISTI AUTHORITY
CORPUS CHRISTI, TEXAS

LOCATION: See Plate 2

COORDINATES: 1481703.897 N
17179077.753 E
(SPCS83 South Texas Zone)

MUDLINE EL.: -60.0' (MLLW)

DEPTH, FT	SAMPLE TYPE	BLOWS PER FOOT	% RECOVERY / RQD	STRATUM DESCRIPTION	STRATUM ELEVATION, FT	UNIT DRY WT, PCF	PASSING NO. 200 SIEVE, %	WATER CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX (PI)	SHEAR STRENGTH (KIPS PER SQ FT)
	SPT	W.O.R		FAT CLAY (CH): very soft, olive gray, wet	-61.3							
	SPT	W.O.R		CLAYEY SAND (SC): very loose, olive gray, wet	-65.0							
5	T			FAT CLAY (CH): very soft, olive gray, wet, with sand			97	62				◇
	T											◇
10				- with sand seam, 9' to 9.5'								
	T			- moist to wet, with traces of shell fragments, below 10'			79	48	51	14	37	□ ◇
	T			- with sandy silt seam, 12' to 14	-74.0		86	29				
15	SPT	26		SILTY SAND (SM): medium dense to dense, gray to olive gray, moist to wet, with fine grained sand								
	SPT	11					15					
20				- gray to greenish gray, with shell fragments, 19.2' to 19.5'								
	SPT	44		- dense, gray to dark gray, below 23'								
25	SPT	34			-86.5							
30												
35												

Shear strength legend: □ Penetrometer; ◇ Torvane; △ Field Vane; Unconfined ▼; Triaxial ●; Miniature Vane ▲. Scale: 0.5, 1.0, 1.5, 2.0, 2.5

NOTES:
Depth to Mudline (ft) = 71.2
Depth to Water (ft) = 9.8
Water Depth (ft) = 61.4
Record Date&Time: 8/2/2018 18:30

DATE: August 2, 2018
TOTAL DEPTH: 26.5'
CAVED DEPTH: Not Applicable
DRY AUGER: Not Applicable
WET ROTARY: 0' to 26.5'
BACKFILL: NONE
HAMMER TYPE: Automatic Trip
LOGGER: A. Bull/J. Soto

LOG OF BORING NO. BH-14
SHIP CHANNEL DEEPENING PROJECT
PORT OF CORPUS CHRISTI AUTHORITY
CORPUS CHRISTI, TEXAS

LOCATION: See Plate 2

COORDINATES: 1479770.208 N
17180720.495 E
(SPCS83 South Texas Zone)

MUDLINE EL.: -59.6' (MLLW)

DEPTH, FT	SAMPLE TYPE	BLOWS PER FOOT	STRATUM DESCRIPTION	STRATUM ELEVATION, FT	UNIT DRY WT, PCF	PASSING NO. 200 SIEVE, %	WATER CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX (PI)	SHEAR STRENGTH (KIPS PER SQ FT)
0	SPT	W.O.R	LEAN CLAY (CL): very soft, olive gray, wet, with traces of sand, with sandy clay pockets - moist to wet, with sand pockets, below 1'	-62.1							
	T		SILTY SAND (SM): gray to olive gray, wet, with fine sand								
5	T			-65.3		69	31				Penetrometer, Torvane
											Penetrometer, Torvane
	SPT	W.O.R	LEAN CLAY (CL): very soft, olive gray, wet - gray to olive gray,with sand pockets, below 7'	-67.6							
	T		SILTY SAND (SM): gray to olive gray, wet, with fine sand, with traces of clay	-69.6							
10	SPT	W.O.R	LEAN CLAY (CL): very soft, gray to greenish gray, moist to wet, with sandy clay pockets, with traces of shell fragments	-72.6		49	32	34	15	19	
	T		SILTY SAND (SM): gray to greenish gray, moist to wet, - with fine grained seam of clay, greenish gray, wet, 15' to 15.7'								
15	SPT	7				94					
	SPT	2	- very loose, gray, wet, fine grained sand, below 18'	-78.9							
20			LEAN CLAY (CL): very soft, gray, wet - soft, moist to wet below 23'	-83.3							
	SPT	6	SILTY SAND (SM): loose, gray, wet, fine grained sand - with shell fragments, 24' to 24.3								
25											
	SPT	6	- dark gray, with traces of shell fragments, below 28'	-89.1		31	29				
30											
35											

Legend: □ Penetrometer; ◇ Torvane; △ Field Vane; Unconfined ▼; Triaxial ●; Miniature Vane ▲

NOTES:
Depth to Mudline (ft) = 71.1
Depth to Water (ft) = 10.2
Water Depth (ft) = 60.9
Record Date&Time: 8/2/2018 23:15

DATE: August 3, 2018
TOTAL DEPTH: 29.5'
CAVED DEPTH: Not Applicable
DRY AUGER: Not Applicable
WET ROTARY: 0' to 29.5
BACKFILL: NONE
HAMMER TYPE: Automatic Trip
LOGGER: J. Soto

LOG OF BORING NO. BH-15
SHIP CHANNEL DEEPENING PROJECT
PORT OF CORPUS CHRISTI AUTHORITY
CORPUS CHRISTI, TEXAS

Report No. 04.10180080

FUGRO

LOCATION: See Plate 2

COORDINATES: 1477794.217 N
17182291.468 E
(SPCS83 South Texas Zone)

MUDLINE EL.: -58.9' (MLLW)

STRATUM DESCRIPTION	STRATUM ELEVATION, FT
SANDY LEAN CLAY (CL): very soft, olive gray, wet, with shell fragments	-60.9
LEAN CLAY (CL): very soft, gray, wet, with sand and shell fragments - olive gray below 4'	-70.9
SAND (SP): very loose, olive gray, wet, with shell fragments and little clay - with abundant shell fragments - 6" clay layer, 22' to 22.5' - with abundant shell fragments and clay - with shell fragments and very little to no clay	-90.9
CLAYEY SAND (SC): medium dense, greenish gray, with shell fragments and calcareous/calcium deposit pockets - olive gray sand (SP) with clay noted at bottom of SPS	-92.4

DEPTH, FT (approx.)	SAMPLE TYPE	BLOWS PER FOOT	UNIT DRY WT, PCF	PASSING NO. 200 SIEVE, %	WATER CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX (PI)
0–1.5	SPT	W.O.R.						
2–4	T							
4–6	T			81	56	43	15	28
6–7.5	SPT	W.O.R.						
8–10	T							
10–12	T			72				
12–13.5	SPT	11						
14–15.5	SPT	W.O.R.						
18–19.5	SPT	3			25			
24–25.5	SPT	3						
28–29.5	SPT	3						
32–33.5	SPT	13		28	20			

SHEAR STRENGTH (KIPS PER SQ FT: 0.5, 1.0, 1.5, 2.0, 2.5)
□ Penetrometer ◇ Torvane △ Field Vane — Unconfined ▼ Triaxial ● Miniature Vane ▲

NOTES:
Depth to Mudline (ft) = 71.1
Depth to Water (ft) = 10.5
Water Depth (ft) = 60.6
Record Date&Time: 8/3/2018 6:45

DATE: August 3, 2018
TOTAL DEPTH: 33.5'
CAVED DEPTH: Not Applicable
DRY AUGER: Not Applicable
WET ROTARY: 0' to 33'
BACKFILL: NONE
HAMMER TYPE: Automatic Trip
LOGGER: A. Bull

LOG OF BORING NO. BH-16
SHIP CHANNEL DEEPENING PROJECT
PORT OF CORPUS CHRISTI AUTHORITY
CORPUS CHRISTI, TEXAS

FUGRO

LOCATION: See Plate 2

COORDINATES: 1475902.092 N
17184004.727 E
(SPCS83 South Texas Zone)

MUDLINE EL.: -52.6' (MLLW)

DEPTH, FT	SAMPLE TYPE	BLOWS PER FOOT	STRATUM DESCRIPTION	STRATUM ELEVATION, FT	PASSING NO. 200 SIEVE, %	WATER CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX (PI)
0	SPT	W.O.R.	SANDY LEAN CLAY (CL): very soft, olive gray, wet, high plasticity to 6'						
	SPT	W.O.R.				44	43	15	28
5	T		- gray, 4' to 8'						
	T		- with shell fragments						
	SPT	W.O.R.	- olive gray						
10	SPT	36	SILTY SAND (SM): dense, gray, with shell fragments	-62.6					
	SPT	10	- loose - with abundant shell fragments, 12' to 16'		22	28			
15	SPT	16	- medium dense, 14' to 28'						
	SPT	20	- with shell fragments to 28'						
20									
	SPT	24	- olive gray to 33'		9				
25									
	SPT	33	- dense, with trace of clay						
30									
	SPT	19	- medium dense, greenish gray and reddish brown below 33'		26	21			
35	SPT			-89.1					

Column headings also include: WATER LEVEL, SYMBOL, SAMPLES, % RECOVERY / RQD, UNIT DRY WT, PCF.

SHEAR STRENGTH (KIPS PER SQ FT: 0.5, 1.0, 1.5, 2.0, 2.5)
□ Penetrometer ◇ Torvane △ Field Vane — Unconfined ▼ Triaxial ● Miniature Vane ▲

NOTES:
Depth to Mudline (ft) = 64.8
Depth to Water (ft) = 10.8
Water Depth (ft) = 54
Record Date&Time: 8/3/2018 11:45

DATE: August 3, 2018
TOTAL DEPTH: 36.5'
CAVED DEPTH: Not Applicable
DRY AUGER: Not Applicable
WET ROTARY: 0' to 36'
BACKFILL: NONE
HAMMER TYPE: Automatic Trip
LOGGER: A. Bull

LOG OF BORING NO. BH-17
SHIP CHANNEL DEEPENING PROJECT
PORT OF CORPUS CHRISTI AUTHORITY
CORPUS CHRISTI, TEXAS

FUGRO

LOCATION: See Plate 2

COORDINATES: 1473486.788 N
17184830.376 E
(SPCS83 South Texas Zone)

MUDLINE EL.: -50.4' (MLLW)

DEPTH, FT	SAMPLE TYPE	BLOWS PER FOOT	STRATUM DESCRIPTION	STRATUM ELEVATION, FT	PASSING NO. 200 SIEVE, %	WATER CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX (PI)
	SPT	W.O.R.	SANDY LEAN CLAY (CL): very soft, olive gray, wet, with shell fragments and sand						
	T				86	41	40	16	24
5	T		- gray						
	SPT	W.O.R.	- olive gray with sand seams below 6'						
			CLAYEY SAND (SC): very soft, olive gray, wet, with shell fragments	-58.4					
	T		- with clean sand starting at 9.5'						
10				-59.9					
	SPT	2	SAND (SP): very loose, olive gray, wet, with shell fragments		27				
	SPT	4	- loose, gray, fine grained, with many shell fragments and sandy clay pockets						
			LEAN CLAY (CL): very soft, gray to greenish gray, moist to wet, with trace sand	-63.4					
15	T			-65.4		28	25	15	10
			SAND (SP): gray to greenish gray, moist to wet, fine grained, with sandy clay pockets and many shell fragments	-66.4					
			LEAN CLAY (CL): very soft, gray to greenish gray, moist	-68.4					
	SPT	11			8				
20			SAND (SP): medium dense, gray, wet, fine grained, with shell fragments and trace silt						
	SPT	53	- very dense						
25									
			CLAYEY SAND (SC): very loose, greenish gray, wet, fine grained	-78.4					
	SPT	0			15				
30									
	SPT	6							
			SAND (SP): loose, greenish gray, wet, fine grained, with silt, clay, and shell fragments	-84.4					
35									
	SPT	10	- with trace silt, trace clay, and trace shell fragments below 37'						
				-88.4					

SHEAR STRENGTH (KIPS PER SQ FT: 0.5, 1.0, 1.5, 2.0, 2.5)

☐ Penetrometer ◇ Torvane △ Field Vane; Unconfined ▼ Triaxial ● Miniature Vane ▲

NOTES:
Depth to Mudline (ft) = 62.6
Depth to Water (ft) = 11.1
Water Depth (ft) = 51.5
Record Date&Time: 8/3/2018 16:50

DATE: August 3, 2018
TOTAL DEPTH: 38'
CAVED DEPTH: Not Applicable
DRY AUGER: Not Applicable
WET ROTARY: 0' to 38'
BACKFILL: NONE
HAMMER TYPE: Automatic Trip
LOGGER: A. Bull/J. Soto

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LOG OF BORING NO. BH-18
SHIP CHANNEL DEEPENING PROJECT
PORT OF CORPUS CHRISTI AUTHORITY
CORPUS CHRISTI, TEXAS

LOCATION: See Plate 2

COORDINATES: 1468718.997 N
17186588.25 E
(SPCS83 South Texas Zone)

MUDLINE EL.: -49.3' (MLLW)

DEPTH, FT	SAMPLE TYPE	BLOWS PER FOOT	STRATUM DESCRIPTION	STRATUM ELEVATION, FT	PASSING NO. 200 SIEVE, %	WATER CONTENT, %
	SPT	W.O.R.	CLAYEY SAND (SC): very loose, gray to olive gray, wet	-51.3	36	36
	SPT	10	SAND (SP): loose, gray to olive gray, moist to wet, fine grained - with silt to 6'			
5	SPT	7	- olive gray to 12' - with shell fragments to 8' - medium dense, with clay pockets			
	SPT	24			36	21
	SPT	56	- very dense - moist with silt to 12'			
10	SPT	44	- dense			
	SPT	61	- fine to medium grained, gray, wet - very dense to 24' - with shell fragments to 13' - fine grained to 18'			
15	SPT	92	- moist below 14'			
	SPT	73	- fine to medium grained, gray to light gray, with many shells and shell fragments		7	
20						
	SPT	40				
25			- fine grained below 24' - dense, gray, with trace silt and trace shell fragments			
	SPT	56	- gray to greenish gray, with many shell fragments and sandy clay pockets - very dense below 28'			
30						
	SPT	73	- light gray below 34' - with silt		7	
35						
	SPT	97		-88.8		

SHEAR STRENGTH: □ Penetrometer, ◇ Torvane, △ Field Vane, Unconfined ▼, Triaxial ●, Miniature Vane ▲ — KIPS PER SQ FT: 0.5, 1.0, 1.5, 2.0, 2.5

NOTES:
Depth to Mudline (ft) = 61.5
Depth to Water (ft) = 10.9
Water Depth (ft) = 50.6
Record Date&Time: 8/3/2018 21:55

DATE: August 3, 2018
TOTAL DEPTH: 39.5'
CAVED DEPTH: Not Applicable
DRY AUGER: Not Applicable
WET ROTARY: 0' to 40'
BACKFILL: NONE
HAMMER TYPE: Automatic Trip
LOGGER: J. Soto

LOG OF BORING NO. BH-19
SHIP CHANNEL DEEPENING PROJECT
PORT OF CORPUS CHRISTI AUTHORITY
CORPUS CHRISTI, TEXAS

LOCATION: See Plate 2

COORDINATES: 1466847.92 N
17188337.218 E
(SPCS83 South Texas Zone)

MUDLINE EL.: -50.3' (MLLW)

DEPTH, FT	SAMPLE TYPE	BLOWS PER FOOT	% RECOVERY / RQD	STRATUM DESCRIPTION	STRATUM ELEVATION, FT	UNIT DRY WT, PCF	PASSING NO. 200 SIEVE, %	WATER CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX (PI)
0	SPT	W. O. R.		SILTY SAND (SM): very loose, olive gray, fine grained			25	31			
	SPT	21		- medium dense to 6' fine grained to 10' - with little shells							
5	SPT	12		- with abundant shell fragments to 10'							
	SPT	48		- gray to 12' - dense							
	SPT	68		- very dense to 12'							
10	SPT	50		- with some shell fragments to 18'							
	SPT	20		- medium dense, olive gray			12				
15	SPT	41		- dense, gray to olive gray							
	SPT	48		- very dense, gray, with little shells							
20											
	SPT	11		SANDY LEAN CLAY (CL): stiff, greenish gray to brown, with sand seams and high plasticity	-73.3		72	28	36	13	23
25											
	SPT	9		- hard with gray sand seams, possibly clay with sand, high plasticity							
30											
	SPT	50		SAND (SP): very dense, gray, with trace shells	-83.3		13				
35	SPT	50			-86.3						

SHEAR STRENGTH (KIPS PER SQ FT: 0.5, 1.0, 1.5, 2.0, 2.5) — □ Penetrometer, ◇ Torvane, △ Field Vane, Unconfined ▼, Triaxial ●, Miniature Vane ▲

NOTES:
Depth to Mudline (ft) = 62.5
Depth to Water (ft) = 11.2
Water Depth (ft) = 51.3
Record Date&Time: 8/4/2018 13:00

DATE: August 4, 2018
TOTAL DEPTH: 36.5'
CAVED DEPTH: Not Applicable
DRY AUGER: Not Applicable
WET ROTARY: 0' to 36.5'
BACKFILL: NONE
HAMMER TYPE: Automatic Trip
LOGGER: A. Bull

LOG OF BORING NO. BH-20
SHIP CHANNEL DEEPENING PROJECT
PORT OF CORPUS CHRISTI AUTHORITY
CORPUS CHRISTI, TEXAS

LOCATION: See Plate 2

COORDINATES: 1464871.929 N
17189908.192 E
(SPCS83 South Texas Zone)

MUDLINE EL.: -51.8' (MLLW)

DEPTH, FT	SAMPLE TYPE	BLOWS PER FOOT	STRATUM DESCRIPTION	STRATUM ELEVATION, FT	PASSING NO. 200 SIEVE, %	WATER CONTENT, %
0	SPT	WOR	SAND (SP): very loose, olive gray, wet		12	27
2	SPT	8	- loose, with trace shell fragments and trace clay	-55.8		
4	SPT	WOR	FAT CLAY (CH): very soft, olive gray, with sand pockets and shells	-56.8		
6	SPT	24	SAND (SP): very loose, olive gray, with shell fragments - medium dense, 6' to 12' gray, 6' to 28'			
8	SPT	27	- with trace shell fragments			
10	SPT	25				
12	SPT	45	- dense, with abundant shells			
14	SPT	77	- very dense, with trace shell fragments		7	
18	SPT	28	- medium dense, with abundant shell fragments			
23	SPT	31	- with shells and few clay pockets - dense, 23' to 34'			
28	SPT	40	- greenish gray to brownish green, with clay		26	
34	SPT	30	- medium dense, greenish gray	-87.8		

Shear strength legend: Penetrometer, Torvane, Field Vane, Unconfined, Triaxial, Miniature Vane — KIPS PER SQ FT (0.5, 1.0, 1.5, 2.0, 2.5)

NOTES:
Depth to Mudline (ft) = 66.3
Depth to Water (ft) = 13.2
Water Depth (ft) = 53.1
Record Date&Time: 8/17/2018 07:20

DATE: August 17, 2018
TOTAL DEPTH: 36'
CAVED DEPTH: Not Applicable
DRY AUGER: Not Applicable
WET ROTARY: 0' to 36'
BACKFILL: NONE
HAMMER TYPE: Automatic Trip
LOGGER: A. Bull

LOG OF BORING NO. BH-21
SHIP CHANNEL DEEPENING PROJECT
PORT OF CORPUS CHRISTI AUTHORITY
CORPUS CHRISTI, TEXAS

LOCATION: See Plate 2

COORDINATES: 1463044.417 N
17191731.071 E
(SPCS83 South Texas Zone)

MUDLINE EL.: -39.3' (MLLW)

DEPTH, FT	SAMPLE TYPE	BLOWS PER FOOT	STRATUM DESCRIPTION	STRATUM ELEVATION, FT	PASSING NO. 200 SIEVE, %	WATER CONTENT, %	SHEAR STRENGTH (KIPS PER SQ FT)
0	SPT	W.O.H.	SAND (SP): very soft, olive gray to dark gray, wet, fine grained, with trace medium grained				
2	SPT	6	- loose		7	23	
4	SPT	W.O.R.	- very loose, with silt				
5			LEAN CLAY (CL): very soft, gray to olive gray, moist to wet	-44.3			
6	SPT	13	SAND (SP): medium dense, olive gray, wet, fine grained	-45.3			
8	SPT	17	- olive gray to gray - moist to wet to 12'				
10	SPT	26	- gray to 14' - with trace shell fragments				
12	SPT	31	- dense, moist, fine to medium grained sand, with many shells and shell fragments				
14	SPT	58	- very dense, moist - with many shells and shell fragments - gray to light gray, fine grained sand to 24'				
18	SPT	31	- dense, gray to light gray, moist to wet, with shells and shell fragments		8	25	
23	SPT	58	- very dense, moist, fine to medium grained sand - gray below 24'				
28	SPT	49	- dense, fine grained sand, wet, with partings of organic material at 28.8'				
33	SPT	W.O.H.	FAT CLAY (CH): soft, gray to greenish gray, moist, very sticky	-72.3			Penetrometer ~1.0
38	SPT	W.O.H.	- greenish gray to 43'				Penetrometer ~1.0

Shear strength legend: □ Penetrometer; ◇ Torvane; △ Field Vane; Unconfined ▼; Triaxial ●; Miniature Vane ▲. KIPS PER SQ FT: 0.5, 1.0, 1.5, 2.0, 2.5

NOTES:
Depth to Mudline (ft) = 54.1
Depth to Water (ft) = 13.3
Water Depth (ft) = 40.5
Record Date&Time: 8/6/2018 21:30

DATE: August 6, 2018
TOTAL DEPTH: 48'
CAVED DEPTH: Not Applicable
DRY AUGER: Not Applicable
WET ROTARY: 0' to 48'
BACKFILL: NONE
HAMMER TYPE: Automatic Trip
LOGGER: J. Soto

LOG OF BORING NO. BH-22
SHIP CHANNEL DEEPENING PROJECT
PORT OF CORPUS CHRISTI AUTHORITY
CORPUS CHRISTI, TEXAS

DEPTH, FT	WATER LEVEL	SYMBOL	SAMPLES	SAMPLE TYPE	BLOWS PER FOOT	% RECOVERY / RQD	LOCATION: See Plate 2 COORDINATES: 1463044.417 N 17191731.071 E (SPCS83 South Texas Zone) MUDLINE EL.: -39.3' (MLLW) STRATUM DESCRIPTION	STRATUM ELEVATION, FT	UNIT DRY WT, PCF	PASSING NO. 200 SIEVE, %	WATER CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX (PI)	SHEAR STRENGTH, KIPS PER SQ FT
45				T			- stiff, gray to greenish gray - with seam of shell fragments, 44.4' to 44.6'		74	93	47	97	25	72	
				T			SANDY FAT CLAY (CH): stiff, gray to greenish gray, moist, with shells, 46' to 46.5' - with clayey sand pockets below 47'	-85.3 -87.3		53	26				
50															
55															
60															
65															
70															
75															

SHEAR STRENGTH legend: □ Penetrometer; ◇ Torvane; △ Field Vane; Unconfined ▼; Triaxial ●; Miniature Vane ▲. Scale: 0.5, 1.0, 1.5, 2.0, 2.5

NOTES:
Depth to Mudline (ft) = 54.1
Depth to Water (ft) = 13.3
Water Depth (ft) = 40.5
Record Date&Time: 8/6/2018 21:30

DATE: August 6, 2018
TOTAL DEPTH: 48'
CAVED DEPTH: Not Applicable
DRY AUGER: Not Applicable
WET ROTARY: 0' to 48'
BACKFILL: NONE
HAMMER TYPE: Automatic Trip
LOGGER: J. Soto

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LOG OF BORING NO. BH-22
SHIP CHANNEL DEEPENING PROJECT
PORT OF CORPUS CHRISTI AUTHORITY
CORPUS CHRISTI, TEXAS

LOCATION: See Plate 2

COORDINATES: 1460094.874 N
17191650.348 E
(SPCS83 South Texas Zone)

MUDLINE EL.: -47.0' (MLLW)

DEPTH, FT	STRATUM DESCRIPTION	STRATUM ELEVATION, FT
0 – 0.5	SANDY LEAN CLAY (CL): soft, black to light gray, wet	-47.5
0.5 – 18	SAND (SP): medium dense, light gray, wet, fine grained - greenish gray, 2.6' to 3.5' - gray and greenish gray at 4' - dense, 4' to 7.5' - gray, 6' to 9.5' - medium dense at 8' - dense, gray and dark gray, with trace shell fragments at 10' - loose at 12' - gray below 12' - dense at 14'	-65.0
18 – 23	FAT CLAY (CH): medium stiff, gray to olive gray, moist, with trace sand pockets and seams	-70.0
23 – 33	SAND (SP): gray, wet, fine grained, with trace shell fragments - loose, gray to dark gray, with organic matter intermixed at 28'	-80.0
33 – 38	CLAYEY SAND (SC): medium dense, greenish gray to olive, wet, fine grained, with shell fragments	-85.0
38 –		

DEPTH, FT (approx.)	SAMPLE TYPE	BLOWS PER FOOT	% RECOVERY / RQD	UNIT DRY WT, PCF	PASSING NO. 200 SIEVE, %	WATER CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX (PI)	SHEAR STRENGTH, KIPS PER SQ FT
0.5	SPT	16								
2.5	SPT	25			5	24				
4.5	SPT	33								
6.5	SPT	41								
8.5	SPT	22								
10.5	SPT	43								
12.5	SPT	8								
14.5	SPT	31								
18.5	SPT	5				46	72	21	51	1.0 (Penetrometer)
26	T									
29	SPT	8								
34	SPT	12			14					
39	SPT	16								

SHEAR STRENGTH legend: □ Penetrometer, ◇ Torvane, △ Field Vane, Unconfined ▼, Triaxial ●, Miniature Vane ▲ — KIPS PER SQ FT (0.5, 1.0, 1.5, 2.0, 2.5)

NOTES:
Depth to Mudline (ft) = 61.1
Depth to Water (ft) = 12.8
Water Depth (ft) = 48.3
Record Date&Time: 8/15/2018 20:45

DATE: August 16, 2018
TOTAL DEPTH: 41.5'
CAVED DEPTH: Not Applicable
DRY AUGER: Not Applicable
WET ROTARY: 0' to 41.5'
BACKFILL: NONE
HAMMER TYPE: Automatic Trip
LOGGER: J. Soto

LOG OF BORING NO. BH-26
SHIP CHANNEL DEEPENING PROJECT
PORT OF CORPUS CHRISTI AUTHORITY
CORPUS CHRISTI, TEXAS

DEPTH, FT	WATER LEVEL	SYMBOL	SAMPLES	SAMPLE TYPE	BLOWS PER FOOT	% RECOVERY / RQD	LOCATION: See Plate 2 COORDINATES: 1460094.874 N 17191650.348 E (SPCS83 South Texas Zone) MUDLINE EL.: -47.0' (MLLW) STRATUM DESCRIPTION	STRATUM ELEVATION, FT	UNIT DRY WT, PCF	PASSING NO. 200 SIEVE, %	WATER CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX (PI)	SHEAR STRENGTH (KIPS PER SQ FT)
				SPT	36		SAND (SP): medium dense, greenish gray, wet, fine grained, with shells, shell fragments, and trace clay - dense, gray to greenish gray, moist to wet at 40' - with shell fragments 40' to 40.6'	-88.5							
45															
50															
55															
60															
65															
70															
75															

Shear strength legend: □ Penetrometer, ◇ Torvane, △ Field Vane, Unconfined ▼, Triaxial ●, Miniature Vane ▲; scale 0.5, 1.0, 1.5, 2.0, 2.5

NOTES:
Depth to Mudline (ft) = 61.1
Depth to Water (ft) = 12.8
Water Depth (ft) = 48.3
Record Date&Time: 8/15/2018 20:45

DATE: August 16, 2018
TOTAL DEPTH: 41.5'
CAVED DEPTH: Not Applicable
DRY AUGER: Not Applicable
WET ROTARY: 0' to 41.5'
BACKFILL: NONE
HAMMER TYPE: Automatic Trip
LOGGER: J. Soto

LOG OF BORING NO. BH-26
SHIP CHANNEL DEEPENING PROJECT
PORT OF CORPUS CHRISTI AUTHORITY
CORPUS CHRISTI, TEXAS

DEPTH, FT	SAMPLE TYPE	BLOWS PER FOOT	STRATUM DESCRIPTION	STRATUM ELEVATION, FT	PASSING NO. 200 SIEVE, %	WATER CONTENT, %
0–2	SPT	W.O.R.	CLAYEY SAND (SC): very loose, olive gray, with shells			
2–3.4	SPT	12	- medium dense, greenish gray to light gray at 2' - with clean sand starting at 3.4'	-68.9	54	22
4	SPT	5	SILTY SAND (SM): loose, gray, wet, with trace shell fragments			
6	SPT	9	- gray to brownish gray, with shells at 6'			
8	SPT	10	- gray to light gray, with few shells at 8'			
10	SPT	15	- gray at 10' - medium dense below 10'			
12	SPT	12	- gray and brown, 12' to 15.5' - wet at 12'			
14	SPT	16	- with gravel, 15.3' to 18.2'		16	
18	SPT	20	- brownish gray to gray at 18'			
23	SPT	24	-			
25				-90.5		

LOCATION: See Plate 2
COORDINATES: 1458663.804 N, 17193161.142 E (SPCS83 South Texas Zone)
MUDLINE EL.: -65.5' (MLLW)

Columns also include: WATER LEVEL, SYMBOL, SAMPLES, % RECOVERY / RQD, UNIT DRY WT, PCF, LIQUID LIMIT, PLASTIC LIMIT, PLASTICITY INDEX (PI).

SHEAR STRENGTH (KIPS PER SQ FT: 0.5, 1.0, 1.5, 2.0, 2.5): □ Penetrometer, ◇ Torvane, △ Field Vane, Unconfined ▼, Triaxial ●, Miniature Vane ▲

NOTES:
Depth to Mudline (ft) = 79.9
Depth to Water (ft) = 13.1
Water Depth (ft) = 66.8
Record Date&Time: 8/15/2018 17:10

DATE: August 15, 2018
TOTAL DEPTH: 25'
CAVED DEPTH: Not Applicable
DRY AUGER: Not Applicable
WET ROTARY: 0' to 25'
BACKFILL: NONE
HAMMER TYPE: Automatic Trip
LOGGER: A. Bull

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LOG OF BORING NO. BH-27
SHIP CHANNEL DEEPENING PROJECT
PORT OF CORPUS CHRISTI AUTHORITY
CORPUS CHRISTI, TEXAS

LOCATION: Aransas Pass

COORDINATES: 1457292.035 N
17194377.851 E
(SPCS83 South Texas Zone)

MUDLINE EL.: -74.0' (MLLW)

DEPTH, FT	SAMPLE TYPE	BLOWS PER FOOT	STRATUM DESCRIPTION	STRATUM ELEVATION, FT	PASSING NO. 200 SIEVE, %	WATER CONTENT, %
0	SPT	W.O.R.	SILTY SAND (SM): very loose, black to olive gray and light gray, wet, fine grained, with calcareous particles, 1.3' to 1.5'			
2	SPT	8	- loose, 2' to 8' - gray to greenish gray, 2' to 8' - sulfur odor coming from drill area at 4'		16	25
4	SPT	10				
6	SPT	9				
8	SPT	12	- medium dense, 8' to 14' - gray to olive, 8' to 12'			
10	SPT	13				
12	SPT	17	- green to greenish gray, 12' to 23' - with plot of shell fragments at 13' - with rock fragments, 12.4' to 12.7' - moist to wet at 14' - dense, 14' to 19.5'			
14	SPT	39			17	
18	SPT	44	- gray to greenish gray, moist at 18' - with calcareous particles, 18.8' to 19'			
23	SPT	58	- very dense, olive to olive green at 23' - wet below 23'			
25	SPT	41	- dense, gray to greenish gray at 25'			
26.5				-100.5		

Other columns (not filled): WATER LEVEL, SYMBOL, SAMPLES, % RECOVERY / RQD, UNIT DRY WT, PCF, LIQUID LIMIT, PLASTIC LIMIT, PLASTICITY INDEX (PI).

SHEAR STRENGTH (KIPS PER SQ FT: 0.5, 1.0, 1.5, 2.0, 2.5) — □ Penetrometer, ◇ Torvane, △ Field Vane, Unconfined ▼, Triaxial ●, Miniature Vane ▲

NOTES:
Depth to Mudline (ft) = 88.3
Depth to Water (ft) = 13.2
Water Depth (ft) = 75.1
Record Date&Time: 8/12/2018 02:00

DATE: August 12, 2018
TOTAL DEPTH: 26.5'
CAVED DEPTH: Not Applicable
DRY AUGER: Not Applicable
WET ROTARY: 0' to 26.5'
BACKFILL: NONE
HAMMER TYPE: Automatic Trip
LOGGER: J. Soto

R:\04100\2018 PROJECTS\0001-0099\04.10180080 - CORPUS CHRISTI CHANNEL DEEPENING\00_GIS\GINT\04.10180080.GPJ 04.10180080 PCCA CORPUS CHRISTI 2/18/2019 BH-28C

LOG OF BORING NO. BH-28C
SHIP CHANNEL DEEPENING PROJECT
PORT OF CORPUS CHRISTI AUTHORITY
CORPUS CHRISTI, TEXAS

FUGRO

DEPTH, FT	SAMPLE TYPE	BLOWS PER FOOT	STRATUM DESCRIPTION	STRATUM ELEVATION, FT	PASSING NO. 200 SIEVE, %	WATER CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX (PI)	SHEAR STRENGTH (KIPS PER SQ FT)
0	SPT	W.O.R.	SILTY SAND (SM): very loose, olive gray, with shell fragments							
2	SPT	9	- loose, 2' to 6' - dark gray, 2.5' to 7.3'		6	28				
4	SPT	10	- organic order, 4' to 8'							
6	SPT	31	- dense at 6' - brown, 7.3' to 11'							
8	SPT	23	- medium dense below 8' - with shells, 8' to 14'							
10	SPT	15	- dark gray at 11' - olive gray at 12'							
12	SPT	19			20					
14	SPT	14	- greenish gray, with some shells, 14' to 19.5'							
18	SPT	13								
23	SPT	11	- light gray, with cemented sand nodules and trace of clay at 23'							
28	SPT	19	LEAN CLAY (CL): very stiff to hard, brown to light gray, with sand partings	-78.3	74	21	46	15	31	Penetrometer ≈ 2.4
34	SPT	83	SAND (SP): very dense, gray, moist, fine grained	-84.3						
35.5				-85.8						

LOCATION: Aransas Pass
COORDINATES: 1455562.455 N
17194989.156 E
(SPCS83 South Texas Zone)
MUDLINE EL.: -50.3' (MLLW)

Columns: WATER LEVEL, SYMBOL, SAMPLES, % RECOVERY / RQD, UNIT DRY WT, PCF (no entries)

SHEAR STRENGTH legend: □ Penetrometer, ◇ Torvane, △ Field Vane, Unconfined ▼, Triaxial ●, Miniature Vane ▲
KIPS PER SQ FT: 0.5, 1.0, 1.5, 2.0, 2.5

NOTES:
Depth to Mudline (ft) = 63.5
Depth to Water (ft) = 11.7
Water Depth (ft) = 51.8
Record Date&Time: 8/10/2018 15:00

DATE: August 10, 2018
TOTAL DEPTH: 35.5'
CAVED DEPTH: Not Applicable
DRY AUGER: Not Applicable
WET ROTARY: 0' to 35.5'
BACKFILL: NONE
HAMMER TYPE: Automatic Trip
LOGGER: A. Bull

R:\04100\2018 PROJECTS\0001-0099\04.10180080 - CORPUS CHRISTI CHANNEL DEEPENING\00_GIS\GINT\04.10180080.GPJ 04.10180080 PCCA CORPUS CHRISTI 2/18/2019 BH-29B

LOG OF BORING NO. BH-29B
SHIP CHANNEL DEEPENING PROJECT
PORT OF CORPUS CHRISTI AUTHORITY
CORPUS CHRISTI, TEXAS

Report No. 04.10180080

LOCATION: Aransas Pass

COORDINATES: 1453435.814 N
17195973.571 E
(SPCS83 South Texas Zone)

MUDLINE EL.: -55.1' (MLLW)

STRATUM DESCRIPTION	STRATUM ELEVATION, FT
SANDY FAT CLAY (CH): medium dense, greenish gray to brown and gray, with few shells - with shell fragments below 2' - loose, greenish gray and brown at 4'	-61.1
SAND (SP): loose, greenish gray to brown, with trace clay - medium dense, brown with some greenish gray, with some clay at 8 '	-64.1
FAT CLAY (CH): very stiff, brown to greenish gray, with sand pockets - hard, with sand seams, 11' to 14'	-69.1
CLAYEY SAND (SC): medium dense, greenish gray to brown, moist, fine grained	-73.1
SILTY SAND (SM): medium dense, light gray, moist to wet, fine grained, with trace clay and trace silt - with calcareous particles, 18.5' to 18.7' - olive. 18.7' to 24.1' - moist, with shell fragments at 23' - greenish gray, 24.1' to 24.5' - olive to brown, with silt at 28' - with clay, 29.3' to 29.5'	-89.1
SANDY FAT CLAY (CH): very stiff, brown to gray, with shells	-91.1

DEPTH, FT (approx.)	SAMPLE TYPE	BLOWS PER FOOT	UNIT DRY WT, PCF	PASSING NO. 200 SIEVE, %	WATER CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX (PI)	SHEAR STRENGTH, KIPS PER SQ FT
0-1.5	SPT	W.O.R.							
2-3.5	SPT	16		53	21				
4-5.5	SPT	6							
6-7.5	SPT	7							
8-9.5	SPT	12							
10-12	T		108	89	21	59	17	42	Penetrometer (at top of scale); Triaxial 5.8
12-13.5	SPT	35							
14-15.5	SPT	21							
18-19.5	SPT	21		14	22				
23-24.5	SPT	25							
28-29.5	SPT	23							
34.5-36	SPT	11							

SHEAR STRENGTH legend: □ Penetrometer; ◇ Torvane; △ Field Vane; Unconfined ▼; Triaxial ●; Miniature Vane ▲. KIPS PER SQ FT: 0.5, 1.0, 1.5, 2.0, 2.5

NOTES:
Depth to Mudline (ft) = 67.5
Depth to Water (ft) = 11.0
Water Depth (ft) = 56.5
Record Date&Time: 8/9/2018 14:15

DATE: August 9, 2018
TOTAL DEPTH: 36'
CAVED DEPTH: Not Applicable
DRY AUGER: Not Applicable
WET ROTARY: 0' to 36'
BACKFILL: NONE
HAMMER TYPE: Automatic Trip
LOGGER: A. Bull/J. Soto

LOG OF BORING NO. BH-30
SHIP CHANNEL DEEPENING PROJECT
PORT OF CORPUS CHRISTI AUTHORITY
CORPUS CHRISTI, TEXAS

DEPTH, FT	SAMPLE TYPE	BLOWS PER FOOT	STRATUM DESCRIPTION	STRATUM ELEVATION, FT	PASSING NO. 200 SIEVE, %	WATER CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX (PI)	SHEAR STRENGTH (KIPS PER SQ FT)
	SPT	W.O.R.	SAND (SP): very loose, olive gray to brown and greenish gray, with shell fragments - with gravels at top 3"							
	SPT	18	- medium dense below 2' - brown, olive gray, and green, statified, with trace shells and gravel at 2'		5	23				
5	SPT	15	- cemented seam (2") at 5'							
	SPT	23	- grayish brown and brown, with 3" sandy clay seam at 6'							
	SPT	20	- brown, with fine shell fragments at 8'							
10	SPT	9	- olive gray, with abundant shell fragments at 10'	-57.7	63	22				
	SPT	6	SANDY FAT CLAY (CH): soft, greenish gray to gray, with shell fragments	-59.5						
15	SPT	3	SAND (SP): loose, greenish gray, with shell fragments and trace clay - very loose, brown, 14' to 15.5'							
	SPT	8	- with trace clay at 18'							
20										
25	SPT	23	FAT CLAY (CH): hard, greenish gray to brown, with sand partings	-70.2		21	66	19	47	□
30	SPT	29	SAND (SP): medium dense, gray to brown, wet, stratified	-75.2						
35	SPT	15	- greenish brown below 33'							
40	SPT	23		-87.2						

LOCATION: Aransas Pass

COORDINATES: 1453890.358 N
17196664.533 E
(SPCS83 South Texas Zone)

MUDLINE EL.: -47.2' (MLLW)

Shear strength legend: □ Penetrometer, ◇ Torvane, △ Field Vane, Unconfined ▼, Triaxial ●, Miniature Vane ▲. KIPS PER SQ FT: 0.5, 1.0, 1.5, 2.0, 2.5

Other columns: WATER LEVEL, SYMBOL, SAMPLES, % RECOVERY / RQD, UNIT DRY WT, PCF

NOTES:
Depth to Mudline (ft) = 60.5
Depth to Water (ft) = 11.6
Water Depth (ft) = 48.9
Record Date&Time: 8/12/2018 11:30

DATE: August 12, 2018
TOTAL DEPTH: 40'
CAVED DEPTH: Not Applicable
DRY AUGER: Not Applicable
WET ROTARY: 0' to 40'
BACKFILL: NONE
HAMMER TYPE: Automatic Trip
LOGGER: A. Bull

LOG OF BORING NO. BH-31
SHIP CHANNEL DEEPENING PROJECT
PORT OF CORPUS CHRISTI AUTHORITY
CORPUS CHRISTI, TEXAS

DEPTH, FT	SAMPLE TYPE	BLOWS PER FOOT	STRATUM DESCRIPTION	STRATUM ELEVATION, FT	PASSING NO. 200 SIEVE, %	WATER CONTENT, %
0–2	SPT	W.O.R.	SANDY FAT CLAY (CH): firm, greenish gray, with shells and gravel	-63.7		22
2–6	SPT	2	SAND (SP): very loose, greenish gray, with some clay		31	
	SPT	4		-67.7		
6–8	SPT	7	CLAYEY SAND (SC): loose, greenish gray to gray	-69.7		
8–25	SPT	11	SAND (SP): medium dense, greenish gray, with trace clay			
	SPT	25	- with clay pockets, calcareous nodules, ferrous stains, and gravel at 10'		59	
	SPT	21	- with cemented sand nodules, 12' to 19.5'			
	SPT	7				
	SPT	14				
	SPT	12	- brown, with clay pockets at 23' - with sandy clay starting at 25'	-86.7		

LOCATION: Aransas Pass
COORDINATES: 1452059.924 N, 17197460.882 E (SPCS83 South Texas Zone)
MUDLINE EL.: -61.7' (MLLW)

Columns also shown (no data): WATER LEVEL, SYMBOL, SAMPLES, % RECOVERY / RQD, UNIT DRY WT, PCF, LIQUID LIMIT, PLASTIC LIMIT, PLASTICITY INDEX (PI).

SHEAR STRENGTH (KIPS PER SQ FT: 0.5, 1.0, 1.5, 2.0, 2.5) — Penetrometer, Torvane, Field Vane, Unconfined, Triaxial, Miniature Vane

NOTES:
Depth to Mudline (ft) = 73.4
Depth to Water (ft) = 10.3
Water Depth (ft) = 63.1
Record Date&Time: 8/13/2018 15:25

DATE: August 13, 2018
TOTAL DEPTH: 25'
CAVED DEPTH: Not Applicable
DRY AUGER: Not Applicable
WET ROTARY: 0' to 25'
BACKFILL: NONE
HAMMER TYPE: Automatic Trip
LOGGER: A. Bull

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LOG OF BORING NO. BH-32
SHIP CHANNEL DEEPENING PROJECT
PORT OF CORPUS CHRISTI AUTHORITY
CORPUS CHRISTI, TEXAS

LOCATION: Aransas Pass

COORDINATES: 1451149.414 N
17197277.613 E
(SPCS83 South Texas Zone)

MUDLINE EL.: -26.5' (MLLW)

DEPTH, FT	SAMPLE TYPE	BLOWS PER FOOT	STRATUM DESCRIPTION	STRATUM ELEVATION, FT	UNIT DRY WT, PCF	PASSING NO. 200 SIEVE, %	WATER CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX (PI)
0	SPT	10	FILL: loose, gray to black, FILL: Concrete							
2	SPT	5	CLAYEY SAND (SC): loose, gray, fine to medium grained, with shells	-28.5		15				
4	SPT	W.O.H.	- very loose below 4'							
6	SPT	W.O.H.	- with shell fragments and sulfur odor at 6'			17				
8	SPT	6	LEAN CLAY (CL): medium stiff, greenish gray, moist, with sand and trace shell fragments	-34.5			21			
10	SPT	10	CLAYEY SAND (SC): loose, greenish gray to white, moist to wet, with calcium nodules	-36.5						
12	SPT	7	- calcareous nodules							
14	SPT	12	- light gray to gray, with white pockets and trace clay at 14' - medium dense, 14' to 19.5'			13				
18	SPT	16	- gray and tan, wet at 18' - with seam of clay, 19' to 19.1'							
23	SPT	33	- dense, brown, moist at 23'							
28	SPT	5	SANDY LEAN CLAY (CL): medium stiff, greenish gray to brown, moist to wet, with shell fragments	-54.5			23	27	15	12
33	SPT	8	CLAYEY SAND (SC): loose, gray to tan, wet, fine grained, with trace shell fragments - borderline sand with clay	-59.5						
38.7	SPT	6		-65.2						
39.7				-66.2						

SHEAR STRENGTH: □ Penetrometer, ◇ Torvane, △ Field Vane, Unconfined ▼, Triaxial ●, Miniature Vane ▲ — KIPS PER SQ FT 0.5 1.0 1.5 2.0 2.5

NOTES:
Depth to Mudline (ft) = 36.7
Depth to Water (ft) = 8.2
Water Depth (ft) = 28.5
Record Date&Time: 8/9/2018 02:20

DATE: August 9, 2018
TOTAL DEPTH: 72.5'
CAVED DEPTH: Not Applicable
DRY AUGER: Not Applicable
WET ROTARY: 0' to 72.5'
BACKFILL: NONE
HAMMER TYPE: Automatic Trip
LOGGER: J. Soto/A. Bull

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LOG OF BORING NO. BH-33
SHIP CHANNEL DEEPENING PROJECT
PORT OF CORPUS CHRISTI AUTHORITY
CORPUS CHRISTI, TEXAS

LOCATION: Aransas Pass

COORDINATES: 1451149.414 N
17197277.613 E
(SPCS83 South Texas Zone)

MUDLINE EL.: -26.5' (MLLW)

Sample Type	Blows per Foot	Stratum Description	Stratum Elevation, ft	Passing No. 200 Sieve, %	Water Content, %
		LEAN CLAY (CL): medium stiff, greenish gray to brown, moist			
		CLAYEY SAND (SC): loose, gray to greenish gray, wet, fine grained, with trace shell fragments	-69.5		
SPT	16	FAT CLAY (CH): very stiff, olive to greenish gray, moist, with trace sand and red streaks			23
			-74.5		
SPT	21	SAND (SP): medium stiff, gray, wet, with fine to medium grain sand		13	
SPT	64	- very dense, 53' to 64.2'			
SPT	75	- fine grain, light gray below 58'			
SPT	68				
SPT	42	- dense, with trace clay and trace shell fragments at 68'			
SPT	64	- very dense, with shell fragments at 72'	-99.0		

Depth scale, ft: 45, 50, 55, 60, 65, 70, 75

Column headings: DEPTH, FT; WATER LEVEL; SYMBOL; SAMPLES; SAMPLE TYPE; BLOWS PER FOOT; % RECOVERY / RQD; STRATUM DESCRIPTION; STRATUM ELEVATION, FT; CLASSIFICATION: UNIT DRY WT, PCF; PASSING NO. 200 SIEVE, %; WATER CONTENT, %; LIQUID LIMIT; PLASTIC LIMIT; PLASTICITY INDEX (PI); SHEAR STRENGTH: □ Penetrometer, ◇ Torvane, △ Field Vane, Unconfined ▼, Triaxial ●, Miniature Vane ▲; KIPS PER SQ FT 0.5 1.0 1.5 2.0 2.5

NOTES:
Depth to Mudline (ft) = 36.7
Depth to Water (ft) = 8.2
Water Depth (ft) = 28.5
Record Date&Time: 8/9/2018 02:20

DATE: August 9, 2018
TOTAL DEPTH: 72.5'
CAVED DEPTH: Not Applicable
DRY AUGER: Not Applicable
WET ROTARY: 0' to 72.5'
BACKFILL: NONE
HAMMER TYPE: Automatic Trip
LOGGER: J. Soto/A. Bull

LOG OF BORING NO. BH-33
SHIP CHANNEL DEEPENING PROJECT
PORT OF CORPUS CHRISTI AUTHORITY
CORPUS CHRISTI, TEXAS

Report No. 04.10180080

FUGRO

LOCATION: Aransas Pass

COORDINATES: 1451492.362 N
17198051.824 E
(SPCS83 South Texas Zone)

MUDLINE EL.: -52.6' (MLLW)

DEPTH, FT	SAMPLE TYPE	BLOWS PER FOOT	% RECOVERY / RQD	STRATUM DESCRIPTION	STRATUM ELEVATION, FT	UNIT DRY WT, PCF	PASSING NO. 200 SIEVE, %	WATER CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX (PI)
0	SPT	WOR		SILTY SAND (SM): very loose, grayish brown, with shell fragments							
	SPT	9		- loose, 2' to 6'			20				
5	SPT	6		- greenish gray, 4' to 10' - with shells below 4'							
	SPT	4		- very loose							
	SPT	12		- medium dense, with clay at 8'							
10	SPT	14		CLAYEY SAND (SC): medium dense, greenish gray to brown	-62.6		50				
	T			- very stiff, brown sand and greenish gray clay pockets, with ferrous staining at 12'							
15	T			SANDY FAT CLAY (CH): very stiff, greenish gray to brown, with shells, 15' to 16'	-66.6			21	64	19	45
	SPT	22		SILTY SAND (SM): medium dense, greenish gray, fine grained	-70.6		21				
20											
25	SPT	30		- dense at 23' - light gray below 23'							
30	SPT	28		- medium dense below 28'							
35	SPT	15									
					-88.6						

SHEAR STRENGTH

□ Penetrometer ◇ Torvane △ Field Vane; Unconfined ▼ Triaxial ● Miniature Vane ▲

KIPS PER SQ FT: 0.5 1.0 1.5 2.0 2.5

NOTES:
Depth to Mudline (ft) = 65.7
Depth to Water (ft) = 11.5
Water Depth (ft) = 54.2
Record Date&Time: 8/12/2018 15:15

DATE: August 12, 2018
TOTAL DEPTH: 36'
CAVED DEPTH: Not Applicable
DRY AUGER: Not Applicable
WET ROTARY: 0' to 36'
BACKFILL: NONE
HAMMER TYPE: Automatic Trip
LOGGER: A. Bull

LOG OF BORING NO. BH-34
SHIP CHANNEL DEEPENING PROJECT
PORT OF CORPUS CHRISTI AUTHORITY
CORPUS CHRISTI, TEXAS

Report No. 04.10180080

LOCATION: Aransas Pass

COORDINATES: 1450228.13 N
17197855.77 E
(SPCS83 South Texas Zone)

MUDLINE EL.: -59.5' (MLLW)

STRATUM DESCRIPTION	STRATUM ELEVATION, FT
CLAYEY SAND (SC): very loose, gray to greenish gray, wet, fine grained, with shell fragments	-61.5
SANDY LEAN CLAY (CL): very soft, greenish gray, moist, with tan pockets, shell fragments, and sand pockets	-63.5
SAND (SP): greenish gray, moist to wet, with clay	-65.5
SANDY LEAN CLAY (CL): stiff, greenish gray, moist, with clayey sand seams and pockets	-71.5
FAT CLAY (CH): very stiff, brown to light gray, moist - hard, with sand partings and trace calcareous particles at 14'	-77.5
CLAYEY SAND (SC): light gray, wet, fine grained	-83.6
SAND (SP): dense, brown to gray, wet, fine grained - medium dense, olive gray and greenish gray at 27' - with sandy clay seam, 27.1' to 27.2'	-87.0

SAMPLE TYPE	BLOWS PER FOOT
SPT	W.O.R.
SPT	W.O.R.
T	
SPT	13
SPT	11
SPT	22
SPT	20
T	
T	
SPT	31
SPT	15

UNIT DRY WT, PCF	PASSING NO. 200 SIEVE, %	WATER CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX (PI)
	26	24			
		20	29	12	17
		24	34	14	20
		24	73	22	51
	15				

SHEAR STRENGTH, KIPS PER SQ FT (0.5, 1.0, 1.5, 2.0, 2.5): □ Penetrometer, ◇ Torvane, △ Field Vane, Unconfined ▼, Triaxial ●, Miniature Vane ▲

NOTES:
Depth to Mudline (ft) = 70.4
Depth to Water (ft) = 10.1
Water Depth (ft) = 60.3
Record Date&Time: 8/13/2018 19:00

DATE: August 12, 2018
TOTAL DEPTH: 27.5'
CAVED DEPTH: Not Applicable
DRY AUGER: Not Applicable
WET ROTARY: 0' to 27.5'
BACKFILL: NONE
HAMMER TYPE: Automatic Trip
LOGGER: J. Soto

LOG OF BORING NO. BH-35
SHIP CHANNEL DEEPENING PROJECT
PORT OF CORPUS CHRISTI AUTHORITY
CORPUS CHRISTI, TEXAS

Report No. 04.10180080

FUGRO

DEPTH, FT	SAMPLE TYPE	BLOWS PER FOOT	% RECOVERY / RQD	STRATUM DESCRIPTION	STRATUM ELEVATION, FT	UNIT DRY WT, PCF	PASSING NO. 200 SIEVE, %	WATER CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX (PI)	SHEAR STRENGTH (KIPS PER SQ FT)
	SPT	W.O.R.		CLAYEY SAND (SC): very loose, gray to dark gray			21	35				
	SPT	W.O.R.		- with shell fragments								
5	SPT	W.O.R.		- dark gray and gray (stratified), with trace of clay								
	T			- with clay pockets, 6.5' to 7'								
	SPT	8		- loose, greenish gray, with shell fragments, 8' to 18' - with trace of clay, 8' to 12'								
10	SPT	2		- very loose			26	20				
	SPT	2		- greenish gray below 12'								
15	SPT	9		- loose, with 4" shell layer starting at 14.8'								
20	SPT	9		SANDY FAT CLAY (CH): very stiff, brown, with sand pockets	-63.5							
25	T			- brown, light gray, and greenish gray - hard below 23'		101	99	25 23	73	23	50	5.2 (Triaxial)
30	T			- greenish gray and brown, with white calcareous nodules and clear cementitious nodules								
35	SPT	42		SAND (SP): dense, brown, with clay	-78.5							
	SPT	21		- medium dense, light gray and brown - with shell fragments below 38'								

LOCATION: Aransas Pass

COORDINATES: 1448852.609 N
17197688.622 E
(SPCS83 South Texas Zone)

MUDLINE EL.: -45.5' (MLLW)

SHEAR STRENGTH legend: □ Penetrometer, ◇ Torvane, △ Field Vane, Unconfined ▼, Triaxial ●, Miniature Vane ▲

KIPS PER SQ FT: 0.5, 1.0, 1.5, 2.0, 2.5

NOTES:
Depth to Mudline (ft) = 58.0
Depth to Water (ft) = 11.0
Water Depth (ft) = 47.0
Record Date&Time: 8/6/2018 13:20

DATE: August 8, 2018
TOTAL DEPTH: 41.5'
CAVED DEPTH: Not Applicable
DRY AUGER: Not Applicable
WET ROTARY: 0 to 41.5'
BACKFILL: NONE
HAMMER TYPE: Automatic Trip
LOGGER: A. Bull

LOG OF BORING NO. BH-36
SHIP CHANNEL DEEPENING PROJECT
PORT OF CORPUS CHRISTI AUTHORITY
CORPUS CHRISTI, TEXAS

DEPTH, FT	WATER LEVEL	SYMBOL	SAMPLES	SAMPLE TYPE	BLOWS PER FOOT	% RECOVERY / RQD	LOCATION: Aransas Pass COORDINATES: 1448852.609 N 17197688.622 E (SPCS83 South Texas Zone) MUDLINE EL.: -45.5' (MLLW) STRATUM DESCRIPTION	STRATUM ELEVATION, FT	UNIT DRY WT, PCF	PASSING NO. 200 SIEVE, %	WATER CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX (PI)	SHEAR STRENGTH (KIPS PER SQ FT)
				SPT	47		- olive gray and brown	-87.0		24	23				

Depth scale: 45, 50, 55, 60, 65, 70, 75

Shear strength legend: □ Penetrometer; ◇ Torvane; △ Field Vane; Unconfined ▼; Triaxial ●; Miniature Vane ▲. KIPS PER SQ FT: 0.5, 1.0, 1.5, 2.0, 2.5

NOTES:
Depth to Mudline (ft) = 58.0
Depth to Water (ft) = 11.0
Water Depth (ft) = 47.0
Record Date&Time: 8/6/2018 13:20

DATE: August 8, 2018
TOTAL DEPTH: 41.5'
CAVED DEPTH: Not Applicable
DRY AUGER: Not Applicable
WET ROTARY: 0 to 41.5'
BACKFILL: NONE
HAMMER TYPE: Automatic Trip
LOGGER: A. Bull

LOG OF BORING NO. BH-36
SHIP CHANNEL DEEPENING PROJECT
PORT OF CORPUS CHRISTI AUTHORITY
CORPUS CHRISTI, TEXAS

DEPTH, FT	WATER LEVEL	SYMBOL	SAMPLES	SAMPLE TYPE	BLOWS PER FOOT	% RECOVERY / RQD	LOCATION: Aransas Pass COORDINATES: 1448180.061 N 17198257.072 E (SPCS83 South Texas Zone) MUDLINE EL.: -67.2' (MLLW) STRATUM DESCRIPTION	STRATUM ELEVATION, FT	UNIT DRY WT, PCF	PASSING NO. 200 SIEVE, %	WATER CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX (PI)	SHEAR STRENGTH, KIPS PER SQ FT (□ Penetrometer, ◇ Torvane, △ Field Vane, Unconfined ▼, Triaxial ●, Miniature Vane ▲)
0–4					W.O.R.		SANDY LEAN CLAY (CL): very stiff, tan to light gray								
3				SPT	W.O.R.						28	38	12	26	□ ~1.7
4							SILTY SAND (SM): loose, greenish gray to brown, fine grained	-71.2							
5				T											
7				SPT	23		- greenish gray, brown and light gray - medium dense to 10'			12	24				
9				SPT	17		- greenish brown								
11				SPT	9		- loose, greenish brown and light gray								
13				SPT	17		- medium dense, 12' to 16', brownish gray - with shell fragments below 12'								
15				SPT	27		- grayish brown								
19				SPT	37		- dense, brown to 19', gray below 19'			16	22				
23				SPT	46										
23.5								-90.7							

NOTES:
Depth to Mudline (ft) = 78.8
Depth to Water (ft) = 9.8
Water Depth (ft) = 69.0
Record Date&Time: 8/8/2018 10:10

DATE: August 8, 2018
TOTAL DEPTH: 23.5'
CAVED DEPTH: Not Applicable
DRY AUGER: Not Applicable
WET ROTARY: 0 to 23.5'
BACKFILL: NONE
HAMMER TYPE: Automatic Trip
LOGGER: A. Bull

LOG OF BORING NO. BH-37
SHIP CHANNEL DEEPENING PROJECT
PORT OF CORPUS CHRISTI AUTHORITY
CORPUS CHRISTI, TEXAS

LOCATION: Aransas Pass

COORDINATES: 1447038.105 N
17197646.706 E
(SPCS83 South Texas Zone)

MUDLINE EL.: -52.0' (MLLW)

DEPTH, FT	SAMPLE TYPE	BLOWS PER FOOT	STRATUM DESCRIPTION	STRATUM ELEVATION, FT	UNIT DRY WT, PCF	PASSING NO. 200 SIEVE, %	WATER CONTENT, %	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX (PI)
0 – 2	SPT	6	SAND (SP): loose, gray to dark gray, wet, with shells and shell fragments - with clay seam, 1.2' to 1.3'	-54.0		9	31			
2 – 12	SPT	28	CLAYEY SAND (SC): medium dense, gray, wet, fine grained							
	SPT	13	medium dense, gray to white, with course sand to fine gravel sized shell fragments and medium grain sand	-57.2		25	18	21	12	9
	SPT	36	- hard, light gray to greenish gray at 7'							
	SPT	24								
	SPT	39	- borderline sandy clay			24	18			
12 – 23	SPT	18	FAT CLAY (CH): very stiff, light gray to brown, moist	-64.0						
	T		- hard below 14' - with silty sand partings at 14' - with pockets of shell fragments, 14' to 15'		98		25	43	14	29
	T		- slickensided, 18 to 18.5' - with sand partings and pockets, 18.5' to 20'							
23 – 28	SPT	18	SANDY FAT CLAY (CH): very stiff, light gray to greenish gray, moist, with brown pockets	-75.0			17			
28 – 34.5	SPT	25	SAND (SP): medium dense, gray to greenish gray, moist, fine grained	-80.0						
	SPT	21		-86.5						

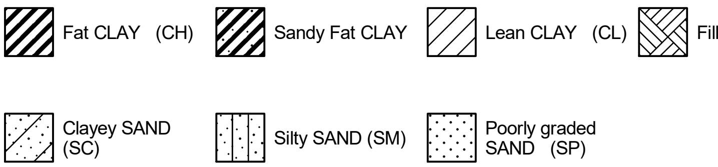
SHEAR STRENGTH (KIPS PER SQ FT: 0.5, 1.0, 1.5, 2.0, 2.5) — □ Penetrometer, ◇ Torvane, △ Field Vane, ▼ Unconfined, ● Triaxial, ▲ Miniature Vane

NOTES:
Depth to Mudline (ft) = 62.2
Depth to Water (ft) = 9.4
Water Depth (ft) = 51.8
Record Date&Time: 8/13/2018 20:20

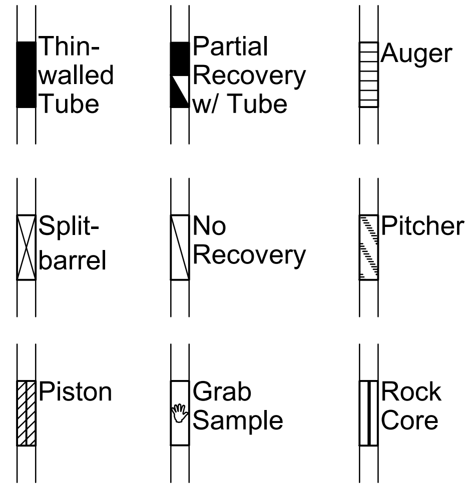
DATE: August 13, 2018
TOTAL DEPTH: 34.5'
CAVED DEPTH: Not Applicable
DRY AUGER: Not Applicable
WET ROTARY: 0' to 34.5'
BACKFILL: NONE
HAMMER TYPE: Automatic Trip
LOGGER: J. Soto

LOG OF BORING NO. BH-38
SHIP CHANNEL DEEPENING PROJECT
PORT OF CORPUS CHRISTI AUTHORITY
CORPUS CHRISTI, TEXAS

SOIL TYPES



SAMPLER TYPES

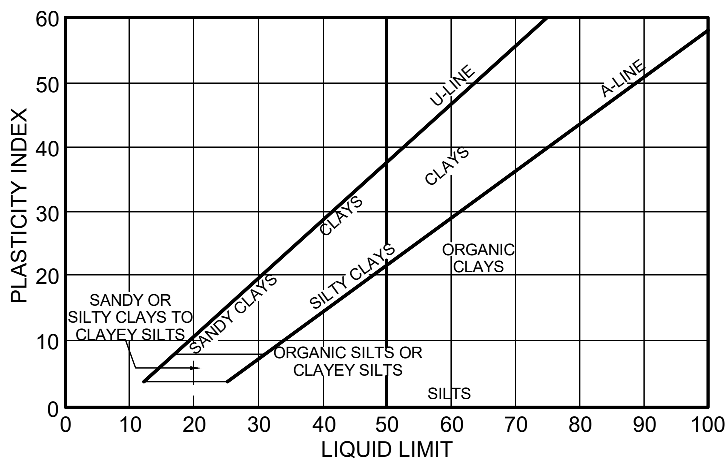


SOIL GRAIN SIZE

U.S. Standard Sieve

6"	3"	3/4"	4	10	40	200		
Boulders	Cobbles	Gravel		Sand			Silt	Clay
		Coarse	Fine	Coarse	Medium	Fine		
152	76.2	19.1	4.76	2.00	0.420	0.074	0.002	(mm)

PLASTICITY CHART



SOIL STRUCTURE

Slickensided .... Having planes of weakness that appear slick and glossy.
Fissured .... Containing shrinkage or relief cracks, often filled with fine sand or silt; usually more or less vertical.
Pocket .... Inclusion of material of different texture that is smaller than the diameter of the sample.
Parting .... Inclusion less than 1/8 inch thick extending through the sample.
Seam .... Inclusion 1/8 inch to 3 inches thick extending through the sample.
Layer .... Inclusion greater than 3 inches thick extending through the sample.
Laminated .... Soil sample composed of alternating partings or seams of different soil type.
Interlayered .... Soil sample composed of alternating layers of different soil type.
Intermixed .... Soil sample composed of pockets of different soil type and layered or laminated structure is not evident.
Calcareous .... Having appreciable quantities of carbonate.
Carbonate .... Having more than 50% carbonate content.

TERMS AND SYMBOLS USED ON BORING LOGS

SOIL CLASSIFICATION (1 of 2)

STANDARD PENETRATION TEST (SPT)

A 2-in.-OD, 1-3/8-ID split spoon sampler is driven 1.5 ft into undisturbed soil with a 140-pound hammer free falling 30 in. After the sampler is seated 6 in. into undisturbed soil, the number of blows required to drive the sampler the last 12 in. is the Standard Penetration Resistance or "N" value, which is recorded as blows per foot as described below.

SPLIT-BARREL SAMPLER DRIVING RECORD

Blows Per Foot	Description
25	25 blows drove sampler 12 inches, after initial 6 inches of seating.
50/7"	50 blows drove sampler 7 inches, after initial 6 inches of seating.
Ref/3"	50 blows drove sampler 3 inches during initial 6-inch seating interval.

NOTE: To avoid damage to sampling tools, driving is limited to 50 blows during or after seating interval.

DENSITY OF GRANULAR SOILS

Descriptive Term	*Relative Density, %	**Blows Per Foot (SPT)
Very Loose	< 15	0 to 4
Loose	15 to 35	5 to 10
Medium Dense	35 to 65	11 to 30
Dense	65 to 85	31 to 50
Very Dense	> 85	> 50

*Estimated from sampler driving record.

**Requires correction for depth, groundwater level, and grain size.

STRENGTH OF COHESIVE SOILS

Term	Undrained Shear Strength, ksf	Blows Per Foot (SPT) (approximate)
Very Soft	< 0.25	0 to 2
Soft	0.25 to 0.50	2 to 4
Firm	0.50 to 1.00	4 to 8
Stiff	1.00 to 2.00	8 to 16
Very Stiff	2.00 to 4.00	16 to 32
Hard	> 4.00	> 32

SHEAR STRENGTH TEST METHOD

U - Unconfined   Q = Unconsolidated - Undrained Triaxial

P = Pocket Penetrometer   T = Torvane   V = Miniature Vane   F = Field Vane

HAND PENETROMETER CORRECTION

Our experience has shown that the hand penetrometer generally overestimates the in-situ undrained shear strength of over consolidated Pleistocene Gulf Coast clays. These strengths are partially controlled by the presence of macroscopic soil defects such as slickensides, which generally do not influence smaller scale tests like the hand penetrometer. Based on our experience, we have adjusted these field estimates of the undrained shear strength of natural, overconsolidated Pleistocene Gulf Coast soils by multiplying the measured penetrometer reading by a factor of 0.6. These adjusted strength estimates are recorded in the "Shear Strength" column on the boring logs. Except as described in the text, we have not adjusted estimates of the undrained shear strength for projects located outside of the Pleistocene Gulf Coast formations.

Information on each boring log is a compilation of subsurface conditions and soil or rock classifications obtained from the field as well as from laboratory testing of samples. Strata have been interpreted by commonly accepted procedures. The stratum lines on the logs may be transitional and approximate in nature. Water level measurements refer only to those observed at the time and places indicated, and can vary with time, geologic condition, or construction activity.

TERMS AND SYMBOLS USED ON BORING LOGS
SOIL CLASSIFICATION (2 of 2)

Appendix C

Bioassay Methods, Analyses, and Reporting

Bioassay Methods, Analyses, and Reporting

1.0 OVERVIEW OF ELUTRIATE CHEMICAL ANALYSES AND BIOLOGICAL TESTING OF SEDIMENT

Elutriate chemical analyses and bioassays will be conducted to assess the potential for adverse impacts from the dredging and placing of new work construction sediments from the Corpus Christ Ship Channel (CCSC) Entrance Channel and Channel Extension.

2.0 GENERATION OF ELUTRIATE SAMPLES FOR CHEMICAL ANALYSES OF DISSOLVED CONSTITUENTS

The Standard Elutriate Test (SET) will be prepared according to USEPA and USACE (1991; 1998) guidance by agitating one part sediment and four parts site water for thirty (30) minutes, followed by a sixty (60) minute settling period. The supernatant will be siphoned, filtered, acidified according to instructions from the ANALTYICAL PROVIDER specified in Section 3.1 of the SOW and shipped overnight from ERDC to the ANALTYICAL PROVIDER specified in Section 3.1 of the SOW for chemical analyses (Tables 3, 4 and 5). This supernatant is defined as the 100% elutriate.

3.0 BIOLOGICAL TESTING OF SEDIMENT

Bioassays will be conducted to assess the potential for biological effects of dredged material in the water column during dredging and placement (elutriate toxicity tests on the suspended phase particulate) as well as after placement (sediment toxicity and bioaccumulation tests). Each type of bioassay will utilize at least two taxonomically and functionally dissimilar species. Elutriate toxicity tests will employ the fish *Menidia beryllina* or *Cyprinodon variegatus* and two life stages of the mysid shrimp *Americamysis bahia*. Sediment toxicity tests will use a surface deposit feeding amphipod (*Leptocheirus plumulosus* or *Ampelisca abdita)* and an epibenthic mysid shrimp (*A. bahia)*. Sediment bioaccumulation tests will be conducted with a bulk deposit-feeding polychaete worm (*Nereis virens)* and the facultative filter feeding and surface deposit feeding clam (*Macoma nasuta)*. Additional details for each test are provided below.

4.0 SUSPENDED PARTICULATE PHASE (SPP-ELUTRIATE) BIOASSAYS

The Standard Elutriate Test (SET) will be prepared according to guidance (USEPA/USACE 1991, 1998) by agitating one part sediment and four parts site water for thirty (30) minutes, followed by a sixty (60) minute settling period. The supernatant will be siphoned and used for testing; this supernatant is defined as the 100% elutriate. Elutriate bioassays will be conducted for 96-hours (or 48-h for zooplankton tests) using the 100% elutriate, in addition to 50% and 10% dilutions of the 100% elutriate water. Reconstituted or natural seawater (or PA water, if provided) will be used as the diluent.

Laboratory performance controls will consist of natural or reconstituted seawater (Crystal Sea Marine Mix®, Enterprises International, Baltimore, MD, USA or Instant Ocean Seasalt®, Mentor, OH, USA) to confirm test organism viability. All concentrations, including the control, will be replicated five (5) times. The standard test organisms Americamysis bahia (formerly Mysidopsis bahia) and Menidia beryllina will be used in testing in basic accordance with dredged material evaluation guidance (US EPA / US ACE 1991, 1998). The fish Cyprinodon variegatus will be used if the water salinity falls below the testing range for Menidia beryllina. Fish and shrimp survival tests will be conducted at 20 ± 1 □C.

Experimental conditions and additional suspended particulate phase bioassays information are summarized in Table 4-1.

4.1 ZOOPLANKTON (AMERICAMYSIS BAHIA)

Less than one (≤1) day old mysid shrimp Americamysis bahia will be exposed to the sediment elutriates. Shrimp will be shipped overnight from Aquatic Biosystems (Fort Collins, CO, USA; or a similar vendor) and immediately observed for potential shipment impacts while being fed brine shrimp (Artemia) upon receipt. The control and dilution water will be reconstituted seawater prepared using Instant Ocean Seasalt® or Crystal Sea Marine Mix®. Tests will be conducted in one (1) L glass beakers containing two hundred (200) mL test media. The larger foot print of the one (1) L beaker is required for to provide greater swimming area to avoid aggressive interactions. Ten (10) A. bahia will be added per replicate and will be fed twice daily to avoid cannibalism. The measurement endpoint is survival after forty-eight (48) h exposure.

4.2 CRUSTACEAN (AMERICAMYSIS BAHIA)

Four to five (4 to 5) day old mysid shrimp Americamysis bahia will be exposed to the sediment elutriates. Shrimp will be shipped overnight from Aquatic Biosystems (Fort Collins, CO, USA; or a similar vendor) and immediately observed for potential shipment impacts and fed brine shrimp (Artemia) upon receipt. The control and dilution water is reconstituted seawater prepared using Instant Ocean Seasalt® or Crystal Sea Marine Mix®. Tests will be conducted in one (1) L glass beakers containing two hundred (200) mL test media. The larger foot print of the one (1) L beaker is required for to provide greater swimming area to avoid aggressive interactions. Ten (10) A. bahia will be added per replicate and will be fed twice daily to avoid cannibalism. The measurement endpoint is survival after ninety-six (96) h exposure.

4.3 FISH (MENIDIA BERYLLINA)

The silverside fish Menidia beryllina will be exposed to the sediment elutriate water at nine to fourteen (9 to 14) days old. Fish will be shipped overnight from Aquatic Biosystems (Fort Collins, CO, USA; or a similar vendor) and immediately observed for potential shipment impacts and fed brine shrimp (Artemia) upon receipt. The M. beryllina will be held for a minimum of one (1) night prior to testing. The control and dilution water will be reconstituted seawater prepared using Crystal Sea Marine Mix® or Instant Ocean Seasalt®. Tests will be conducted in two hundred (200) mL or one (1) L beakers containing two hundred (200) mL test media. Ten (10) M. beryllina will be added per replicate and will be fed at 48-h into the bioassay. The measurement endpoint is survival after ninety-six (96) h exposure. The C. variegatus test is performed in the same fashion.

If sufficient mortality is observed in the above tests, NOEC, LOEC and LC50 values will be generated. Test acceptability criteria include water parameters within the specified range (USEPA/USACE 1991, 1998), at least ninety percent (90%) survival in the performance control and sensitivity to a reference toxicant (e.g., KCl) within acceptable control chart ranges (± two (2) S.D. from the mean).

4.4 WHOLE SEDIMENT TOXICITY (SOLID PHASE) BIOASSAYS

Whole sediment toxicity (solid phase) tests will be conducted to simulate exposure of benthic or epibenthic organisms to the in-place dredged material at the PA. Prior to testing, sediments will be thoroughly homogenized using an impeller mixer. Two standard test organisms, including 1) the amphipod Leptocheirus plumulosus or Ampelisca abdita and 2) Americamysis bahia, will be used in testing in basic accordance with dredged material evaluation guidance (USEPA/USACE 1991, 1998; USEPA 1994). Selection of the amphipods will depend on their suitability and relevance to the physical attributes of the test sediment.

Experimental conditions and additional whole sediment toxicity (solid phase) bioassay information are summarized in Table 4-2.

4.4.1 AMPHIPOD 10-D SEDIMENT TOXICITY BIOASSAY

Leptocheirus plumulosus (3-5 mm; no mature males or females) will be obtained from in-house cultures at the ERDC. If required, Ampelisca abdita (2 to 4 mm; no mature males or females) will be obtained from Aquatic Research Organism (Hampton, NH; or similar vendor). Amphipods will be sieved from culture/holding sediment and kept in clean reconstituted seawater overnight prior to test initiation. Approximately 175 mL (2 cm depth) of each test material and 825 mL overlying seawater (Crystal Sea Marine Mix®) will be placed into each of five replicate 1 L glass beakers. In addition, a performance control using well characterized sediment (Sequim Bay, WA, USA) and a reference sediment specific to the disposal site will be included in the study. Bulk sediment pore water ammonia concentrations will be measured upon sediment receipt.

The system will be allowed to equilibrate overnight under gentle aeration. The following day a chemistry ammonia duplicate will be sacrificed and pore water total ammonia will be measured. Pore water ammonia concentrations will be compared to species specific values listed in USEPA/USACE (1998) guidance. If ammonia levels exceed 60 mg/L for Leptocheirus plumulosus, or 30 mg/L for Ampelisca abdita, ammonia reduction procedures will be employed as described in section 11.2. of the Inland Testing Manual (USEPA/USACE, 2008). The study will be conducted at 25 ± 1°C and 20% salinity (Leptocheirus plumulosus) or 20 ± 1°C and 28% salinity (Ampelisca abdita) under a 24 hour light regime.The test will not be fed.

Water quality parameters will be measured from each replicate chamber (i.e., temperature, pH, dissolved oxygen, salinity and overlying water ammonia) at test initiation and termination. Water bath temperature will be monitored and recorded daily. Aeration will be provided to test chambers. In addition, daily observations (e.g., burrowing behavior) that may be significant to test results will be recorded. Following a 10-day exposure each beaker will be sieved and surviving organisms recovered and enumerated. Performance control survival must be ≥90% and reference toxicant test value must be within control chart ranges (± two (2) S.D. from the mean).

4.4.2 AMERICAMYSIS BAHIA 10-D SEDIMENT TOXICITY BIOASSAY

Americamysis bahia 10-d sediment toxicity testing will be conducted in basic accordance with standard guidance (USEPA/USACE 1991, 1998). Americamysis bahia (1-5 days old) will be obtained from Aquatic Biosystems (Fort Collins, CO, USA) or a similar vendor. Shrimp will be kept in clean reconstituted Instant Ocean® seawater overnight prior to test initiation. Approximately 175 mL of each test material and 825 mL overlying seawater (Instant Ocean Seasalt®) at 30‰ will be placed into each of five replicate 1 L glass beakers. In addition, a performance control using a well-characterized sediment (Sequim Bay, WA, USA) and a reference sediment specific to the disposal site will be included. Bulk sediment pore water ammonia concentrations will be measured upon sediment receipt.

The study will be conducted at 20 ± 1°C under a 16L:8D hour light regime. The test will be fed a concentrated suspension of Artemia nauplii ≤24 h old daily. Water quality parameters will be measured from each replicate chamber (i.e., temperature, pH, dissolved oxygen salinity and overlying water ammonia) at test initiation and termination. Water bath temperature will be monitored and recorded daily. Aeration will be provided to test chambers.

At test initiation, a minimum of ten (10) shrimp will be added to each replicate. Daily observations (e.g., swimming behavior) that may be significant to test results will be recorded daily. Following a 10-day exposure, sediment will be passed through a 425 µm sieve and surviving organisms recovered and enumerated. Performance control survival must be ≥90% and the reference toxicant test value must be within control chart ranges (± two (2) S.D. from the mean).

5.0 REFERENCE TOXICITY TESTS

5.1 SUSPENDED PARTICULATE PHASE TOXICITY REFERENCE TESTS

Forty-eight to ninety-six (48-96) hour reference toxicant tests will be conducted on each shipped batch of test organisms to assess test organism sensitivity relative to historic information recorded in laboratory control charts (± two (2) S.D. from the mean). Control charts from Aquatic Biosystems (or similar vendor) or ERDC will be used to compare to reference toxicity tests performed at ERDC. The selected reference toxicant is potassium chloride (KCl). Five concentrations (n = 1 to 3) will be prepared. Ten (10) organisms will be added to each replicate. The endpoint measured will be survival (LC50) after a 96-hour exposure.

5.2 WHOLE SEDIMENT TOXICITY (SOLID PHASE) REFERENCE TESTS

Reference toxicant tests will be conducted on each batch of test organisms used in whole sediment testing to assess test organism sensitivity relative to historic information recorded in laboratory control charts. In-house or vendor control charts will be used for comparison of both test organisms. The reference toxicant will be potassium chloride (KCl) or cadmium chloride (CdCl2). Six (6) concentrations will be prepared with three replicates per concentration containing 10 organisms each. The endpoint measured for both organisms will be survival after a 96-hour exposure.

6.0 BIOACCUMULATION BIOASSAYS

The standard organisms Nereis virens (polychaete worm) and Macoma nasuta (clam) will be used in whole sediment bioaccumulation testing in basic accordance with dredged material evaluation guidance (USEPA /USACE 1991, 1998). Approximately Six (6) L of each composite test material and twenty-four (24) L overlying seawater (Instant Ocean Seasalt®) will be placed into each of five (5) replicated, ten (10) gallon glass tanks. In addition, a reference sediment specific to the disposal site will be tested. The system will be allowed to equilibrate overnight under aeration.

The next day, approximately thirty-five (35) grams of live organism tissue will be added to each test chamber; an additional thirty-five (35) grams of unexposed tissue will be collected for background tissue residues. The static renewal bioassays will be conducted for twenty-eight (28) days and seventy percent (70%) of the water will be exchanged every Monday, Wednesday and Friday. Survival and mass of recoverable tissue will be measured at test termination. Prior to preservation, test organisms will be purged of undigested sediment (specifics are described below). Recovered tissue will be thoroughly homogenized using a tissumizer or will be ground to a powder by mortar and pestle over liquid nitrogen prior to residue analysis. Lipid analysis will be conducted using a method modified from Van Handel (1985) and is described in detail in Kennedy et al. (2010). All analyses will be performed on a wet tissue mass basis. The wet/dry ratio of tissue will also be determined.

Experimental conditions and additional bioaccumulation bioassay information are summarized in Table 4-3.

6.1 NEREIS VIRENS 28-D BIOACCUMULATION BIOASSAY

The polychaete worm Nereis virens will be field-collected (Aquatic Research Organisms, Hampton, NH, USA; or similar vendor) and acclimated to laboratory conditions for at least twenty-four (24) hours prior to testing. Tests will be conducted at 20 ± 1 ºC (20 ºC recommended) and any worms that do not burrow within the first two (2) hours following addition will be promptly replaced.

After twenty-eight (28) days exposure, the N. virens will be removed from the test sediment and allowed to purge their guts for twenty (24) hours in 3.75 L jars containing clean reconstituted seawater. Following gut purging, worms will be removed from water, thoroughly rinsed with deionized water, cleaned of any debris and either shipped immediately or frozen until shipped to the ANALTYICAL PROVIDER specified in Section 3.1 of the SOW for chemical analysis. Sample handling procedures will be confirmed with the ANALTICAL PROVIDER specified in Section 3.1 of the SOW one week prior to sample collection.

6.2 MACOMA NASUTA 28-D BIOACCUMULATION BIOASSAY

The bent nose clam Macoma nasuta will be field-collected (Aquatic Research Organisms, Hampton, NH, USA; or similar vendor) and acclimated to laboratory conditions for at least forty-eight (48) hours prior to testing. Tests will be conducted at 15 ± 1 ºC and any clams that do not burrow within the first twentyfour (24) hours following addition will be promptly replaced. After 28-days exposure, the M. nasuta will be removed from the test sediment and will be dissected to remove gut contents (undigested sediment) since purging in water is often insufficient to purge the gut of clams (Kennedy et al. 2010). Shells will be removed by cutting the hinge with a scalpel. Any remaining undigested sediment will be removed from the gut using a scalpel, and tissue will be thoroughly rinsed with deionized water and either shipped immediately or frozen until shipped to the ANALTYICAL PROVIDER specified in Section 3.1 of the SOW for chemical analysis. Sample handling procedures will be confirmed with the ANALTICAL PROVIDER Specified in Section 3.1 of the SOW one week prior to sample collection.

7.0 DATA ANALYSIS AND INTERPRETATION

7.1 STATISTICAL ANALYSES

For solid phase particulate bioassay data, statistical analyses will be conducted using Toxcalc® statistical software (Version 5.0, Tidepool Scientific Software, McKinleyville, CA) or SigmaStat® statistical software (SPSS, Chicago IL). All data will be statistically compared to data from references. Data normality (Kolmogorov–Smirnov test), homogeneity (Levene’s Test), and treatment differences compared to the reference (one way by ANOVA and Dunnett’s Method) will be determined at the $\alpha = 0.05$ level. Survival data will be arcsine-square-root transformed where appropriate. If normality cannot be achieved, t-tests will be used to compare elutriate treatments to the dilution water. The lethal median concentration producing 50% mortality (LC50) in elutriate or reference toxicity test dilutions will be determined by the Spearman–Karber method using Toxcalc® (verison 5.0, Tidepool Scientific Software, McKinleyville, CA).

For whole sediment and bioaccumulation bioassay data, statistical analyses will be conducted using Toxcalc® statistical software (Version 5.0, Tidepool Scientific Software, McKinleyville, CA), SigmaStat® (SPSS, Chicago IL) or SAS (SAS Institute, Cary, NC). All data will be statistically compared to data from the Reference Site (controls will not be included in statistical comparisons). For whole sediment testing, data normality will be evaluated using

Kolmogorov-Smirnov test. Homogeneity of variance will be evaluated using the Levene's median test. Where data are normal and homogeneous or can be made normal and/or homogeneous through a data transformation (e.g., arc-sine square root or log), the Dunnett's or Fisher's LSD method for all pair-wise comparisons will be utilized. Where data are not normal and/or variances not homogenous, the Steel Many Rank Test, Conover T Test or paired t-tests for unequal variance will be employed. Statistical significance will be determined at $\alpha = 0.05$.

7.2 DATA INTERPRETATION

US EPA R6 has issued a memo titled, "How to Report and Use Non-Detect Data When Evaluating MPRSA Section 103 Evaluations" (Oct 03, 2016). In addition to the data interpretation outlined below, non-detect data will be handled in a manner that is consistent with this draft memo. This memo is appended to this attachment as Supplemental Attachment 4-1.

7.2.1 Suspended Particulate Phase Toxicity Evaluation

Survival in all of the dredging site elutriate treatments will be compared to survival in the dilution water treatments. If survival is greater than, or equal to, survival in the dilution water treatment, the LPC for the suspended particulate phase has been met. If survival in the dredged material treatments is less than survival in the dilution water treatment, but the difference does not exceed 10%, the LPC for the suspended particulate phase will have been met.

If the difference in survival exceeds 10% the survival in the 100% dredged material elutriate treatment will be statistically compared to survival in the dilution water. If the 100% dredged material elutriate treatment is not statistically different from the dilution water, the LPC for the suspended particulate phase will have been met.

If survival in the 100% dredged material elutriate treatment is statistically lower than the dilution water, a numerical model will be required to determine compliance with the LPC (USEPA/USACE, 1991). The modeled concentrations of the dredged material in the water column outside the boundary of the disposal site during the 4-hour initial mixing period and the maximum concentration in the water column in the marine environment after the 4-hour mixing period will be compared with the LPC, as determined by multiplying the 48- or 96-hour LC50 by an appropriate application factor, to determine compliance.

If mortality is greater than 10% in the control treatment or in the dilution water treatment for a particular test species (30% mortality/abnormality for zooplankton), the test should be rejected and the bioassay repeated.

The default application factor is 0.01 but alternative factors can be used if justification is given. If both modeled concentrations are less than the LPC, compliance for the suspended particulate phase will have been met. If either of the modeled concentrations exceeds the LPC, the compliance for the suspended particulate phase is not met and placement of the dredged sediment cannot be conducted without appropriate management.

7.2.2 Whole Sediment Toxicity (Solid Phase) Bioassay Data Interpretation

Two conditions will be required to designate sediment as potentially toxic based on survival in whole sediment toxicity (solid phase) testing: 1) mortality that is more than 10% greater (A. bahia) or 20% greater (amphipod) than mortality in the reference; and 2) a statistically significant reduction in survival compared to survival in the reference sediment (USEPA/USACE 1998). If mortality exceeds reference mortality by the magnitude described in condition(1) above, dredging sediment toxicity data will be statistically compared to data from the reference sediments as described in the Inland Testing Manual (EPA/USCAE 1998). If both conditions are met, then the sediment will have failed to meet the LPC and will be deemed unsuitable for open water placement. If one or both of these conditions are not met, then sediment will have met the LPC for whole sediment toxicity (solid phase).

If greater than 10% mean mortality occurs in the control sediment, the test should be repeated.

7.2.3 Bioaccumulation Bioassay Test Data Interpretation

For bioaccumulation tests, tissue residues will be conservatively compared to the Food and Drug Administration (FDA) action levels (where available) using the 95th percentile of the data distribution. If concentrations of one or more contaminants statistically exceed the FDA action level, then the sediment will not meet the LPC for open water placement.

If tissue concentrations do not exceed the FDA action levels, then the tissue residue levels will be statistically compared to tissue concentrations of organisms exposed to reference sediment. In cases where tissue residues are less than detection limits, half the detection limit will be applied to statistical comparisons as recommended by Clark (1998). If tissue concentrations in organisms exposed to sediment from the dredging site do not statistically exceed the contaminant concentrations in tissues exposed to the reference sediment, adverse effects are not likely and the sediment will have met the LPC for bioaccumulation.

If tissue concentrations are statistically greater in organisms exposed to sediment from the dredging site than in organisms exposed to the reference sediment, further evaluation will be required by assessing the eight factors described in the Regional Implementation Agreement (USEPA/USACE 2003). The factors will be assessed in a weight-of evidence-approach (WOE) for determination of LPC compliance.

If a compliance decision still cannot be reached following evaluation of the eight factors, further actions will be developed and agreed upon by both the EPA and the USACE.

8.0 REPORTING

A report containing the finding of the toxicity and bioaccumulation studies will be provided. The report will include an executive summary, introduction, methods and results section. The report will include test endpoint tables providing means, standard deviations for survival, tissue mass, etc. Water quality analysis tables will include mean, standard deviation, N, and range of values for each endpoint measured. One (1) hard copy and an electronic PDF version of the report will be provided. Experimental data will be provided in an Excel Electronic Data Deliverable (EDD) (Supplemental Attachment 3-2).

9.0 REFERENCES

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Van Handel, E. 1985. Rapid determination of total lipids in mosquitoes. *Journal of the American Mosquito Control Association* 1:302–304.

Table 4-1: Suspended Particulate Phase Bioassays Information and Conditions

Parameter	Zooplankton (*Americamysis bahia*)	Invertebrate (*Americamysis bahia*)	Fish (*Menidia beryllina*)	Fish (*Cyprinodon variegatus*)*
Supplier	Aquatic Bio Systems, INC, Fort Collins, CO, or similar	Aquatic Bio Systems, INC, Fort Collins, CO, or similar	Aquatic Bio Systems, INC, Fort Collins, CO, or similar	Aquatic Bio Systems, INC, Fort Collins, CO, or similar
Age class	Neonate, ≤ 1 day old	Juvenile, 1-5 day old (24h range)	Larval, 9-14 day old (24h range)	Larval, 1-14 day old (24h range)
Test Procedures	OTM, ITM (EPA/USACE 1991, 1998)	OTM, ITM (EPA/USACE 1991, 1998)	OTM, ITM (EPA/USACE 1991, 1998)	OTM, ITM (EPA/USACE 1991, 1998)
Test type/duration	Static non-renewal – 48h	Static non-renewal – 96h	Static non-renewal – 96h	Static non-renewal – 96h
Control water	Laboratory reconstituted salt water, Crystal Sea/Instant Ocean	Laboratory reconstituted salt water, Crystal Sea/Instant Ocean	Laboratory reconstituted salt water, Crystal Sea/Instant Ocean	Laboratory reconstituted salt water, Crystal Sea/Instant Ocean
Test temperature	Recommended: 20 ± 1oC	Recommended: 20 ± 1oC	Recommended: 20 ± 1oC	Recommended: 20 ± 1oC
Test salinity	Range: 15 - 30 ppt (± 10%)	Range: 15 - 30 ppt (± 10%)	Range: 20 - 30 ppt (± 10%)	Range: 5 - 30 ppt (± 10%)
Test dissolved oxygen	Recommended: >4.5 mg/L	Recommended: >4.5 mg/L	Recommended: >4.5 mg/L	Recommended: >4.5 mg/L
Test pH	Recommended:7.8 ± 0.5	Recommended:7.8 ± 0.5	Recommended: 7.8 ± 0.5	Recommended: 7.8 ± 0.5
Control performance	≥ 90% survival	≥ 90% survival	≥ 90% survival	≥ 90% survival
Test photoperiod	16L:8D	16L:8D	16L:8D	16L:8D
Test chamber	1 L beaker	1 L beaker	250mL or 1 L beaker	250mL beaker
Exposure volume	200 mL	200 mL	200 mL	200 mL
SPP concentrations	100, 50, 10%	100, 50, 10%	100, 50, 10%	100, 50, 10%
Replicates/concentration	5	5	5	5
Organisms/replicate	10	10	10	10
Feeding	500 Artemia *Artemia nauplii* prior to test, am and pm daily	500 Artemia *Artemia nauplii* prior to test, am and pm daily	500 *Artemia nauplii* prior to test, pm 24h, am 72h	500 *Artemia nauplii* prior to test, pm 24h, am 72h
Water renewal	no	no	no	no
Endpoint	Survival	Survival	Survival	Survival

Table 4-2: Whole Sediment Toxicity (Solid Phase) Bioassays Information and Conditions

Parameter	*Leptocheirus plumulosus*	**Ampelisca abdita*	*Americamysis bahia*
Supplier	Aquatic Bio Systems, Inc., Fort Collins, CO, or similar; in-house cultures	Aquatic Research organisms Inc., Hampton, NH or similar	Aquatic Bio Systems, Inc., Fort Collins, CO, or similar
Age class	2-4 mm (500-710 µm);	3-5 mm; no mature males or females	1-5 day old (24h range)
Test Procedures	OTM, ITM (EPA/USACE 1991, 1998); EPA 1994	OTM, ITM (EPA/USACE 1991, 1998); EPA 1994	OTM, ITM (EPA/USACE 1991, 1998)
Test type/duration	10-d	10-d	10-d
Control water	Laboratory reconstituted salt water (e.g., Crystal Sea®)	Laboratory reconstituted salt water (e.g., Crystal Sea®)	Laboratory reconstituted salt water (e.g., Instant Ocean®)
Test temperature	Recommended: 25 ± 1$_o$C	Recommended: 20 ± 1$_o$C	Recommended: 20 ± 1$_o$C
Test salinity	20‰	28‰	30‰
Test dissolved oxygen	Recommended: >4.5 mg/L	Recommended: >4.5 mg/L	Recommended: >4.5 mg/L
Test photoperiod	Continuous light	Continuous Light	16L:8D
Test chamber	1 L beaker	1 L beaker	1 L beaker
Sediment volume	175 mL (2 cm depth)	175 mL (2 cm depth)	175 mL (2 cm depth)
Overlying water volume	825 mL	825 mL	825 mL
Replicates/sediment	5	5	5
Organisms/replicate	20	20	20
Feeding	none	none	Concentrated suspension of *Artemia nauplii*
Water renewal	none	none	none
Endpoint	Survival	Survival	Survival
Acceptability Criteria	≥ 90% Survival in Control	≥ 90% Survival in Control	≥ 90% Survival in Control

* replacement amphipod if sediment is too dense for *L. plumulosus*

Table 4-3: Bioaccumulation Bioassays Information and Conditions

Parameter	*Neries virens*	*Macoma nasuta*
Supplier	Aquatic Research organisms Inc., Hampton, NH or similar	Aquatic Research organisms Inc., Hampton, NH or similar
Test Procedures	OTM, ITM (EPA/USACE 1991, 1998)	OTM, ITM (EPA/USACE 1991, 1998)
Test type/duration	28-d	28-d
Control water	Laboratory reconstituted salt water (e.g., Instant Ocean®)	Laboratory reconstituted salt water (e.g., Instant Ocean®)
Test temperature	Recommended: 20 ± 1_{o}C	Recommended: 15 ± 1_{o}C
Test salinity	30‰	30‰
Test dissolved oxygen	Recommended: >4.5 mg/L	Recommended: >4.5 mg/L
Test photoperiod	16L:8D	16L:8D
Test chamber	10 gal aquarium	10 gal aquarium
Sediment volume	Target tissue mass dependent; 200 grams wet sediment per gram wet tissue	Target tissue mass dependent; 200 grams wet sediment per gram wet tissue
Overlying water volume	~20 L	~20 L
Replicates/sediment	5	5
Organisms/replicate	1 gram wet tissue per 200 grams wet sediment (target: 35 grams)	1 gram wet tissue per 200 grams wet sediment (target: 35 grams)
Feeding	none	none
Water renewal	70% renewal 3 times per week (i.e., M,W,F)	70% renewal 3 times per week (i.e., M,W,F)
Endpoint	Tissue residue Level	Tissue residue level
Acceptability Criteria	Adequate tissue mass for tissue residue analysis	Adequate tissue mass for tissue residue analysis

10.0 SUPPLEMENT INFORMATION: HOW TO REPORT AND USE NON-DETECT DATA WHEN EVALUATING MPSRA SECTION103 EVALUATIONS (OCTOBER 03, 2016)

How to Report and Use Non-Detect Data When Evaluating MPRSA Section 103 Evaluations

The purpose of this document is to clarify how non-detect data are reported and used in calculations, statistical analyses, comparisons to water quality standards and marine water quality criteria, and chemical summations when evaluating water, elutriate, sediment, and tissue data.

Background Information

Quality Assurance/Quality Control (QA/QC)

To support sediment management decisions, it is imperative that QA/QC procedures be implemented during field and laboratory activities. It is also important that the quality of the data be evaluated and reported.

Standard laboratory QA/QC procedures may include, depending on the particular method and analyte, matrix spikes/matrix spike duplicates, laboratory duplicates, method blanks, surrogate spikes, laboratory control samples, calibration protocols, and other procedures necessary to quantify the accuracy and precision of the analytical results. Laboratory QA/QC procedures are prescribed in the analyti al method specifications or laboratory standard operating procedures (SOPs).

Analytical Sensitivity

Analytical sensitivity is characterized by metho detection limits (MDLs) and laboratory reporting limits (LRLs) [also known as reporting limits, practical quantitation limits, and others] (ERDC/TN EEDP-04-36).

The Method Detection Limit (MDL) is a minimum concentration of a substance that can be measured and reported with 99 percent confidence that the analyte concentration is greater than zero (ERDC/TN EEDP-04-36). MDL studies are conducted using ideal, laboratory-prepared samples of a spiked clean matrix.

The Laboratory Reporting Limit (LRL) is established by the low standard of the initial calibration curve. At a minimum, the LRL should be three to five times the MDL.

For analysis of dioxins and PCB congeners using high-resolution gas chromatographic/mass spectrometric (GC/MS) methods, the sample-specific estimated detection limit (EDL) is analogous to the MDL and the MDL may be estimated based on the lower calibration limit, statistical analysis of historical method blank data, or other method specified by the laboratory.

To generate useable data, achieve data quality objectives, and support sediment management decisions, the LRLs should be less than the target detection limits (TDLs) listed in the RIA (Appendix C).

For undetected compounds, laboratories should report both the MDL and the LRL. If problems or questions arise regarding the ability to achieve sufficiently low MDLs and LRLs, the contractor should contact the USACE project manager who then would consult with Region 6. In all cases, sediments or extracts should be archived under proper storage conditions until the chemistry data are deemed acceptable by the regulatory agencies. This retains the option for re-analysis and lower-level quantitation, if necessary.

Detection Limit Terminology

Method Detection Limit (MDL) – Statistically-deri d minimum level that can be measured and reported with 99% confidence that it is greater than zero.

Laboratory Reporting Limit (LRL) – minimum level a lab will report with confidence in quantitative accuracy.

Target Detection Limit (TDL) – Performance goal for project set to be lower than prevailing regulatory limits (WQC, WQS, NOAA SQUIRT tables)

MDL < LRL ≤TDL

Proposed Policy for Treatment of Non-Detected Chemical Data

1. All Analysis (water, elutriate, sediment, tissues)
   a. If analyte concentrations are equal to or greater than the MDL but below the LRL, the result will be qualified with a "J" flag as having lower precision and greater uncertainty. "J" values represent potential concentrations of contaminants that are detected below the laboratory reporting limit (LRL) and are acceptable for use in sediment management decisions
   b. Whenever "J" values are reported, they should be used as real values in the calculation of mean concentrations and for all statistical analyses.
   c. If the LRL exceeds the Target Detection Limit (TDL), then the LRL should be used in calculations and for all statistical analyses.
   d. If analyte concentrations are below the MDL, they should be reported in the summary tables as <###.##, where ###.## is the LRL.

2. Water and elutriate data used in comparison to state water quality standards (WQS) and/or Federal (marine) water quality criteria (WQC)
   a. When the disposal site is in federal jurisdiction, marine WQC is used for comparison.
   b. If the site overlaps with both state and federal waters, the data should be compared to the lowest number from either the marine WQC or the state WQS.
   c. When comparing results to the marine WQC, the Criterion Maximum Concentration (CMC) and not the Criteria Continuous Concentration (CCC) should be used (EPA, 2006).

3. "Non-detects" in tissue data used in calculation of means and statistical comparisons
   a. When the TDL <u>**is not**</u> met
      i. If 1 to 4 of the treatment tissue replicates are reported as non-detect (U-flagged) substitute the LRL.
      ii. If all five treatment tissue replicates are reported non-detect (U- flagged) then carry the analyte forward to the risk assessment phase (RIA Section 10.2.3). There is no need to compare to reference tissue results because the conservative assumption is to use "zero" (see 3(a)iii) for the reference tissues in which case the treatment reps are all greater than the reference tissues.
      iii. For reference tissue replicates reported as non-detect (U-flagged) substitute "zero".
   b. If the TDL <u>is</u> met
      i. If 1 or 2 treatment tissue replicates are reported as non-detect; then substitute the LRL for U-flagged data
      ii. If 3 or 4 of the treatment tissue replicates are reported as non-detect; then substitute one-half the LRL for the U-flagged data
      iii. For reference tissue replicates reported as "non-detect" substitute one-half the LRL
   c. For all calculations,
      i. if the LRL exceeds the TDL, then the LRL should be used (no half substitutions allowed) except for the reference.

4. Tissue Chemistry Reporting for PCB Aroclors and PAHs
    a. PCB Aroclors should be reported as
        i. Individual Aroclors and
        ii. Total PCB Aroclors
            - Sum of the following Aroclors: Aroclor-1016, 1221, 1232, 1242, 1248, 1254, and 1260.
            - If present, Aroclor-1262 and Aroclor-1268 should be reported, but not included in the total PCB summation.
        iii. Statistical comparison of Treatment tissue means to reference tissue means will be made on the basis of mean Total PCBs and not individual PCBs.
        iv. It should be noted that total PCBs calculated by summing PCB Aroclor mixtures is not comparable to total PCBs calculated by summing individual PCB congeners due to fundamental differences in the methods of analysis and quantitation.
    b. PAHs should be reported as
        i. Individual PAHs
        ii. Total low molecular weight (LMW) PAH
            - Include naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, and anthracene. 2-methylnaphthalene and methylnaphthalene are not routinely analyzed.
        iii. Total high molecular weight (HMW) PAH
            Include the following compounds: fluoranthene, pyrene, benzo(a)anthracene, chrysene, benzo(b+k)fluoranthenes, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, dibenzo(a,h)anthracene, and benzo(g,h,i)perylene.
        iv. Total PAHs = sum of all LPAH and HPAH compounds
        v. Statistical comparison of Treatment tissue means to reference tissue means will be made   the basis of mean Total PAH and not individual PAHs.

5. Dioxin/Furans (water, elutriate, sediment and tissue) should be reported as individual dioxin/furan congeners (carbon un-normalized)
    a. Total Toxic Equivalency Quotients (TEQs)
        i. Each cogener result is multiplied by the appropriate Mammalian Toxicity Equivalency Factor (TEF) found in the *2005 world health Organization Reevaluation of Human and Mammalian Toxic Equivalency Factors for Dioxins and Dioxin-Like Compounds* (Van de B erg et al., 2006)
        ii. Total TEQ = sum TEFs
        iii. Statistical comparison of Treatment tissue means to reference tissue means will be made on the basis of mean Total TEQ and not individual dioxin/furan congeners.
    b. Rules for Chemical Summation for TEFs are as follows:
        i. Group summation is performed using all detected concentrations.
        ii. Undetected results are included in the summations at half the value of the LRL
        iii. The estimated values between the MDL and the LRL (i.e., J-flagged

values) are included in the summation at face value.

iv. If the LRL exceeds the TDL, then the LRL should be used

v. If all constituents in a chemical group are undetected, the group sum is reported as undetected, and the highest MDL and LRL of all the constituents are reported as the MDL and LRL for the group sum.

OBJECTIVE

The objective of this work is to use a technically justifiable, Lines-of-Evidence (LOE) to reduce the COC list for the CCSC New Work Predredging Evaluation study that covers the area from the open waters of the Gulf of Mexico (Station -30+00) through to the Ferry Landing (Station +70+00).

APPROACH

The starting COC list is from the Regional Implementation Agreement (RIA) between the US-ACE Galveston District (SWG) and US EPA Region 6 (R6). Media were worked through sequentially, from sediment, to tissue to surface water. The reduction of the COC list from the more comprehensive list in the USEPA/USACE Regional Implementation Agreement (RIA) is project specific and site specific to this portion of the CCSC associated with new work (widening and deepening).

SEDIMENT

For sediment (SD), the overall operating premise for the section of the CCSC being evaluated in this particular effort is that this portion of the ship channel is dredged regularly as part of the SWG's Operations maintenance program and is not heavily industrialized. The maintenance material from these dredging events are tested and have always been approved for ocean placement at the Maintenance ODMDS.

The starting list of COCs for SD can be found in Table 1 with strikethrough to show which analytes have been removed. The following rationale were applied as LOE to remove COCs:

i) Metals:

   a. Common elements were removed from further evaluation (i.e., aluminum and iron)

   b. Metals without SD criteria, metals not detected in maintenance dredging and metals associated specifically with industry were removed from further evaluation (i.e., barium, Cr+3, Cr+6, cobalt, manganese, organotin, thallium, tin

ii) Conventional/Ancillary Parameters:

   a. Constituents for which there are no criteria with which to evaluate or are not used in the evaluation were removed (i.e., cyanides, total recoverable petroleum hydrocarbons, total phenols, acid volatile sulfides, total sulfides, total volatile solids, specific gravity, total moisture content and oil/grease)

iii) LPAH/HPAH:

   a. Uncommon LPAHs/HPAHs or those without criteria were removed from the list (1- methylnaphthalene, 1-methylphenanthrene, 2,6-dimethylnapthalene, methyl naphthalene, 2- methylnapthalene, benzo(e)pyrene, perylene)

iv) Organonitrogen Compounds were removed

v) Phthalate Esters: this category was removed based upon lack of related industry in this reach of the CCSC, widespread presence in the environment and the ease with which they can be introduced during sampling and analysis

vi) Phenols/Substituted Phenols: with the exception of pentachlorophenol, this category was removed based upon lack of related industry in this reach of the CCSC

vii) Dioxins/Dibenzofurans: this category was removed based upon lack of related industry in this reach of the CCSC

viii) PCBs: Since the testing involves whole sediment testing, all but total PBCs will be removed from the analysis list. Based upon Sloan (1993, 2005) and EPA Method 8082, Total PCBs is calculated from individual congeners. Table 9-3 in the Inland Testing Manual, defines total PCBs as the sum of 18 congeners. These 18 congeners are: PCB-8, -18, -28, -44, -52, -66, -77, -101, 105, -118, -126, -128, - 138, -153, -169, -170, -180, -187

ix) Pesticides: constituents not detected or detected infrequently in maintenance material, without criteria or not tested for in the other regions were removed (i.e., 2,4-DDE, 2,4-DDT, 2,4-DDD, a- chlordane, alpha/beta/delta/gamma BHC, chlorbenside, dacthal, heptachlor epoxide, hexachlorobenzene, malathion, parathion, total chlorinated pesticides, trans nonachlor)

x) Chlorinated Hydrocarbons: Associated specifically with industry, these were removed.

xi) Volatile Organic Compounds: Associated specifically with industry, these were removed

xii) Halogenated Ethers: Associated specifically with industry, these were removed

xiii) Miscellaneous: Associated specifically with industry, these were removed

xiv) Butyltins: Associated specifically with industry, these were removed The COC list resulting from this evaluation is presented in Table 2.

TISSUE

The COC list for tissue will parallel the COC list for sediment, with the exception of the conventional/ancillary parameters, which will be medium specific parameter and include percent lipids (Table 3).

SURFACE WATER

For surface water (SW), the overall operating premise for the section of the CCSC being evaluated in this particular effort is also that this portion of the ship channel is dredged regularly as part of the SWG's Operations maintenance program and is not industrialized. The surface water from these dredging events has also been tested and has never shown impacts that prohibited ocean placement at the Maintenance ODMDS.

The starting list of COCs for SW can be found in Table 4 with strikethrough to show which analytes have been removed. The following rationale were applied as LOE to remove COCs:

i. Metals:

a. Common elements were removed from further evaluation (i.e., aluminum)

b. Metals not detected in maintenance dredging and metals associated specifically with industry were removed from further evaluation (i.e., Cr+6, organotin, tin)

ii. Conventional/Ancillary Parameters: parameters that are not used in the evaluation for placement

c. Constituents for which there are no criteria with which to evaluate or are not used in the evaluation were removed (i.e., cyanides, total petroleum hydrocarbons, total recoverable petroleum hydrocarbons, total phenols, total sulfides, total settleable solids)

iii. Organonitrogen Compounds: Associated specifically with industry, these were removed

iv. Phthalate Esters: this category was removed based upon lack of related industry in this reach of the CCSC, widespread presence in the environment and the ease with which they can be introduced during sampling and analysis

v. Phenols/Substituted Phenols: with the exception of pentachlorophenol, this category was removed based upon lack of related industry in this reach of the CCSC

vi. Dioxins/Dibenzofurans: this category was removed based upon lack of related industry in this reach of the CCSC

vii. PCBs: All but total PBCs will be removed from the analysis list. Since the testing involves whole sediment testing, all but total PBCs will be removed from the analysis list. Based upon Sloan (1993, 2005) and EPA Method 8082, Total PCBs is calculated from individual congeners. Table 9- 3 in the Inland Testing Manual, defines total PCBs as the sum of 18 congeners. These 18 congeners are: PCB-8, -18, -28, -44, -52, -66, -77, -101, 105, -118, -126, -128, -138, -153, -169, - 170, -180, -187

viii. Chlorinated Hydrocarbons: Associated specifically with industry, these were removed.

ix. Volatile Organic Compounds: Associated specifically with industry, these were removed

x. Halogenated Ethers: Associated specifically with industry, these were removed

xi. Miscellaneous: Associated specifically with industry, these were removed The COC list resulting from this evaluation is presented in Table 5.

Table 5 shows additional analytes that have been removed based on a lack of Texas Surface Water Quality Standards (TSWQS) or federal water quality criteria. This removed the following from the COC list:

i. Metals: antimony, barium, beryllium, Cr+3, chromium (total), cobalt, iron, manganese, thallium

ii. LPAH/HPAH compounds

iii. PCBs: Total PCBs

iv. Pesticides: 4,4'-DDD, 4,4'-DDE

The COC list resulting from both of these evaluations is presented in Table 6.

Summary:

Table 7 presents the final COC list with TDLs and screening benchmarks (i.e., NOAA ERL, Region 6, NOAA ERM) for sediment.

Table 8 presents the final COC list with TDLs and screening benchmarks (i.e., TSWQS, EPA WQC) for surface water.

REFERENCES:

Sloan, R.J. 1993. Update on 1992 Hudson River Fish PCB Results. Internal memorandum and short textual report with tables and figures summarizing PCB results in fish from 1977 through 1992. Bureau of Environmental Protection, Division of Fish and Wildlife, New York State Department of Environmental Conservation, Albany, New York. July 13, 1993. 37 p.

R.J. Sloan, M.W. Kane, L.C. Skinner Of Time, PCBs and the Fish of the Hudson River, NY State Department of Environmental Conservation, Albany, NY (2005) Available at: http://www.dec.ny.gov/docs/wildlife_pdf/hrpcbtrend.pdf 287 pp

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https://www.epa.gov/hw-sw846

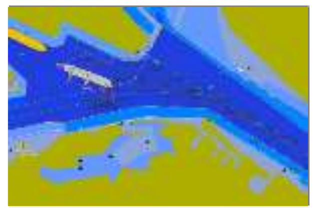
https://www.epa.gov/hw-sw846/sw-846-test-method-8082a-polychlorinated-biphenyls-pcbs-gas-chromatography

Appendix K

Ship Simulation Report

Note: The Section 508 amendment of the Rehabilitation Act of 1973 requires that the information in Federal documents be accessible to individuals with disabilities. The USACE has made every effort to ensure that the information in this appendix is accessible. However, this appendix is not fully compliant with Section 508, and readers with disabilities are encouraged to contact Mr. Jayson Hudson at the USACE at (409) 766-3108 or at SWG201900067@usace.army.mil if they would like access to the information.

Environmental Impact Statement – Feasibility Study



Contents

Introduction

Study Name	Environmental Impact Statement – Feasibility Study
Project Location	Corpus Christi Ship Channel – Harbor Island, TX
Purpose	To assist Riben Marine and Freese and Nichols with simulation studies for completion of an Environmental Impact Statement (EIS).
Customer	Riben Marine, Inc. and Freese and Nichols
Vendor	Seamen's Church Institute of NY and NJ 50 Broadway Floor 26 New York, NY 10004
CME Contact	Center for Maritime Education 9650 High Level Road Houston, TX 77029 Stephen Polk T: (713) 674-1236 F: (713) 674-1239 spolk@seamenschurch.org
Release Date	March 1, 2022
Project Lead(s)	Capt. Stephen Polk, Director, Center for Maritime Education
Authorized Signature	Capt. Jay Rivera, Riben Marine

Legal Disclaimer

With respect to the Seamen's Church Institute (SCI) simulator, databases, and models used for this study, the inspection, review, accuracy, and acceptance is validated by the customer and the participants prior to the study. SCI cannot accept liability for the findings, conclusions, or recommendations provided by the participants in this simulation study, nor can SCI be responsible for errors within data provided by the clients, or third parties used for programming of the simulator, hydrodynamic models, and databases. Key to any successful simulation is the accuracy of the data programmed into the simulator. SCI creates its simulations based upon information provided and approved by the client. The quality of this data has an impact on the accuracy of these test results.

The 6DOF hydrodynamic-vessel VLCC models used in these simulations are based upon data supplied by the ship builder to Kongsberg Maritime, and validated to 'Pilot Grade' standards, the highest quality available. These models have been vetted by experienced pilots, mooring masters, subject matter experts, SCI staff members, and additional customers. These models provide an idealized approximation of the classes and types of vessels which would be used in real world conditions. Specific vessels in the real world could handle differently from the simulator vessels utilized based on varying specifications and equipment on board. While a set of worst-case environmental factors were tested based on supplied data, the model behaviors can vary based on the dynamics introduced by real world changes in current and wind forces.

While SCI's simulator system provides a close approximation of vessel squat in shallow water, additional safety margin needs to be used to consider channel depths, tidal action, vessel speed and other continuously changing environmental factors. Water currents were modelled by engineering firm, Baird for the Harbor Island area simulated. Current models were constructed using 3D bathymetric meshes to represent future with permit (FWP) profiles for the channel.

The ship models used for the study and model information can be found within Appendix F. The VLCC models selected for this study was VLCC18, an existing pilot grade model in which the draft of the hull was tuned to meet the project specifications for the following configurations:VLCC18Q – 52' even keel, VLCC18R – 68' even keel, and VLCC18L – fully loaded 73' 9" draft.

The tug used for the study was Tug60 which was recently validated by Kotug, Riben Marine, and SCI staff. The tug was designed by Robert Allan, Ltd. for Riben Marine, and built by the STAR Center in Dania Beach, FL modeled hydrodynamically by their hydrodynamicist on staff using the Kongsberg modelling tool (HDMT) licensed and supplied by Kongsberg Digital.

Due to the tug requirements and available ownship bridges we also used one simulated tug for the study. The simulated tug features of the simulator provide a realistic simulation of an assist tug but is not as accurate as a captain in a tug bridge on the full-mission simulator. A simulated tug controlled by the simulator operators were used to control the robot tug during the study.

The results assume that experienced pilots will be manning the seaworthy vessels during real world maneuvers, and all vessels will meet the minimum safety standards and practices.

Operational limits should consider the actual tug and ship capabilities, and the need for all local pilots and mariners to have experience. Limitations can be gradually reduced as pilots and tug masters gain experience.

Process

In February 2021, Riben Marine contracted the Seamen's Church Institute (SCI) for the performance of a port study and environmental impact statement to assist with feasibility for updated channel configurations and dredge profiles, current flow models, and validate tug requirements for safe transit, and determining operational environmental limits for fully loaded VLCCs.

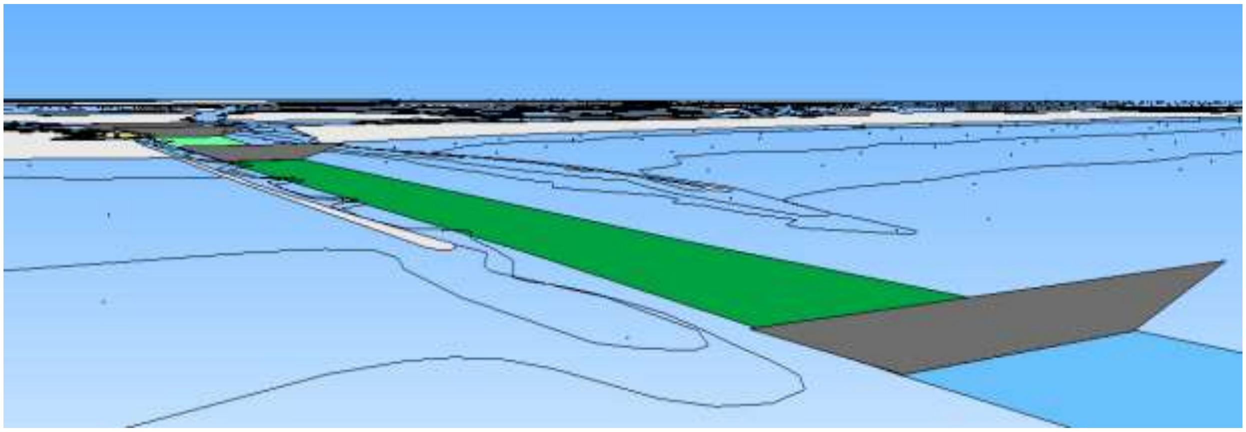
Database Development

Accuracy of existing database area

This visual database of the Corpus Christi/Harbor Island area was produced and maintained by SCI in Houston. Matt Hyner serves as SCI's Visual Database and Development Manager at the Center for Maritime Education. Matt developed the Corpus Christi database in a Flat Earth projection and WGS84 datum based upon a 2019 NOAA ENC Chart, and SRTM Elevation data. Upon commencement of this project, SCI was sent CAD files curated by Freese and Nichols for the dredge profile of the Corpus Christi Ship Channel, including Harbor Island Crude Terminal (HICT) as well as the Axis Terminal.

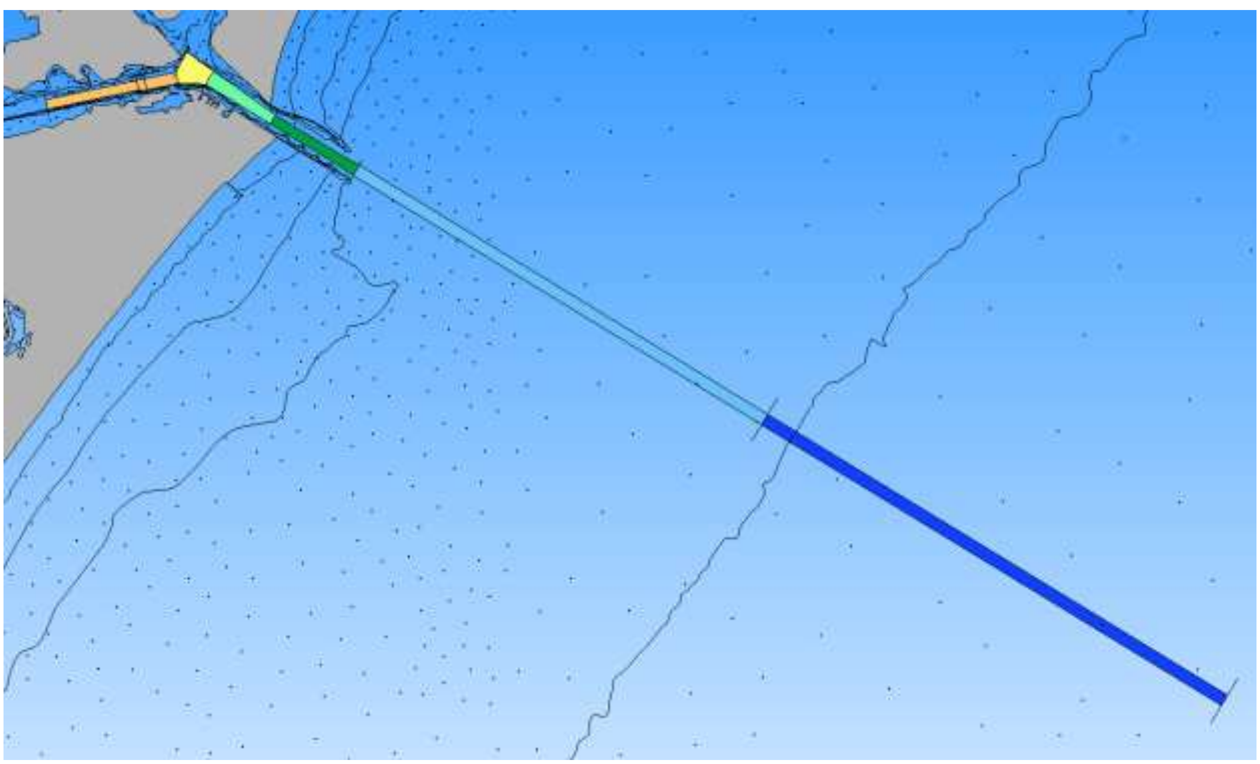
Area of the project

The source data for the database files were converted into WGS84/Flat Earth Projection to properly align them with Presagis and Kongsberg's database building tools. Upon inspection of the final CAD files, no issues were found with the alignment to SCI's existing visual database.



Depth Generation

This study involved the creation of a new depth file based upon the dredge profiles provided for this project in the source data, Appendix D, "PCCA_X-Sections_8.5x11 Final Channel Alignment for 75ft Ship.pdf". Measuring the base of the dredge slope, the widths were confirmed to match the CAD dimensions.



Dredge Profile Layout

New contours were traced along the 3D cutaway and integrated with NOAA's iENC chart data for the area. Additional contour modifications were next made to integrate the Harbor Island Crude Terminal (HICT) and Axis Terminal. The final dredge contours along with the charted depth contours were triangulated into a new mesh depth file using Kongsberg's area generation tools to create the final depth file for the area. These contours were then brought over to the Instructor Map to represent the new profile visually for the simulator operators during simulation runs. The visual 3D model of the area is based upon an existing SCI Training database as populated with trees and cultural features based on photographic reference material from a 2015 site survey when they database was initially created. Additions to the database for terminals at AXIS, HICT, South Texas Gateway and MODA were incorporated and based upon earlier updates to the original area.

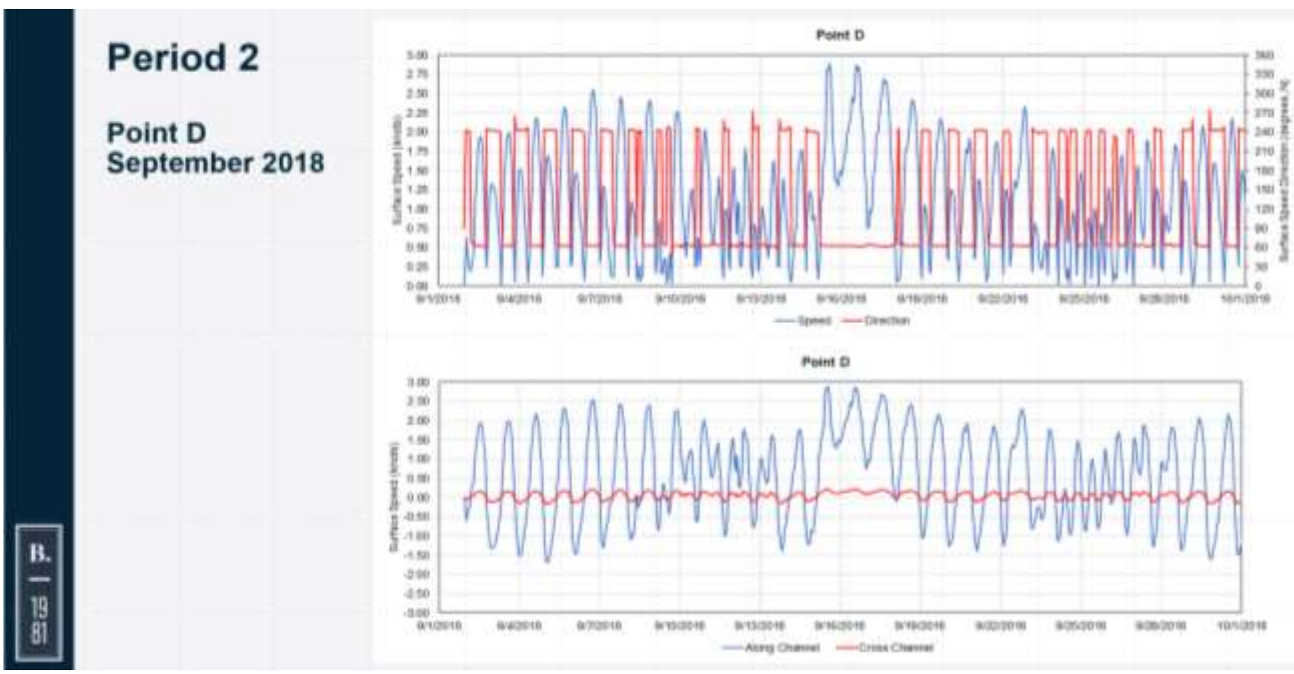
Hydrographic Model

A MIKE3 Flexible Mesh Hydrodynamic Model (HD Model) was developed to simulate the hydrodynamic conditions in the Corpus Christi area by Baird for the Corpus Christi Ship Channel, the approaches, and Harbor Island area. The current model provides currents at each cell node within the domain and vertically at approximately 2m intervals. The currents within and adjacent to the channel were extracted for direct input to the ship simulation model. Additionally, Baird provided snapshots of modeled currents along the water column depth every two meters at five various data points A – F (shown below).

Current meter data points A through F

Data from the model was exported from MIKE into an ETD file, with velocity and heading updated every 15 minutes. Current models were constructed using 3D bathymetric meshes to represent a future with project – FWP dredge profile for a 75' MLLW maintained depth. The Baird current model was based on maintained channel depth, not including advanced maintenance or allowable over dredge. The current data provided by Baird was kept in the original .ETD format and loaded for each corresponding run matrix parameters. Below illustrates the information for the current models provided.

Flow model showing data points and water strata (in red) 3D layered current



Corresponding data of the information from the flow model Sept 2018

Riben Marine and SCI staff reviewed three months of hydro analysis provided by Baird and found the best snapshots of six possible current profiles, Ebb – low, medium, and high, and

Flood – low, medium, and high; for the FWP profile. The information below are the snap shots chosen to simulate and validate the current flow models.

Offshore Currents			Inland Currents		
Flow	**File & Time Stamp**	**Velocity**	**Flow**	**File & Time Stamp**	**Velocity**
North high	P03 - 9/22/2020 @ 1000	0.9 knots	Ebb high	P03 - 09/22/2020 @ 1000	2.5 - 3.0 knots
North medium	P06 - 11/25/2018 @ 0400	0.5 knots	Ebb medium	P02 - 09/15/2018 @ 1300	2.0 - 2.4 knots
North low	P01 - 07/25/2020 @ 0800	N/A	Ebb low	P09 - 09/06/2018 @ 1600	1.3 - 1.6 knots
South high	P01 - 07/25/2020 @ 0300	1.5 knots	Flood high	P01 - 07/25/2020 @ 1500	2.5 - 3.1 knots
South medium	P10 - 09/13/2018 @ 1900	0.9 knots	Flood medium	P01 - 07/25/2020 @ 0800	2.0 - 2.4 knots
South low	P10 - 09/13/2018 @ 2100	0.6 knots	Flood low	P08 - 09/06/2018 @ 0400	0.9 - 1.3 knots

Development of Simulator Exercise Matrix and Study Objectives

A matrix of the exercises to be run, was carefully crafted, reviewed and refined to include those exercise conditions that would best cover the simulation study objectives, which include:

1. Validate channel configuration, approaches to any future terminal developments at Harbor Island;
2. Validate current models and their effects on vessels in the proposed channel. The current models will be created and provided by Baird. The model current's effect on the vessels transiting the channel will then be validated to ensure its realism and accuracy;
3. Develop and validate number and size of tugboats/assist vessels necessary for transit and stand by;
4. Determine operational environmental limitations (wind speed, current flow, current direction, visibility) for vessels approaching and departing facility, if any; and
5. Identify necessary vessel traffic control and vessel monitoring procedures to protect any future terminal developments on Harbor Island, monitor passing vessel traffic, and vessels engaged in cargo transfer operations at the facility.

The variables considered in the development of the run matrix included:

Vessel Types – Three versions of VLCC18 were used. The model VLCC18 was modelled after the "Elizabeth I. Angelicoussi" developed using source documents provided by Daewoo Shipbuilding & Marine Engineering Company, LTD, Project *Kristen 306,000 TDW Cruse Oil Tanker*, Project no. 5194. VLCC18Q was used to simulate the model in a 52' draft even-keel partially-loaded condition, VLCC18R was used to simulate the model in a 68' draft even-keel condition, and VLCC18L was used to simulate a 73' 9" draft fully-loaded condition.

Pilot cards for the vessels used in the study are in Appendix F. The "pilot grade" models were used for the simulations – which are described as having *high-hydrodynamic quality* and additionally have been validated by numerous pilot associations, mooring masters, ship owners, and research firms.

Ship models	Vessel Class & Type	DWT (m3)	Deepest Draft	Year Built	LOA	Beam	Engine & Propeller Type	Max Power (hp)	Rudder Type & Max Angle
VLCC18Q "Elizabeth I. Angelicoussi" (52' even keel draft)	VLCC Tanker	237,859	15.8m	2004	332m	58m	Diesel, FPP	40,015	Semi, 35°
VLCC18R "Elizabeth I. Angelicoussi" (68' even keel draft)	VLCC Tanker	306,229	20.73m	2004	332m	58m	Diesel, FPP	40,015	Semi, 35°
VLCC18L "Elizabeth I. Angelicoussi" (Loaded)	VLCC Tanker	340,488	22.49m	2004	332m	58m	Diesel, FPP	40,015	Semi, 35°
TUG60 "ART120-35W" Rotor Tug	Harbor Assist Tug Boat	1,172	6.08	2021	36.25m	14.55m	Diesel, CPP	10,441	Azipod, 180°

Models used for the study

Tug size, horsepower, placement, and numbers used – Custom designed tugs by Robert Allan, LTD were used (Tug 60) based on customer requests. The decision to utilize 120 MT bollard pull rotor tug was based on project needs and pilot requests, and the decisions to utilize five tugs during the simulations was strictly based on pilot recommendations, procedures, precautionary measures, and local ordinary practice for the ACC Pilots. The target (tug 60) *simulator-tug* used with an understood max rating of 120-metric ton bollard pull instructor-controlled tug. With SCI's simulator configuration of 5-full mission bridges, one simulator as the ship bridge, and the other four bridges as ship-assist tug bridges, so that the simulations could maintain a minimum of five harbor tugs which were needed to perform this study. Additionally, hydraulic winch controls installed in the tug bridges provided tug captains the ability to easily heave in or payout hawsers as needed or required for ship assist work.

Tug 60

Outbound ship maneuvering with ship assist tugs

Wind Condition – Wind was a variable used within the matrix, North wind of 25 knots was used and SSE winds of 25 knots was loaded to either enhance the flood or ebb tidal current. The idea was to simulate the most challenging circumstances to help identify operational limits, safety margins, and what control measures may be needed to minimize risks.

Current condition – Current models used were provided by Baird for the simulations and loaded according to run matrix parameters.

Waves and swell condition – The Kongsberg system uses wind speed to model wave height according to the Beaufort scale. Using the UKC report provided by Baird, in appendix E, SCI programed two wave files in the simulator. The SSE wave file simulated 2m swell at 7.3s between the end of the jetties and the pilot boarding area. With a 1m wave at the end of the jetties, and minimal wave once inside the jetties. The N wave file simulated a 2m swell at 7.3s between the end of the jetties and the pilot boarding area, and a 1m wave at the end of the jetties. This information closely approximates the data provided by Baird for the same areas.

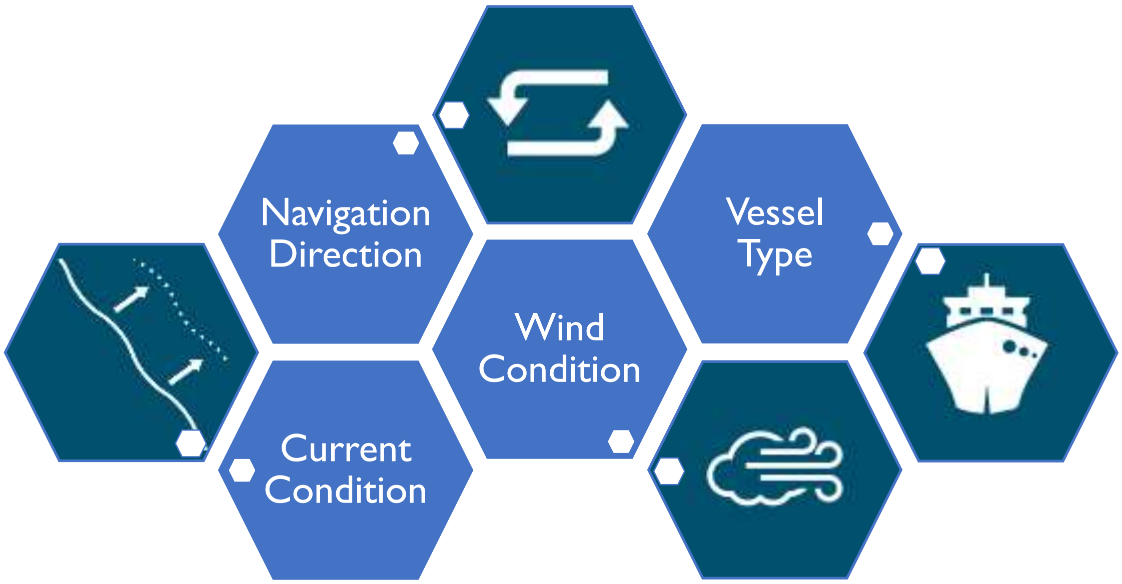
Navigation Direction – Vessels were run inbound and outbound, simulating typical arrivals and departures, for HICT, including VLCCs at various drafts.

Dredge profile configurations and channel dimensions – The depth and fairway files SCI used were built for future with permit (FWP) and that corresponding dredge profile.

We then loaded the VLCC models with the proper drafts according to the dredge profile needed and run parameters.

Simulation Run Matrix

To document the precise conditions encountered during each simulation exercise the team designed a matrix of run parameters (see Appendix C for all matrixes developed). This matrix outlines the various conditions tested, vessel types, sizes, wind, and tidal flows. The run matrix was designed to capture and test each variable to best capture and understand the various navigational safety requirements.



The plan is always to conduct each simulation run once, with the possibility of some runs being performed multiple times either due to complexity, challenge, or simply providing multiple pilots an opportunity to conduct it for themselves.

Simulation Preparation, External Testing, and Validation

Each simulator exercise was configured in accordance with the run matrix parameters agreed upon during preliminary phases. SCI expected each departure simulation to last approximately 12 to 15 minutes, with the approach simulations running about 20 to 40 minutes. Immediately following the simulation, participants would be given standard questions (run survey) which we updated in preparation for the actual study.

During the external testing and validation which occurred on January 10-14, 2022 with participation from Riben Marine, and various tug captains with operational knowledge of the harbor, the validation stage tested the conditions for in bound VLCCs with a 52' draft inbound and loaded VLCCs with a 68' draft outbound using the FWP current channel dredge profile and Baird's current files using tug60.

Run Matrix – planned

The run matrix planned (shown below) illustrates the final plan for the week. We eliminated the Axis runs and most "head-in" scenarios, due to the emphasis on running simulations which are most likely to occur.

			Depth	Draft			Inshore Current				Offshore Wind Current					Tug	
run #	location	destination	81'	52'	68'	74'	25 N Ebb Med	25 N Ebb High	25 SE Flood Med	25 SE Flood High	N Med	N High	S Low	S Med	S High	120	comments
1	Sea	Jetties	x	x							x					x	familiarization
2	Sea	Jetties	x	x								x				x	familiarization
3	Sea	Jetties	x	x										x		x	familiarization
4	Sea	Jetties	x	x											x	x	familiarization
5	Jetties	HI W	x	x			x									x	max tug power
6	Jetties	HI W	x	x				x								x	low score
7	Jetties	HI W	x	x					x							x	max tug power
8	Jetties	HI W	x	x						x						x	max tug power
9	Jetties	HI E	x	x			x									x	max tug power
10	Jetties	HI E	x	x				x								x	low score
11	Jetties	HI E	x	x					x							x	max tug power
12	Jetties	HI E	x	x						x						x	max tug power
13	Ferries	Jetties	x	x			x									x	passing vessel speed
14	Ferries	Jetties	x	x				x								x	passing vessel speed
15	Ferries	Jetties	x	x					x							x	passing vessel speed
16	Ferries	Jetties	x	x						x						x	passing vessel speed
17	Ferries	Jetties	x		x		x									x	passing vessel speed
18	Ferries	Jetties	x		x			x								x	passing vessel speed
19	Ferries	Jetties	x		x				x							x	passing vessel speed
20	Ferries	Jetties	x		x					x						x	passing vessel speed
21	HI W	Jetties	x		x		x									x	max tug power
22	HI W	Jetties	x		x			x								x	low score
23	HI W	Jetties	x		x				x							x	max tug power
24	HI W	Jetties	x		x					x						x	failure
25	HI E	Jetties	x		x		x									x	low score
26	HI E	Jetties	x		x			x								x	low score
27	HI E	Jetties	x		x				x							x	max tug power
28	HI E	Jetties	x		x					x						x	max tug power
29	Jetties	Sea	x		x						x					x	not run
30	Jetties	Sea	x		x							x				x	not run
31	Jetties	Sea	x		x									x		x	max tug power
32	Ingleside	HI W	x	x			x									x	max tug power
33	Ingleside	HI W	x	x				x								x	max tug power
34	Ingleside	HI W	x	x					x							x	max tug power
35	Ingleside	HI W	x	x						x						x	max tug power
36	Ingleside	HI E	x	x			x									x	max tug power
37	Ingleside	HI E	x	x				x								x	max tug power
38	Ingleside	HI E	x	x					x							x	max tug power
39	Ingleside	HI E	x	x						x						x	max tug power
40	HI W	Jetties	x			x	x									x	failure
41	HI W	Jetties	x			x				x						x	failure
42	HI E	Jetties	x			x		x								x	not run
43	HI E	Jetties	x			x			x							x	not run

PCCA TUG STUDY run survey - Pilots

1. Pilot Name: ______________________________

2. The CHANNEL CONFIGURATION (slope, width, depth profile, and layout) was sufficient and adequate. *1 being the channel is inadequate and 5 being the channel is adequate.*
   ◯1 ◯2 ◯3 ◯4 ◯5

3. If the channel configuration was inadequate in any way, please explain why.

4. Did the ENVIRONMENTAL FORCES (current, wind, wave) exceed the operational limitations of your vessel?
   ◯Yes ◯No

5. If any of the environmental forces (wind, wave, current) exceeded operational limitations, please explain what could be changed to safely execute the maneuver.

6. The TUG CONFIGURATION (number of tugs, tug bollard-pull rating, and tug type) was sufficient and adequate. *Please rate based on number of tugs used, bollard pull rating, and tug type used vs. what is needed to do the job safely – 1 being the Tug Configuration is inadequate and 5 being the Tug Configuration is adequate.*
   ◯1 ◯2 ◯3 ◯4 ◯5

7. If the tug configuration was not adequate, please explain why.

8. The overall safety, stress and difficulty level of this run was: *Please rate the based on – 1 being extremely unsafe, stressful, and very difficult and 5 being safest, low stress, and not challenging, and.*
   ◯1 ◯2 ◯3 ◯4 ◯5

9. If not safe, please explain why.

10. Run was ______________________________ based on run parameters
    ◯Successful ◯Unsuccessful

11. If the run was not successful, please explain why.

PCCA TUG STUDY run survey – Tug Captains

ART 120-35W Validation – Tug Survey

1. Tug Captain Designator: ______________________

2. Tug Type: ◯ Robot Tug ◯ Rotor 90 MT ◯ Rotor 120 MT ◯ Rastar 80 MT

3. Tug Test – ***[drop drown]***

   Free running speed fwd
   Free running speed aft
   Free running speed athrwartship
   Bollard pull ahead
   Bollard pull astern
   Escort performance C/L aft
   Acceleration assist C/L fwd
   Acceleration assist/Escort performance off fwd winch P/S shoulder

4. Tug Location – Beginning: ***[drop down]***

   Center lead aft
   Port B1
   Port B2
   Port B3
   Port midship
   Port quarter
   Port transom
   Center lead front
   Starboard B1
   Starboard B2
   Starboard B3
   Starboard midship
   Starboard quarter
   Starboard transom

5. Tug Location – End: ***[drop down]***

   Center lead aft
   Port B1
   Port B2
   Port B3
   Port midship
   Port quarter
   Port transom
   Center lead front
   Starboard B1
   Starboard B2
   Starboard B3
   Starboard midship

Starboard quarter
Starboard transom

6. The tug perfomed/reacted as expected (COMPARISON TO DATA SET) to include (maneuverability, Z drive speed, thrust, vessel motions). *Please rate this statement based on – 1 being not as described and 5 equal to description and provided data).*
◯1 ◯2 ◯3 ◯4 ◯5

7. If the tug performance/beahvior were not as expected, please explain why.

8. Did the ENVIRONMENTAL FORCES (current, wind, waves) cause operational limits to be exceeded?
◯Yes ◯No

9. If any of the environmental forces caused vessel operational limits to be exceeded, please explain why, and if the forces prevented you from performing any specific maneuver, what occurred.

10. The tug configuration and performance were adequate. *Please rate based on - 1 being unsatisfied with the tug configuration and 5 being satisfied with the tug configuration.*
◯1 ◯2 ◯3 ◯4 ◯5

11. If the tug configuration and performance was not adequate, please explain why.

12. The overall safety, stress and difficulty level of this run was: *Please rate the based on –1 being extremely unsafe, stressful, and very difficult and 5 being safest, low stress, and not challenging.*
◯1 ◯2 ◯3 ◯4 ◯5

13. If not safe, please explain why.

14. Were any of the maneuvers or commands given by the pilots difficult relative to the time provided or the environmental conditions simulated? Did you have any trouble getting into position, or staying in shape due to the current, ship's speed, or environmental conditions?
◯Yes ◯No

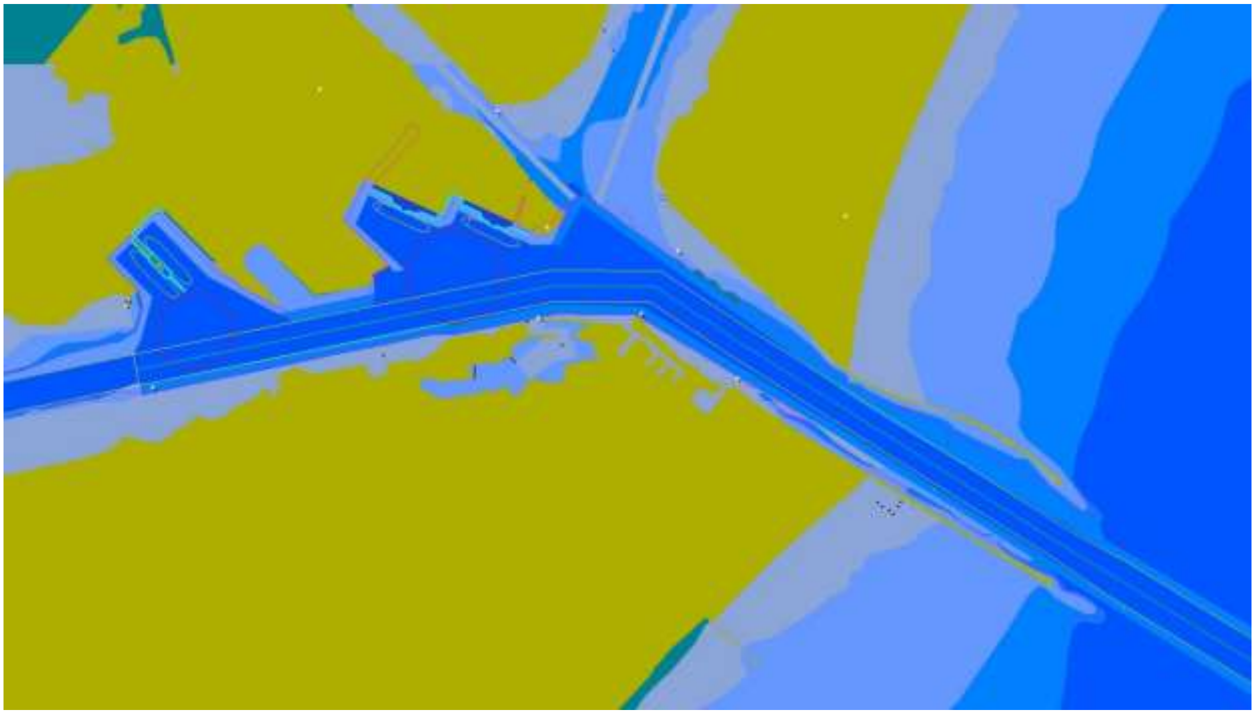
15. If Yes, please explain why.

16. Did you feel that you were asked to operate at max power for an extended period of time?
◯Yes ◯No

17. Run was ______________________________ based on run parameters
◯Successful ◯Unsuccessful

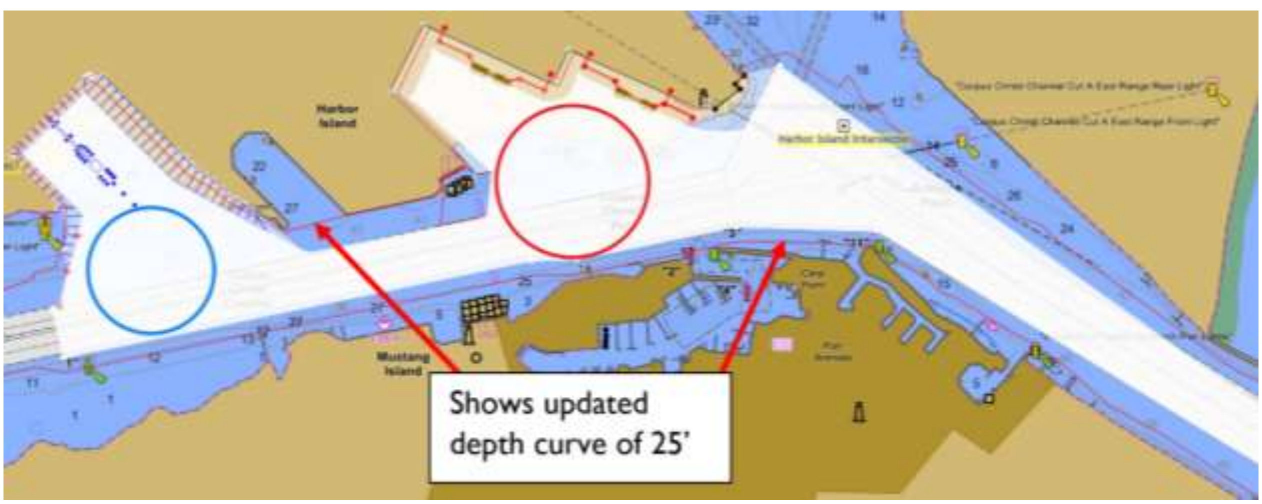
18. If the run was not successful, please explain why.

Pictured below is the base area we used for external testing and validation.



Instructor Station Area Map

The modified navigation chart below shows the updated dock facility and channel limits which was provided in each pilothouse to reflect changes not yet visible on a navigational chart. SCI staff generated a GPX file to be displayed onto Rosepoint ECS so that operators could tell when they were getting close to the edge of the channel to avoid running aground.



Base ECS chart view – with dock and database changes showing channel limits

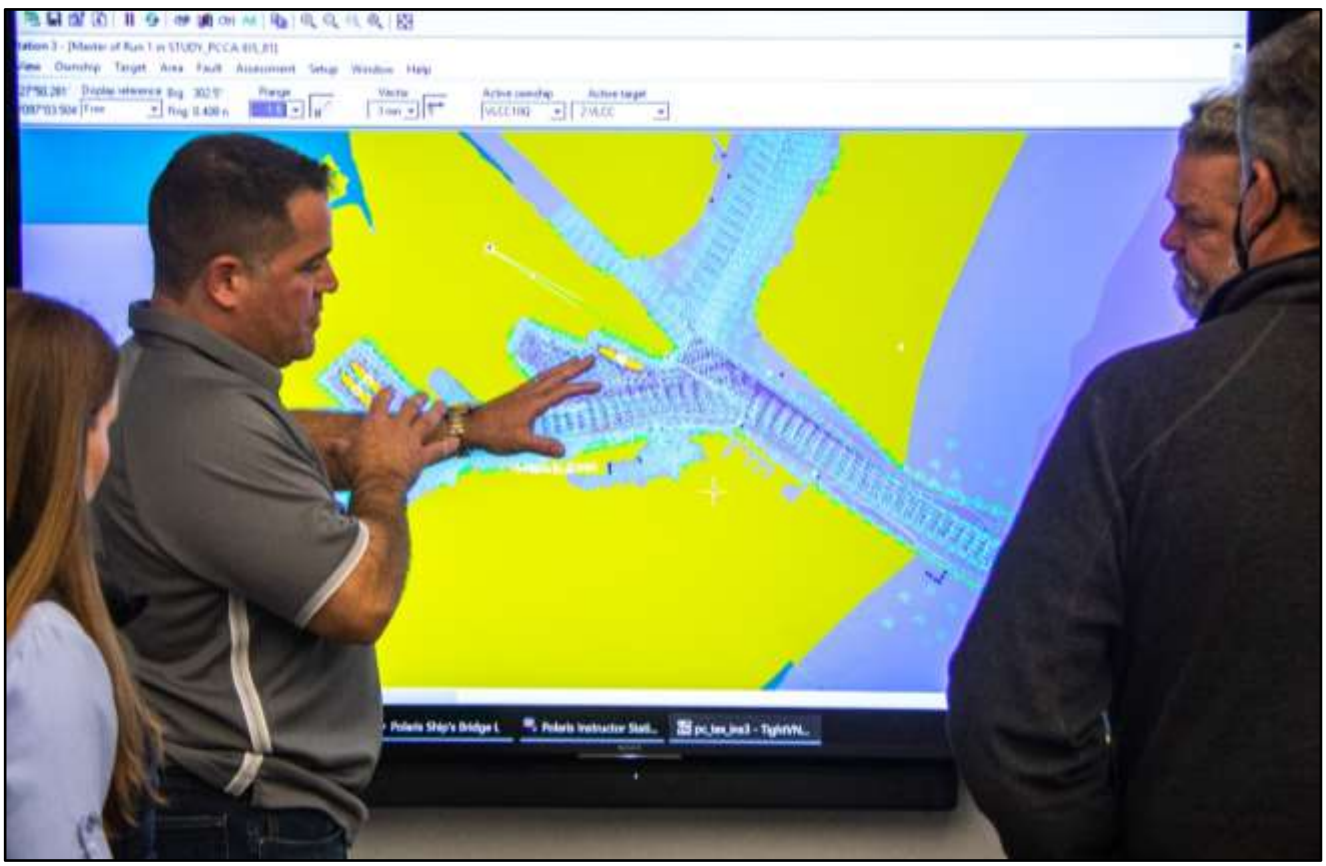
Adding this was helpful for the participants to do a comparison between the navigation chart and the database used at SCI showing the improved channel. The depth file (.DCS) used was provided by data supplied by Freese and Nichols.

Simulation process & sequence of events

Participants

For the simulation phase the project team assembled in Houston, Texas at SCI's facility on January 31 – February 3, 2022. Over the course of the 4-day session the following entities were represented:

- Capt. Mike Kershaw
- Riben Marine
- Aransas-Corpus Christi Pilots Association (ACC Pilots)
- Freese and Nichols
- Seamen's Church Institute (SCI)



Riben Marine debriefing the simulations with representatives from the ACC Pilots

Sequence of events

On commencement of the simulation phase of the project the participants of the study arrived at SCI where they filled out pilot questionnaires, SCI staff explained the run matrix, as well as the expected timeline of events. The team assembled in the briefing room, conducted a facility safety brief, everyone introduced themselves, and a project briefing was provided for the mariners participating in the study who were not present during the testing phase. SCI explained the process of how the study was to be conducted, the study objectives, vessel models used, tug configurations, and environmental conditions. SCI staff advised the group that the Kongsberg simulator can easily determine when *any* vessel runs aground, experiences a collision, or an allision during a simulation, and due to the close tolerances and the operational limits of the VLCC we can easily determine a PASS vs. FAIL. Therefore, if any vessel in a simulation harbor tug or VLCC experienced a problem it would be recorded as a "FAIL" and marked on the survey accordingly.

The sequence of simulation order was decided by pilot preference. Once SCI had the order of simulations to be performed, a pilothouse orientation was conducted. SCI performed a familiarization simulation allowing the participants to become familiar with operational aspects of the simulator. During the study if an exercise was needed to run multiple times, the numbering system was used: 1, 1.2, 1.3, 1.4, and so on. The actual runs performed, and their corresponding score (averaged) are shown below:

				Depth	Draft			Ambient Current				Offshore Wind Current					Tug				
run #	day	location	destination	43'	52'	68'	74'	25 N Ebb Med	25 N Ebb High	25 SE Flood Med	25 SE Flood High	N Med	N High	S Low	S Med	S High	120	Current file	comments	Pilot Average	Tug Average
2	1	Sea	Jetties	x	x								x				x	9/22/2020 @ 1000	familiarization	4.5	5.0
3	1	Sea	Jetties	x	x										x		x	9/15/2018 @ 1900	familiarization	4.0	4.3
7	1	Jetties	HI W	x	x					x							x	7/25/20 @ 0800	max tug power	4.5	5.0
9	1	Jetties	HI E	x	x			x									x	9/15/2018 @ 1300	max tug power	4.8	4.9
12	1	Jetties	HI E	x	x						x						x	7/25/2020 @ 1000	max tug power	5.0	4.8
13	1	Ferries	Jetties	x	x			x									x	9/15/2018 @ 1300	passing vessel speed	3.5	5.0
16	1	Ferries	Jetties	x	x						x						x	7/25/2020 @ 1000	passing vessel speed	5.0	5.0
17	1	Ferries	Jetties	x		x		x									x	9/15/2018 @ 1300	passing vessel speed		5.0
27	1	HI E	Jetties	x		x				x							x	7/25/20 @ 0800	max tug power	4.3	4.7
32	1	Ingleside	HI W	x	x			x									x	9/15/2018 @ 1300	max tug power	5.0	5.0
34	1	Ingleside	HI W	x	x					x							x	7/25/20 @ 0800	max tug power	4.5	5.0
15	2	Ferries	Jetties	x	x					x							x	7/25/20 @ 0800	passing vessel speed	4.8	5.0
20	2	Ferries	Jetties	x		x					x						x	7/25/2020 @ 1000	passing vessel speed		3.9
21	2	HI W	Jetties	x		x		x									x	9/15/2018 @ 1300	max tug power	4.8	4.9
24	2	HI W	Jetties	x		x					x						x	7/24/2020 @ 1000	failure	4.5	4.7
26	2	HI E	Jetties	x		x			x								x	9/22/2020 @ 1000	low score	5.0	5.0
30	2	Jetties	Sea	x		x							x				x	9/22/2020 @ 1000	test run	5.0	5.0
31	2	Jetties	Sea	x		x									x		x	9/13/2018 @ 1900	max tug power	4.5	5.0
37	2	Ingleside	HI E	x	x				x								x	9/22/2020 @ 1000	max tug power	4.5	4.8
38	2	Ingleside	HI E	x	x					x							x	7/25/20 @ 0800	max tug power	5.0	4.9
40	2	HI W	Jetties	x			x	x									x	9/15/2018 @ 1300	failure	4.8	5.0
41	2	HI W	Jetties	x			x				x						x	7/25/2020 @ 1000	failure	4.5	4.7
42	2	HI E	Jetties	x			x		x								x	9/22/2020 @ 1000	test run	5.0	4.6
1	3	Sea	Jetties	x	x							x					x	11/25/2018 @ 0400	familiarization	5.0	5.0
4	3	Sea	Jetties	x	x											x	x	7/25/20 @ 0800	familiarization	4.8	5.0
5	3	Jetties	HI W	x	x			x									x	9/15/2018 @ 1300	max tug power	4.5	5.0
6	3	Jetties	HI W	x	x				x								x	9/22/2020 @ 1000	low score	4.8	5.0
8	3	Jetties	HI W	x	x						x						x	7/25/2020 @ 1000	max tug power	4.5	5.0
10	3	Jetties	HI E	x	x				x								x	9/22/2020 @ 1000	low score	2.3	4.3
11	3	Jetties	HI E	x	x					x							x	7/25/20 @ 0800	max tug power	4.0	5.0
14	3	Ferries	Jetties	x	x				x								x	9/22/2020 @ 1000	passing vessel speed	4.8	4.9
18	3	Ferries	Jetties	x		x			x								x	9/22/2020 @ 1000	passing vessel speed	4.8	5.0
22	3	HI W	Jetties	x		x			x								x	9/22/2020 @ 1000	low score	3.8	4.8
28	3	HI E	Jetties	x		x					x						x	7/25/2020 @ 1000	max tug power	2.8	3.0
28.2	3	HI E	Jetties	x		x					x						x	7/25/2020 @ 1000	max tug power	4.0	5.0
29	3	Jetties	Sea	x		x						x					x	11/25/2018 @ 0400	test run		5.0
36	3	Ingleside	HI E	x	x			x									x	9/15/2018 @ 1300	max tug power	5.0	5.0
19	4	Ferries	Jetties	x		x				x							x	7/25/20 @ 0800	passing vessel speed	4.3	5.0
23	4	HI W	Jetties	x		x				x							x	7/25/20 @ 0800	max tug power	4.8	5.0
25	4	HI E	Jetties	x		x		x									x	9/15/2018 @ 1300	low score	4.8	5.0
33	4	Ingleside	HI W	x	x				x								x	9/22/2020 @ 1000	max tug power	4.3	5.0
35	4	Ingleside	HI W	x	x						x						x	7/25/2020 @ 1000	max tug power	5.0	5.0
39	4	Ingleside	HI E	x	x						x						x	7/25/2020 @ 1000	max tug power	4.8	5.0
43	4	HI E	Jetties	x			x			x							x	7/25/20 @ 0800	test run	4.8	5.0
44	4	Jetties	Sea	x			x									x	x			4.8	5.0

Averaged matrices for the week

Data collection Process

After each simulator run attempt from the matrix listed above the participants document their findings on detailed surveys. This process for data collection occurs after each simulation and is uploaded in real-time after each simulator run. Copies of the original and completed survey data can be found in Appendix H.

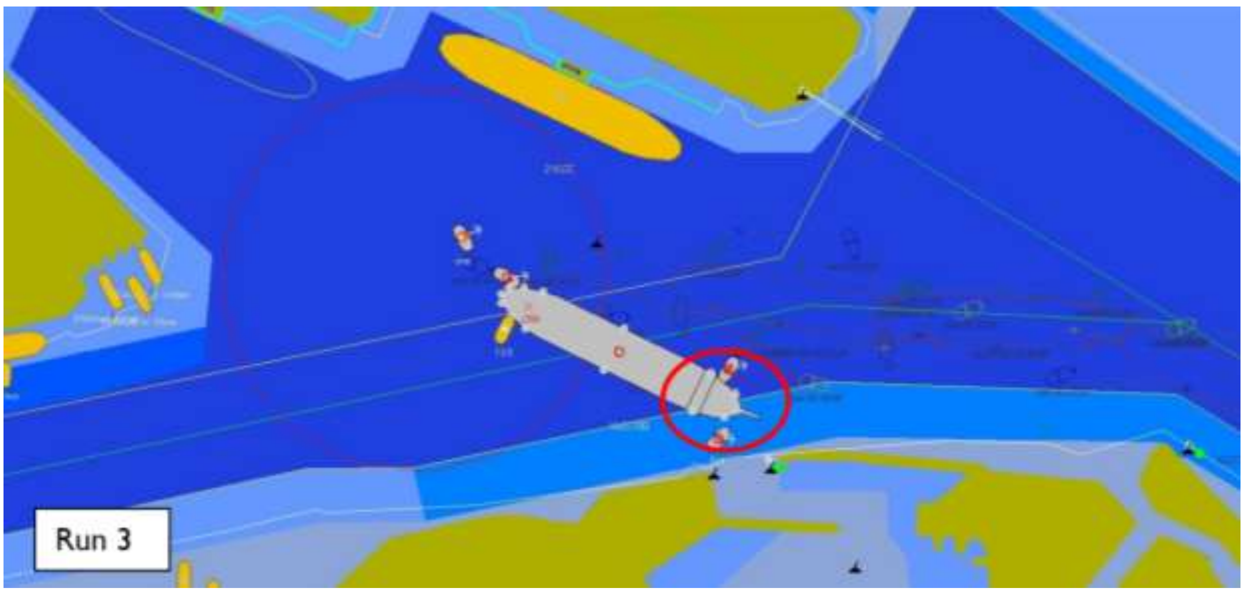
SCI needed to perform 44 runs over 4 days, therefore, we would need to conduct roughly 11-12 simulation runs per day, to allow for multiple attempts, if requested because of a fail or due to participant requests.

SCI staff reminded participants to exercise caution when working near the stern of a ballasted VLCC (pictured to the right), because of the difficulties operating in push mode near a due to the curvature of the hull. Tugs working at these problematic locations aft of the bridge wing were only operated in "pull" mode to account for this real-life limitation.

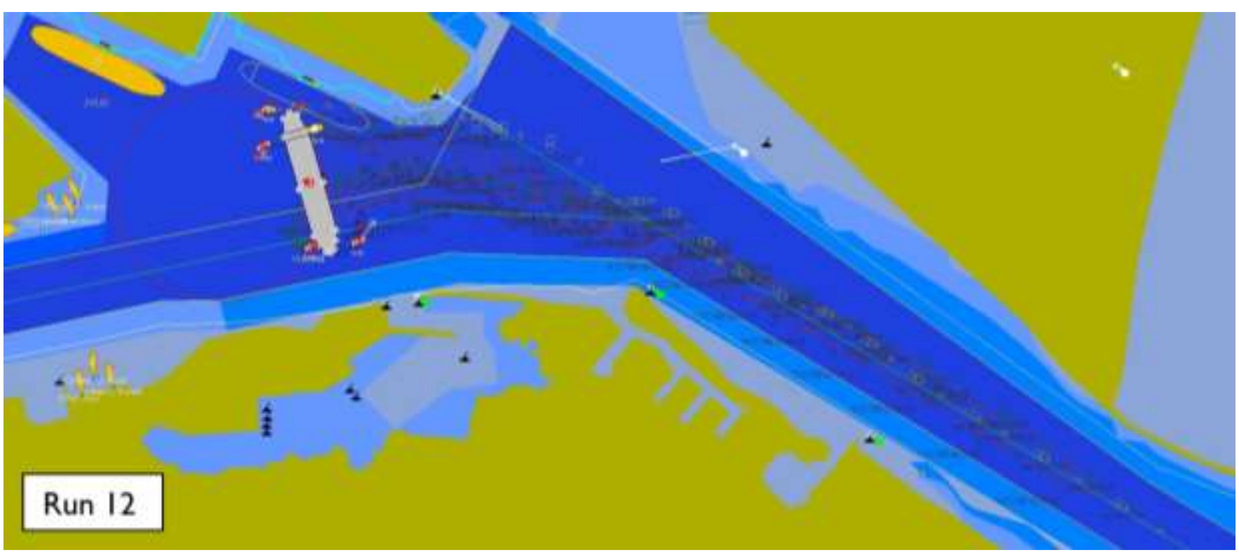
DAY ONE

On day one of the study, we performed 12 runs, specifically runs 2, 3, 3.2, 7, 7.2, 9, 12, 14, 15, 27, 32, and 34. The focus of day one is to target inbound runs to HICT with a VLCC loaded to 52' with medium current flows for pilot group one. The second objective was to slowly increase environmental conditions with a lighter loaded ship, prior to increasing to max flood and ebb flows with a fully loaded ship, which was scheduled for day two and day four for the respective pilot groups.

We experienced one failure on day one (run 3) pictured below, where the ship ran aground during a familiarization run, the rest of the simulations were successful runs for day 1.



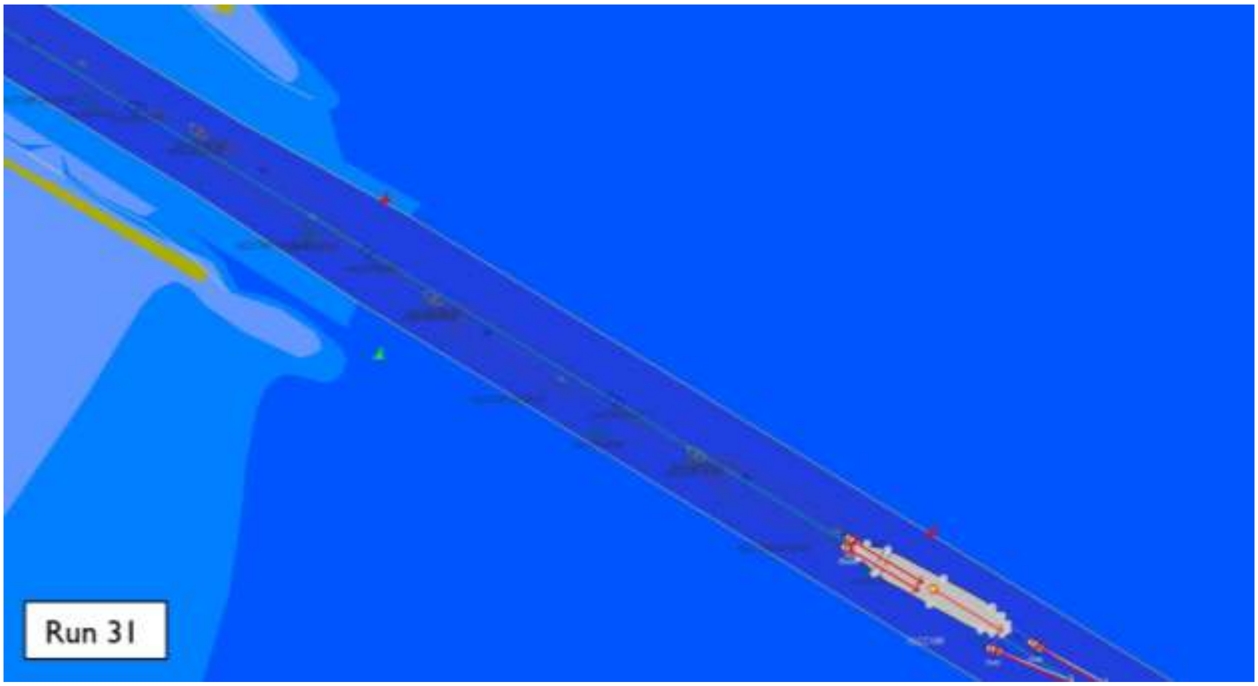
Shows stern of VLCC aground with medium flood velocity at the intersection



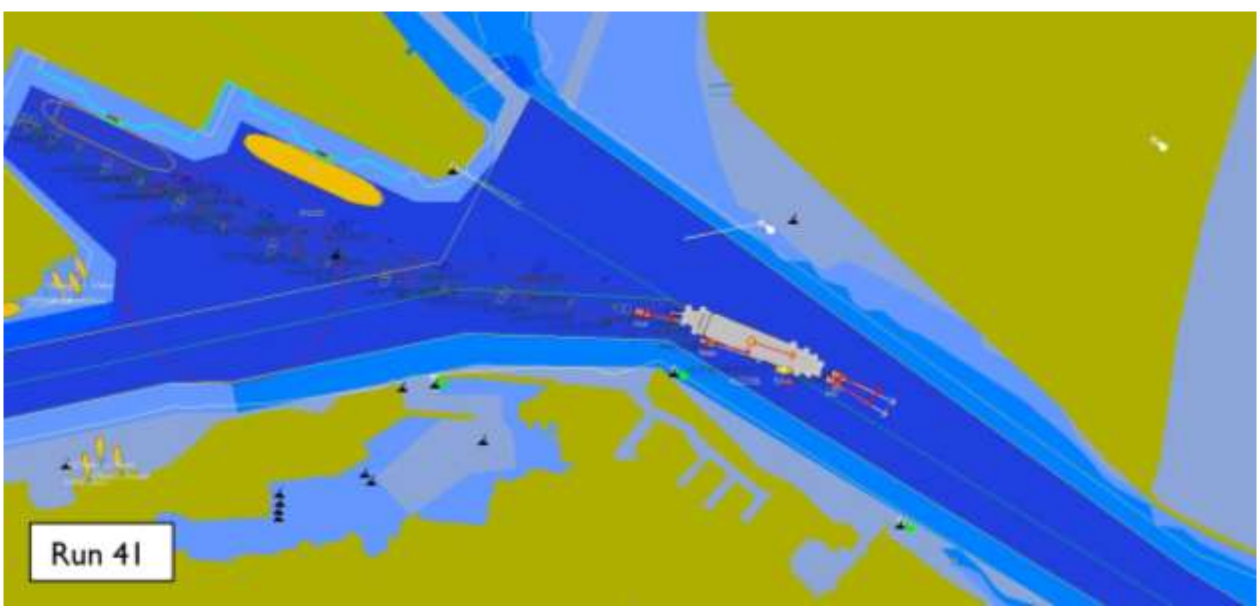
Showing a 52' VLCC maneuvering in a high flood tide to HI East Berth

DAY TWO

On day two of the study, we performed 12 runs, specifically runs 17, 20, 21, 24, 26, 30, 31, 37, 38, 40, 41, and 42. For day two scenarios we focused on running exercises with the fully loaded VLCC with a 68' draft and high flood and ebb tide environmentals. There were no failures on day 2 with pilot group one.



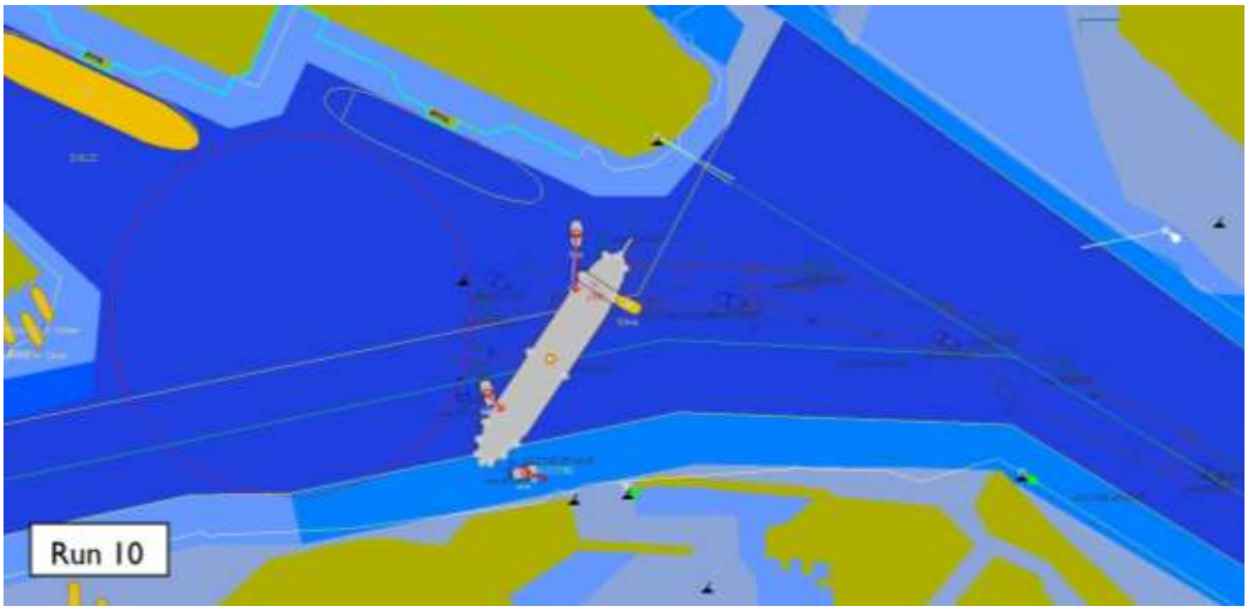
Fully loaded VLCC maneuvering with a 0.9 knot Southerly set near the end of the jetties



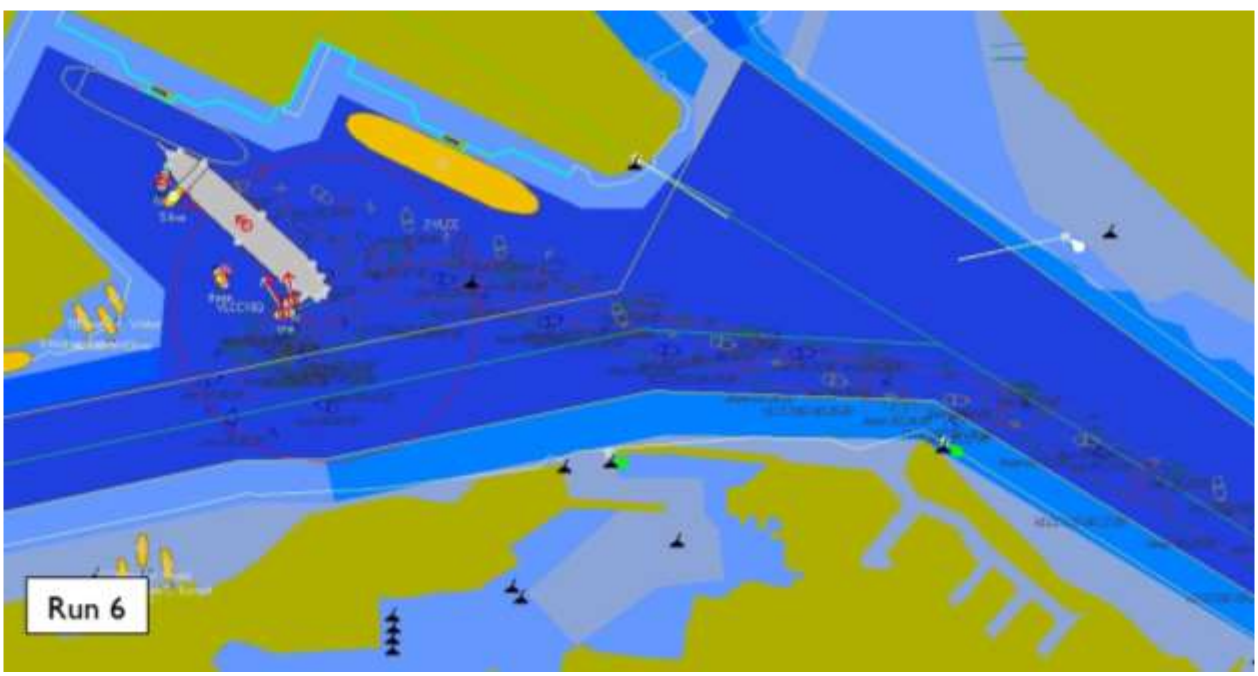
74' loaded VLCC outbound from HI-West with a high flood

DAY THREE

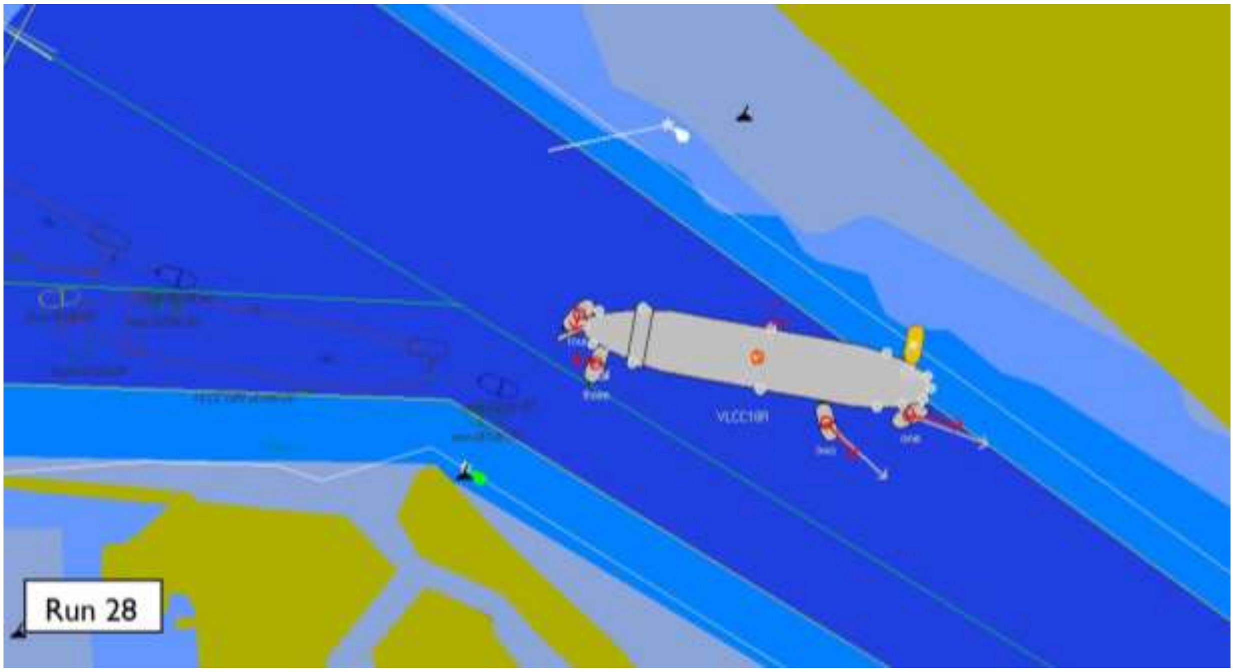
On day three of the study, we performed 16 runs, specifically runs 1, 1.2, 4, 4.2, 5, 6, 6.2, 8, 8.2, 10, 11, 13, 16, 18, 22, 28, 28.2, 28.3, 29, and 36. The focus of day three is to target inbound runs with a 52' loaded VLCC and medium current flows with the second pilot group. The other goal was to slowly ramp up the environmental conditions prior to increasing to max flood and ebb flows with a fully loaded ship, which is scheduled for day four.



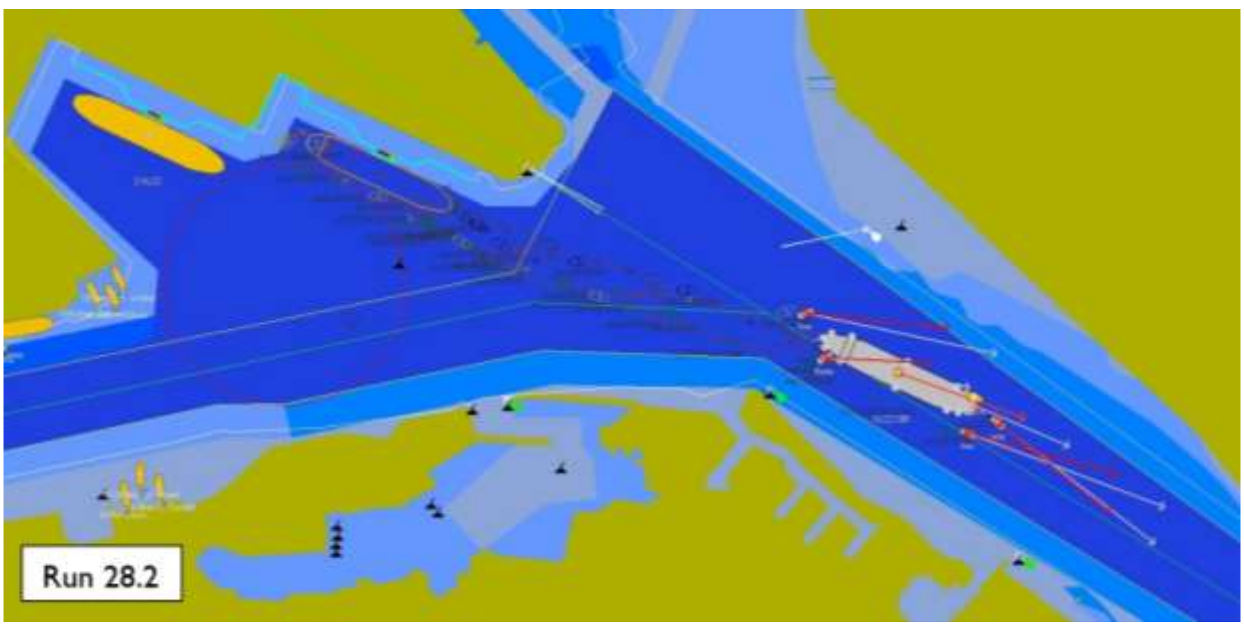
Bow aground while turning with an ebb high current (emergency run)



Successful run inbound with an ebb high current



Fully loaded VLCC ran aground at St. Joe Island on a high flood

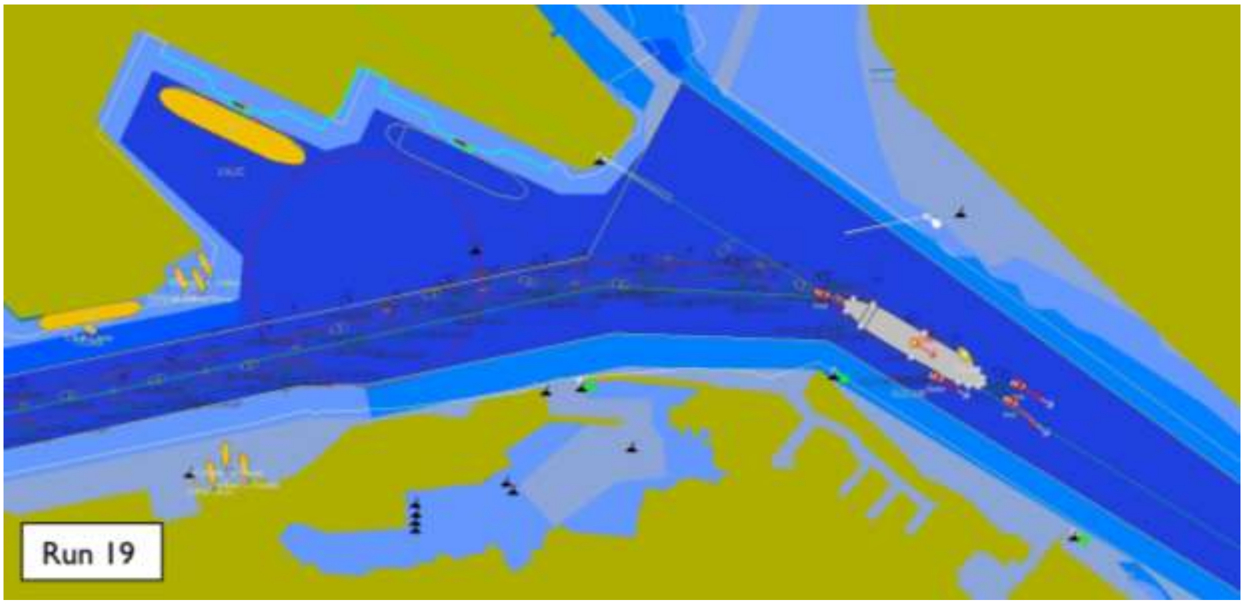


Second attempt of Run 28 with a high flood

During the second attempt of run 28 the fully loaded VLCC was able to overcome the max flood tidal conditions and complete the turn at Harbor Island outbound. Then they were able to hold up on the high side of the channel as the ship transited out to prepare for the southerly set just past the jetties. The picture above shows the ship under control with the max flood and the tugs which helped make the maneuver be successful and avoid grounding on the south side of the channel.

DAY FOUR

On day four of the study, we performed 9 runs, specifically runs 19, 23, 25, 33, 35, 39, 39.2, 43, and 44. The focus was on finishing up three of the inbound 52' VLCC runs from Ingleside to HI-W and E, with the high ebb and flood. After that, we planned to perform the rest of the 68' and 74' outbound runs. There were no failures on day 4.



68' VLCC outbound from the ferries with a medium flood tide

One of the objectives of the week was to better understand if a fully loaded VLCC could make the turn at harbor island at a slow rate of speed to accommodate ships berthed at HICT, which previous studies did not address. We ran at least eight simulations to evaluate if the turn could be made by slow steering, and understand at what tidal flow it was possible, and lastly if the tugs could overcome the tidal current forces on the ship's hull. The only failure was the first attempt of run 28, with a 68' loaded VLCC from HI East to the Jetties with a high flood current. Most of the runs were successful between 3-5 knots outbound and the tugs utilized were able to keep the ship under control the entire time.

Additionally, there was a need to perform more emergency runs with a fully loaded VLCC, which had not been adequately dealt with by previous studies. This was needed to better understand if operational risks were being addressed and proper safety margins were in place for common types of failures. During the week we incorporated nine emergencies ranging from jammed rudder on the ship, tug winch failure, broken tug hawser, tug sinking, tug experiencing black out conditions, and ship's loss of engine. All the emergencies experienced by participants occurred at the most stressful times during high-risk situations. It was important to note that there was only one failure (run 10) during the emergencies performed. During run 10 we simulated emergencies on two tugs at the same time, which resulted in a ship failure.

For all other emergencies performed when a tug experienced a casualty, the other tugs were adequate for maintaining control of the VLCC.

Over the course of the week, we were able to complete 44 runs. When study concluded, everyone was thanked for their time and dedication to the project. The simulation phase proved to be extremely useful in the development and transfer of understanding among participants. The range and number of simulations conducted adequately addressed the key parameters required to bring out the most important issues and objectives. The simulations conducted were challenging scenarios and any residual risks can be controlled by waiting on weather conditions to improve, adding additional pilots, requesting more tugs or more horsepower, and restricting traffic flow. Below are the project's recommendations and conclusions followed by a summary of each simulation from both sessions.

The remarks below are comments from the ACC Pilots participating in the study:

- Cross currents at the channel entrance offshore of the jetties and resulting leeway were manageable with minimal use of assist tugs.

- 120 MT rotor tugs provided adequate power for assisting fully loaded VLCCs in the currents within the ship channel and proposed Harbor Island terminal as represented in the simulation.

- Simulation models representing currents within the proposed Harbor Island Terminal Basin and Lydia Ann ebb currents not accurately represented. Pilots believe actual resulting currents in an as-built project will pose forces that will be more difficult to overcome. Current restrictions may be required.

- Overall, the pilots believe the project is feasible in terms of safe margins for maneuvering as represented in the simulations.

Recommendations and conclusions

Recommendations

1. The future with permit (FWP) channel dimensions, depth profile, and ship channel currents used were found to be acceptable for operating fully loaded VLCCs out of HICT. Run data and participant feedback recommended using 5–120-ton rotor tugs. Pilots and tug captains found the conditions tested to be highly accurate and provided acceptable margins of safety.

2. As dredging in the port continues, additional analysis of the currents will be needed. Pilot feedback currently supports this recommendation. During the study the pilots commented that tidal current velocities have increased as channel dredging progresses. Pilot feedback gathered varied regarding the strength of the currents and effect on VLCCs at the Harbor Island intersection. During the debriefs there was continued discussion of adding current meters at or near the Lydia Ann Channel for additional reference points. There were eight comments from participants about the fidelity of the current model. Comments for four of the runs (2, 3, 4, and 35) state the current was favorable, realistic, true to life, and that it felt correct. While comments on another four runs (11, 13, 23, and 28) state that the currents were extreme, weaker than expected, stronger than expected, or more than anticipated during the maneuvers. If the currents in the area are expected to be stronger in real life, then reducing the operational parameters of the terminal or VLCC when max flood or max ebb conditions exist may be required to offset the effect of the current flow.

3. Pilot comments recommend the use of 5-120T rotor tugs for the FWP runs and a 52’ VLCC. The 120-ton bollard pull tugs were found to be necessary – based on participant feedback and tug power data gathered. The use of five rotor tugs rated at 120-ton bollard pull VLCCs with 52’ draft runs for maneuvering in the FWP profile greatly enhances safety and allows for operating in more difficult environmental conditions.

4. During the FWP runs using a 68’ VLCC, most pilots used five tugs. Tug power graphs for a majority of the runs show the 120T rotor tugs using short bursts of power, and not operating at maximum capacity for extended periods of time. Some of the inbound runs show maximum engine usage, during the inbound transit when the ship is at 12 knots or more. Additionally, 8 of 17 outbound runs with the 68’ loaded VLCCs show tug power at or near maximum power, however 2 of the 8 simulations were emergency scenarios, and 4 of the 8 scenarios were evaluations of slow speed maneuvers outbound to better understand if the turn at harbor island can be made at reduced speeds, when a loaded ship is largely dependent on tugs and tug power. The tug power graphs are shown in appendix H.

5. The study revealed that all of the 74' runs were successful according to the data and the UKC was adequate. Tug performance data, scores, and participant feedback collected during those runs show the ship and tug operating parameters were pushed to the maximum. Pilot feedback call for operational restrictions for maneuvering ships at that draft at certain tidal flows to allow for acceptable margins of safety.

6. Regarding traffic management, when operating VLCC ships, it is recommended for the Corpus Christi Channel to employ one way traffic, with no meeting or overtaking of any vessels other than harbor-assist tugs when in transit.

7. Concerning simulations in which an emergency occurred, we performed 44 simulations total, and 7 runs included 9 emergencies such as ship rudder failure, ship engine failure, broken tug hawser, tug winch failure, tug experiencing a black out condition, and a tug sinking. Four runs were VLCCs with a 52' draft inbound for HICT. 1 out of the 7 emergency runs resulted in a failure when the ship ran aground (run 10) the lowest scoring simulation of the 44 conducted. This is a critical finding due to it being an emergency where two tugs experienced casualties, therefore, the ship was not able to maintain control with just three remaining tugs. For the 6 other emergencies conducted during runs the simulations were successful and scored well 4.5 out of 5 or better.

8. One of the study objectives was to better understand what the tug power needs are for a slow speed maneuver of an outbound partially or loaded VLCC shaping up for a turn at Harbor Island. We conducted 8 maneuvers where the objective was to make the turn at slower than normal speed to see if the tugs could overcome the environmental conditions. 3 of the 8 runs were with a 52' VLCC and 5 of the runs were with the 68' VLCC, the slowest speed transited safely was roughly 3 knots, and there were a few situations where the tugs towed the ship out with no engine and no rudder successfully. All slow speed maneuvers were successful using the 5-120T rotor tugs.

Conclusions

1. Failures summarized: 3 out of 44 simulations were *unsuccessful*, resulting in failure. Run 10 – 52' VLCC inbound from Jetties to HI-E with a high Ebb current, ship grounded after two tugs experienced failures. Run 3 – with a 52' VLCC from Sea to Jetties with a South Medium set, the ship ran aground when it could not overcome the environmental conditions. Run 28 – a 68' VLCC departing HI-E to the Jetties with a high flood current, got too close to Cline Point, ran across the channel and ran aground on the other side.

2. Successful runs: 41 of 44 *successful* runs were with environmental conditions described as very difficult and challenging, the use of 5 rotor tugs rated at 120 MT bollard pull are sufficient for handling up to fully loaded VLCCs. Out of 44 runs over the 4 days of simulation, we experienced 9 emergencies during 7 runs, of which 6 with successful outcomes.

3. The study concludes that the FWP channel dimensions are adequate, depth and currents were accurate in the channel areas, operating the VLCC with a 68' draft was possible, and the pilots could do it safely and reliably using the 5-120 MT Rotor Tugs. The simulations proved that the vessels could operate at maximum flood and ebb conditions. During the maneuvers data shows that the tugs used were not operating at maximum power for extended periods of time, and that there was power left in reserve to account for unforeseen risks. More training for tug masters with subject matter experts would be beneficial once the rotor tugs are in service, this would maximize tug use and operational output of the vessel.

4. It is a challenge to handle VLCCs in confined narrow waterways with shallow draft. In addition to the various forces affecting the vessel there is also high volume of commercial and recreational traffic. With more restrictive environmental fuel and engine regulations on the horizon success of these types of maneuvers will largely be dependent on the tugs available and the tug master's ability and skill. Having the 5-120T rotor tugs available combined with a competent operator will greatly increase safety and reliability of the maneuvers. In summary, we conclude the use of 5-120 MT Rotor Tugs was proven to be necessary and effective for safe navigation when fully loaded VLCCs are operating in the channel with the environmental conditions simulated.

Appendix L

Propeller Scour Study

Note: The Section 508 amendment of the Rehabilitation Act of 1973 requires that the information in Federal documents be accessible to individuals with disabilities. The USACE has made every effort to ensure that the information in this appendix is accessible. However, this appendix is not fully compliant with Section 508, and readers with disabilities are encouraged to contact Mr. Jayson Hudson at the USACE at (409) 766-3108 or at SWG201900067@usace.army.mil if they would like access to the information.

Port Corpus Christi Access Channel

Propeller Scour Study

October 04 2021 | 13242.102.R1.RevA

Baird.

Innovation Engineered.

baird.com

Port Corpus Christi Access Channel

Propeller Scour Study

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13242.102.R1.RevA

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Revision	Date	Status	Comments	Prepared	Reviewed	Approved
A	05/10/2021	Draft	Issued for Client Comments	PJJ	SBV	LAW

Executive Summary

Freese and Nichols, Inc. (FNI) has engaged W.F. Baird & Associates Ltd. to provide coastal engineering and modeling services for the Corpus Christi Channel Deepening project. The project will comprise deepening of the Outer and Approach Channels to 77 ft, and the Jetty Channel and seaward-most portion of the Corpus Christi Ship Channel to 75 ft. The channel will be used by vessels including laden VLCC's at a maximum draft of 68 ft departing from the planned Axis and Harbor Island terminals. A propeller scour assessment as described in this Report was part of these studies developed for the purposes of assessing project adequacy for the Environmental Impact Statement. The study included navigation simulation assessment, model calibration to analytical methods, modeling of the propeller wash, and determination of scour potential.

The maneuvers modelled were based on simplifying assumptions of vessel position and time, which were developed from the navigation simulations for both Axis and Harbor Island terminals and validated with the Aransas Corpus Christi Pilots. From the numerical modelling results the following maneuvers were determined to be the most concerning for propeller induced scour:

- Laden VLCC's directing their wash towards the shoreline, structures, or slopes.
- Tugs that are close to the shoreline for an extended period of time.

The maximum scour potential was determined for each of the six simulations and their potential to influence structures was also commented on. These results are summarized as:

- Area 2 resulted in a maximum scour potential of 14.45 mm (0.57 in) and is unlikely to cause scour issues along the revetment at the shoreline.
- Area 3a (Tug) resulted in a maximum scour potential of 747.78 mm (2.45 ft) and may be a concern for slope stability and undermining of the wall located on the shoreline.
- Area 3b (VLCC) resulted in a maximum scour potential of 3787.15 mm (12.43 ft) and may be a concern for slope stability and underkeel clearance due to sediment deposition.
- Area 5 resulted in a maximum scour potential of 29.38 mm (1.16 in) and is unlikely to cause scour issues along the revetment at the shoreline.
- Alternative Area 1 resulted in a maximum scour potential of 69.99 mm (2.76 in) and is unlikely to be a concern for scour potential.
- Alternative Area 2 resulted in a maximum scour potential of 10.82 mm (0.43 in) and is unlikely to cause scour issues along the breakwater at the shoreline.

Baird recommends that as Area 3 developed the largest scour potential, a monitoring program be put in place to monitor scour adjacent to the wall at the shoreline and slope stability at the toe of slope. Furthermore, the potential for propeller scour to uncover buried pipelines and cables should also be analyzed.

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Tables

Figures

1. Introduction

1.1 Project Background

W.F. Baird & Associates Ltd. (Baird) was engaged by Freese & Nichols, Inc. (FNI) to provide coastal engineering and modeling services for the Corpus Christi Ship Channel Deepening Project (CDP). The project is the proposed deepening the Offshore Channel to a nominal depth of 77 ft (Segments 1 and 2 in Figure 1.1), and the Entrance Channel and seaward-most portion of the Corpus Christi Ship Channel to 75 ft (Segments 3 to 6 in Figure 1.1). The channel will service the planned Harbor Island and Axis terminals with laden VLCC's departing from these terminals.

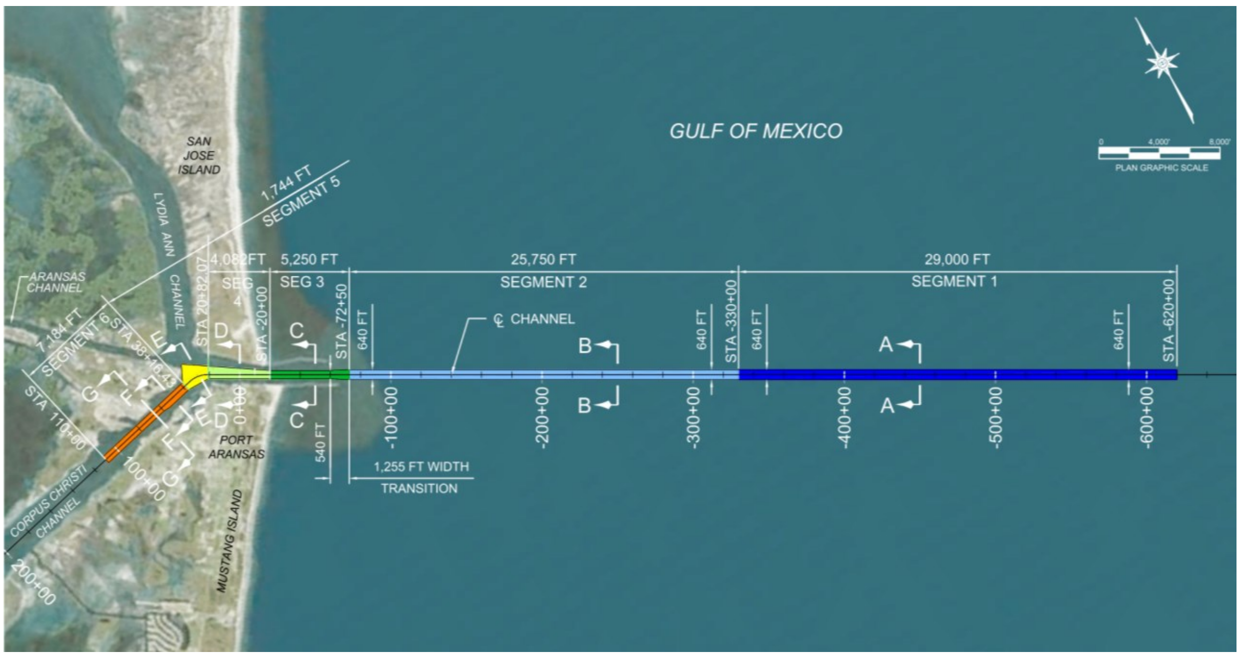

Figure 1.1: Dredging plan for the Corpus Christi Ship Channel Deepening Project

Baird's services include the following tasks:

- Vessel wake analysis
- Dynamic underkeel clearance (UKC) study
- Propeller scour study
- Tidal and hydrodynamic modeling
- Storm surge analysis
- Sediment transport modeling

The propeller scour study is addressed in this Report.

1.2 Study Objectives

The dredged depths for all channel segments have been proposed by PCCA for the present phase of the channel design. The objective of the propeller scour study is to assess the scour potential around the channel improvement areas and existing structures. The potential for scouring is derived from the propeller wash of the project vessel and supporting tug thrusters. The results of the propeller scour modeling will provide insight into areas that may be a concern for scouring and undermining of structures.

1.3 Report Outline

The outline of the report is as follows:

- Section 2 provides a brief description of the numerical model that is used to determine the velocity fields generated by the propeller wash. The input data used for the propeller wash assessment is also presented.
- Section 3 describes the model calibration phase.
- Section 4 presents the results of the modeling and the erosion potential due to propeller wash.
- Section 5 outlines the conclusions and recommendations of the study.

2. Model Description

2.1 General

Baird has completed a numerical modeling study that used FLOW-3D® to model the hydrodynamics induced by propeller generated flow (i.e., propeller wash). The model used is a Computational Fluid Dynamics (CFD) model that solves the three-dimensional incompressible Navier-Stokes equations and uses a fan/impeller model to simulate propellers.

The FLOW-3D® fan/impeller model is capable of replicating the axial and swirl components of a propeller by introducing a 'phantom' obstacle. The phantom obstacles are right-circular cylinders with a specified radius and thickness, which defines the region swept out by the rotating blades. The propeller model is characterized by a linear pressure drop across the cylinder length versus the net flow rate passing through it. Additionally, the performance of the fan/impeller is defined by its rotation rate, an accommodation coefficient (A_d) that controls how effective the blades are in setting fluid into motion, and a coefficient (B_d) that controls the amount of axial flow induced (Flow Science, 2018).

2.2 Bathymetry

The bathymetry for the proposed channels and terminals was obtain from FNI and was combined with bathymetry from the NOAA NCEI CUDEM grid to produce the bathymetry for the CFD model. The bathymetry used as input into the propeller wash modeling is presented in Figure 2.1.

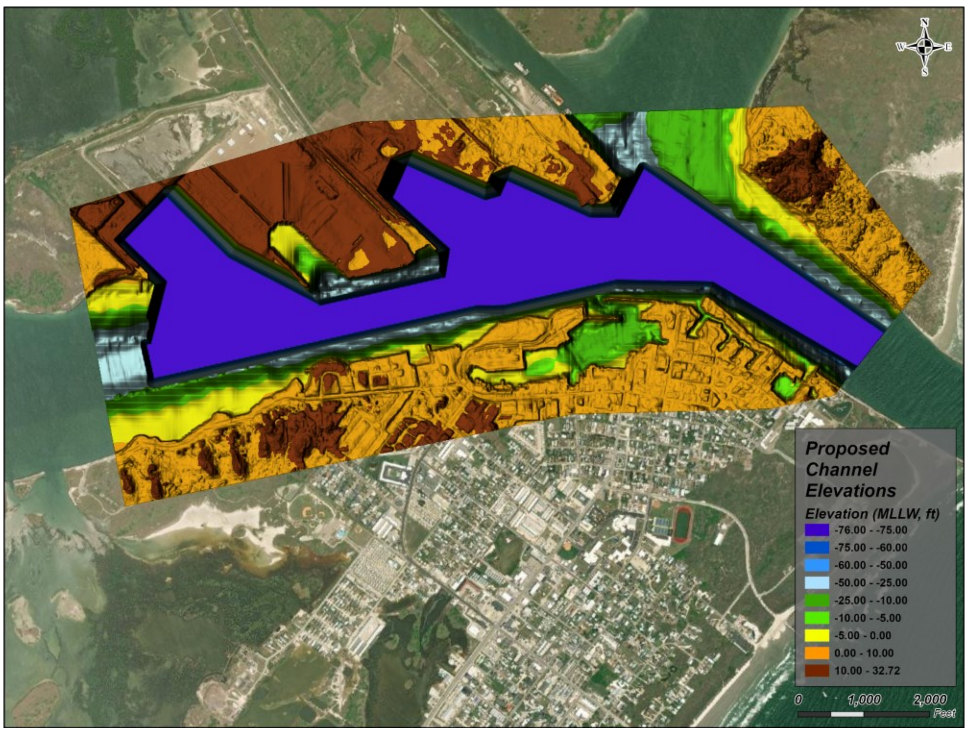

Figure 2.1: Model Bathymetry

2.3 Vessels

The design vessel for the project is a 306k DWT VLCC. The VLCC has one 10 m (32.8 ft) propeller located at the stern of the vessel at approximately 1 m (3.3 ft) above the keel. The tug simulated in the model is based off the Preliminary Design Summary Report for the terminal / escort tug ART 110-35 designed by Robert Allan Ltd. (Robert Allan Ltd., 2021). The tug designed by Robert Allan Ltd. is a rotor tug with three 2.8 m (9.2 ft) ducted propellers. The two propellers located at the bow of the tug are separated by 6.1 m (20 ft) and the propeller at the stern of the tug is located at approximately 20.1 m (66 ft) away from the forward propellers. These three propellers were assumed to have the same draft at approximately 5.2 m (17 ft).

2.4 Model Domains and Scenarios

The model domains are broken down into key areas presented in Figure 2.2. These domains were derived from the Harbor Island and Axis terminal navigation simulations and a summary of the modeling scenarios for each area is presented in the following sections. The scenarios were developed in conjunction with the Aransas Corpus Christi Pilots. All models were run only for the mean lower low water (MLLW) level as this represents a conservative estimate of the scour potential. Areas 1 and 4 which were initially identified in the scope of work were not seen to have significant propeller scour potential from review of the simulations and were therefore replaced with Alternative Areas 1 and 2.

Figure 2.2: Model Domains

2.4.1 Area 2

The propeller wash modeling scenario for area two is shown in Figure 2.3. The vessel being modeled is an inbound unladen VLCC transiting at full ahead, which is at a propeller spin rate of approximately 57 rpm. This scenario is based off Axis Run 4 at time stamp 0:16:08 and was modeled for two minutes of time.

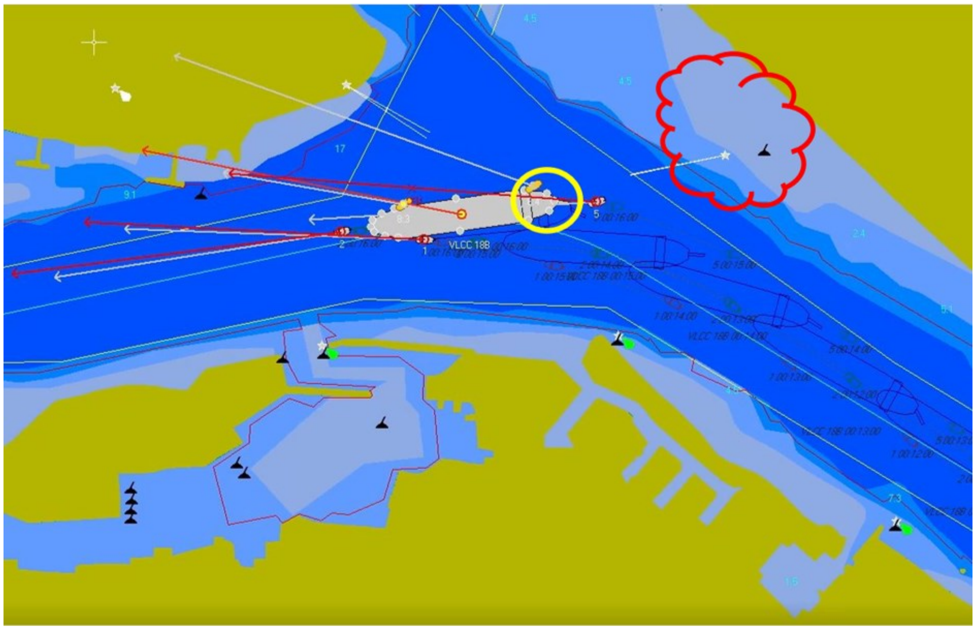

Figure 2.3: Area 2 Propeller Wash Modeling Scenario

2.4.2 Area 3a

The propeller wash modeling scenario for area three is shown in Figure 2.4. The vessel being modeled is the starboard bow tug at full power, which is at a propeller spin rate of approximately 240 rpm. This scenario is based off HICT Run 1 at time stamp 0:26:48 and was modeled for three minutes of time.

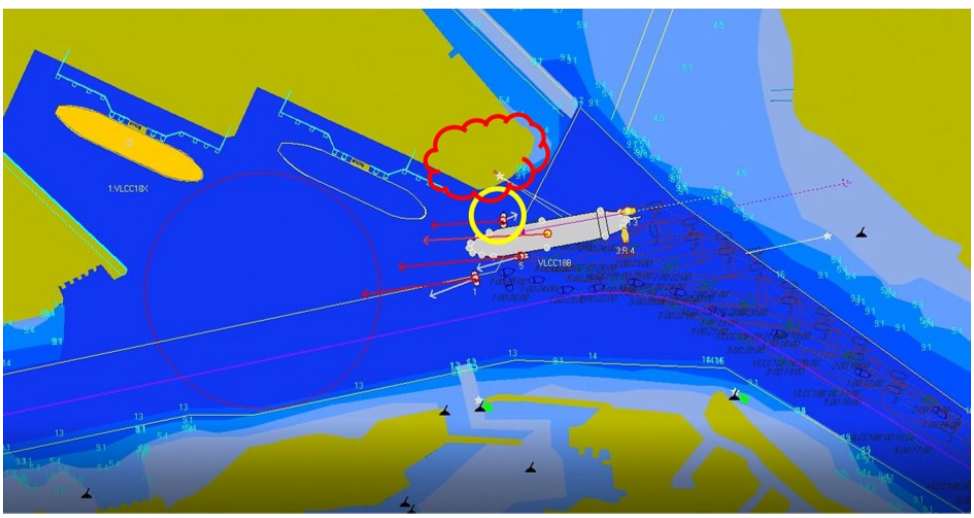

Figure 2.4: Area 3a (Tug) Propeller Wash Modeling Scenario

2.4.3 Area 3b

The propeller wash modeling scenario for area three is shown in Figure 2.5. The vessel being modeled is a laden VLCC transiting at full ahead, which is at a propeller spin rate of approximately 57 rpm. This scenario is based off Axis Run 11 at time stamp 0:17:44 and was modeled for two minutes of time.

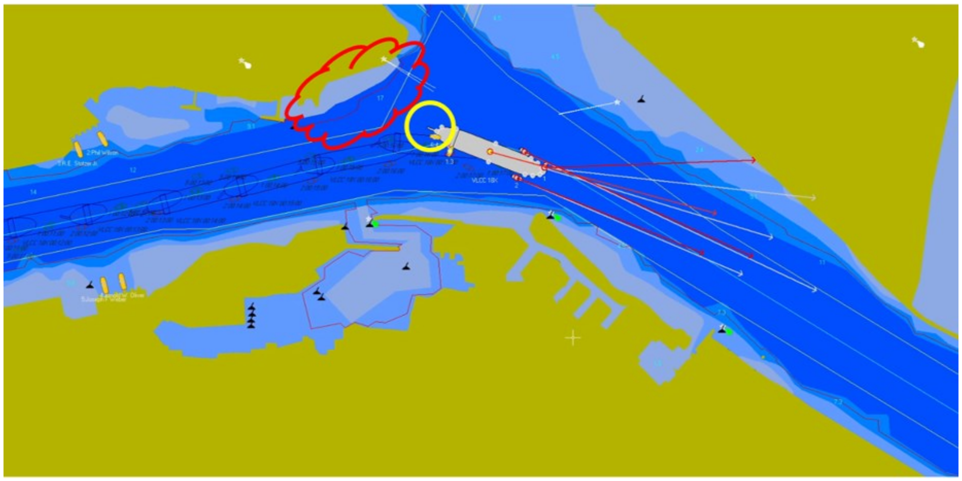

Figure 2.5: Area 3b (VLCC) Propeller Wash Modeling Scenario

2.4.4 Area 5

The propeller wash modeling scenario for area five is shown in Figure 2.6. The vessel being modeled is the starboard bow tug at full power, which is at a propeller spin rate of approximately 240 rpm. This scenario is based off HICT Run 1 at time stamp 0:37:54 and was modeled for four minutes of time.

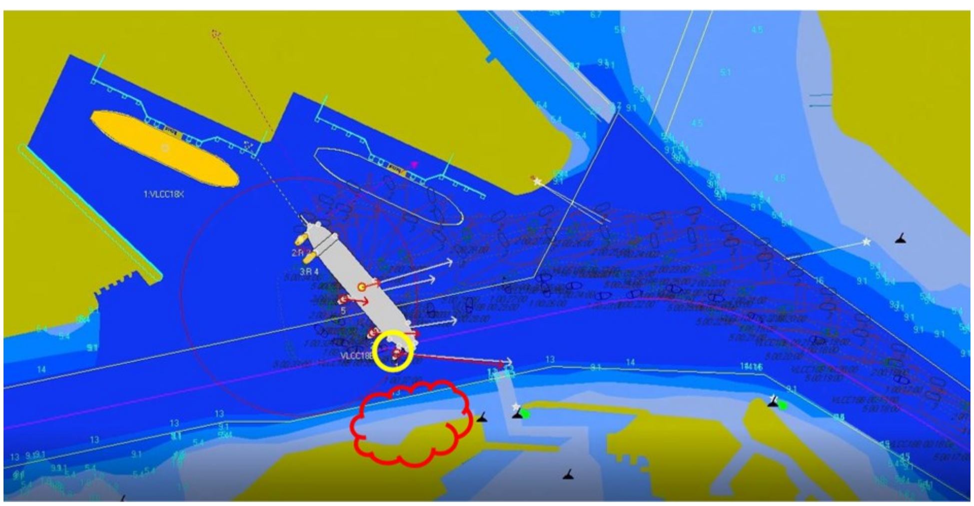

Figure 2.6: Area 5 Propeller Wash Modeling Scenario

2.4.5 Alternative Area 1

The propeller wash modeling scenario for alternative area one is shown in Figure 2.7. The vessels being modeled are the port bow tugs at full power, which is at a propeller spin rate of approximately 240 rpm. This scenario is based off Axis Run 10 at time stamp 0:11:42 and was modeled for four minutes of time.

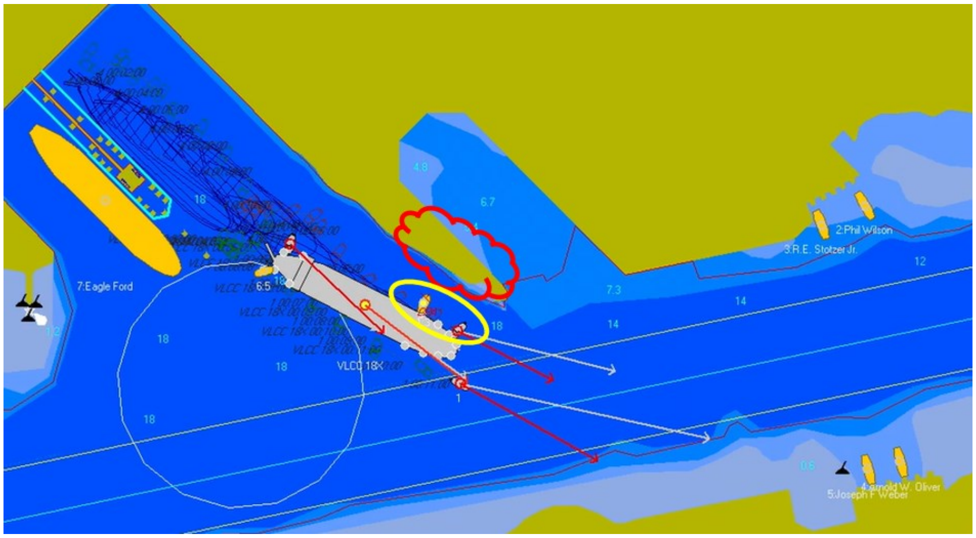

Figure 2.7: Alternative Area 1 Propeller Wash Modeling Scenario

2.4.6 Alternative Area 2

The propeller wash modeling scenario for alternative area two is shown in Figure 2.8. The vessel being modeled is the starboard bow tug at full power, which is at a propeller spin rate of approximately 240 rpm. This scenario is based off Axis Run 9.2 at time stamp 0:14:06 and was modeled for three minutes of time.

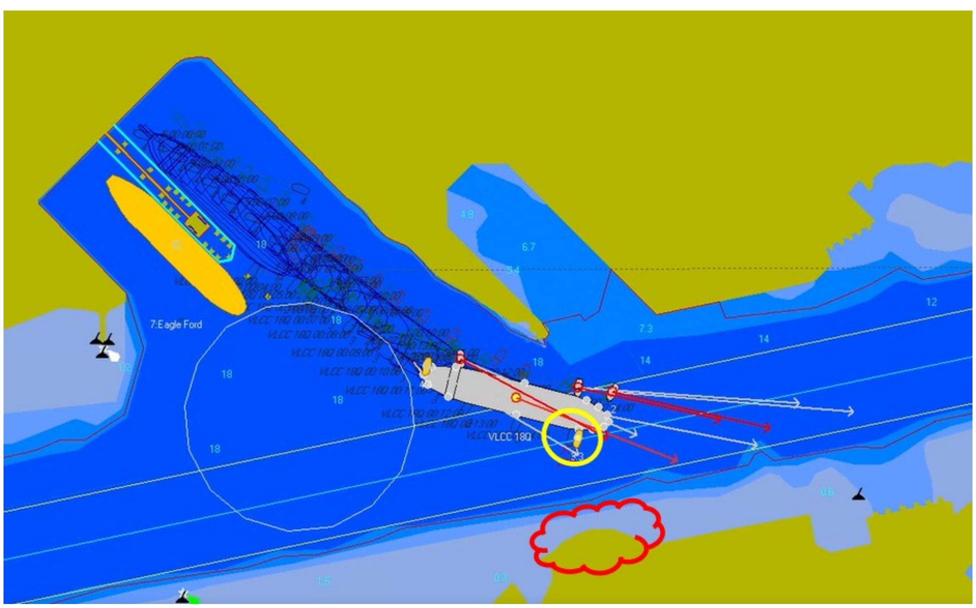

Figure 2.8: Alternative Area 2 Propeller Wash Modeling Scenario

3. Model Calibration

3.1 Calibration Parameters

FLOW-3D® provides two calibration parameters for the fan/impeller model, these two parameters are the accommodation coefficient (A_d) and the coefficient to account for axial flow (B_d). For this study these two coefficients were iterated until the propeller centerline velocities for the VLCC and tug approximated an analytical solution. The analytical solution for propeller centerline velocities was taken from Blaauw & van de Kaa (1978), who derived their formulas from physical experiments of a jet in a flume. One key difference between the analytical method and a spinning propeller is that the analytical method assumes the maximum velocity of the propeller occurs at the centerline and radially decreases away from the center. This differs from a spinning propeller, where the velocity is maximum at the blade tips close to the propeller and converges to the velocity at the centerline as you move further away from the propeller.

3.2 VLCC Model Calibration

As described in Section 3.1, the VLCC propeller model was calibrated to the analytical solution for the propeller centerline velocity for non-ducted propellers (Blaauw & van de Kaa, 1978). The calibration runs resulted in an A_d coefficient equal to 0.8 and a B_d coefficient equal to 1.5. Figure 3.1 presents the calibrated propeller centerline velocity curves.

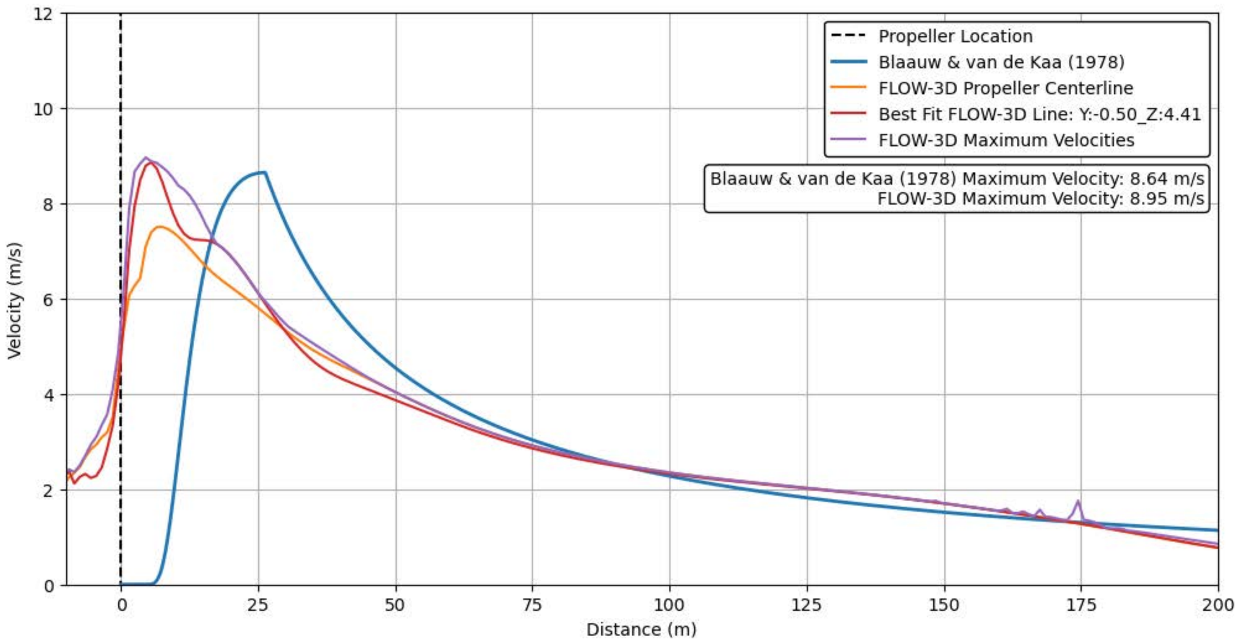

Figure 3.1: Velocity Profile Calibration Along VLCC Propeller Centerline

Four curves are presented on Figure 3.1, the first curve is the analytical solution provided by Blaauw and van de Kaa (1978), while all other curves are results from the FLOW-3D® simulation. As described in Section 3.1, Blaauw and van de Kaa (1978) provided a solution along the propeller centerline which is assumed to be the maximum velocity. The orange curve outlines the propeller centerline velocity from FLOW-3D® and compared to Blaauw and van de Kaa (1978), the FLOW-3D® simulation approximates the analytical solution well in the far-field but not in the near-field. This is expected behavior as the FLOW-3D® simulation does not assume that the maximum velocity occurs at the propeller centerline near the propeller. The red curve represents the grid line in the FLOW-3D® simulation that best represents analytical curve, which from the plot legend is not located directly at the propeller centerline at (Y:0, Z:0). The line that best represents the analytical curve is located 0.50 m horizontally and 4.41 m vertically away from the propeller center. Since, the analytical curve represents the maximum velocities generated by the propeller it is best to compare it to the maximum velocities generated by the propeller in the FLOW-3D® simulation. The purple curve represents the maximum velocities generated by the propeller in the FLOW-3D® simulation and it is clear that the simulation represents both the magnitude and shape of the analytical curve well. The simulation slightly overestimates the maximum velocity as predicted by the analytical solution while bounding the far-field velocity. The simulation overestimates the maximum velocity by 0.31 m/s (1.01 ft/s). The shift in the x-coordinate between the FLOW-3D® simulation results and the analytical curve is due to the analytical curve assuming it takes a distance of approximately 2.6 times the propeller diameter to establish the flow (Blaauw & van de Kaa, 1978). Whereas FLOW-3D® establishes the flow directly at the propeller along the length of the propeller.

3.3 Tug Single Propeller Model Calibration

As described in Section 3.1, the tug propeller model was calibrated to the analytical solution of the propeller centerline velocity for ducted propellers (Blaauw & van de Kaa, 1978). For the calibration runs only a single tug propeller was used as Blaauw & van de Kaa (1978) is only applicable for a single propeller. The calibration runs resulted in an A_d coefficient equal to 0.7 and a B_d coefficient equal to 1.25. Figure 3.2 presents the calibrated propeller centerline velocity curves.

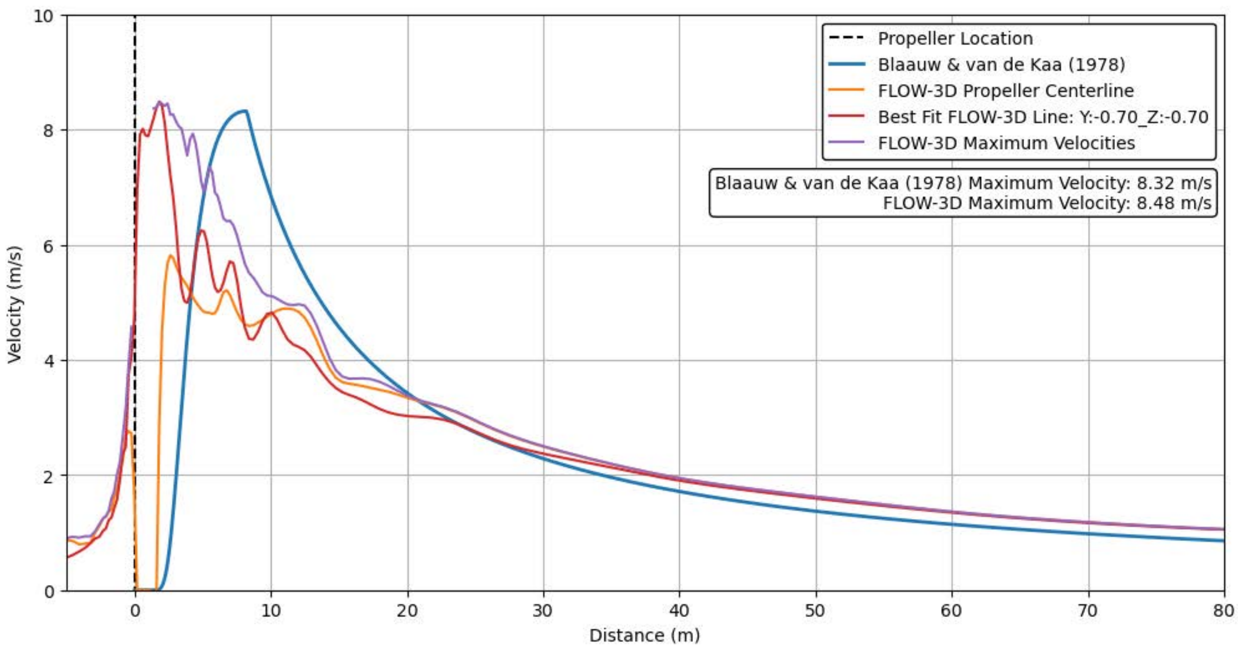

Figure 3.2: Velocity Profile Calibration Along Tug Propeller Centerline

Four curves are presented on Figure 3.2, the first curve is the analytical solution provided by Blaauw and van de Kaa (1978), while all other curves are results from the FLOW-3D® simulation. As described in Section 3.1, Blaauw and van de Kaa (1978) provided a solution along the propeller centerline which is assumed to be the maximum velocity. The orange curve outlines the propeller centerline velocity from FLOW-3D® and compared to Blaauw and van de Kaa (1978), the FLOW-3D® simulation approximates the analytical solution well in the far-field but not in the near-field. This is expected behavior as the FLOW-3D® simulation does not assume that the maximum velocity occurs at the propeller centerline near the propeller. The red curve represents the grid line in the FLOW-3D® simulation that best represents analytical curve, which from the plot legend is not located directly at the propeller centerline at (Y:0, Z:0). The line that best represents the analytical curve is located 0.70 m horizontally and 0.70 m vertically away from the propeller center. The purple curve represents the maximum velocities generated by the propeller in the FLOW-3D® simulation and it is clear that the simulation represents both the magnitude and shape of the analytical curve well. The simulation slightly overestimates the maximum velocity as predicted by the analytical solution while also slightly overestimating the far-field velocity. The maximum velocity is overestimated by 0.16 m/s (0.52 ft/s) whereas the far-field velocity is overestimated by approximately 0.19 m/s (0.62 ft/s). The shift in the x-coordinate between the FLOW-3D® simulation results and the analytical curve is due to the analytical curve assuming it takes a distance of approximately 2.6 times the propeller diameter to establish the flow (Blaauw & van de Kaa, 1978). Whereas FLOW-3D® establishes the flow directly along the length of the propeller.

4. Model Results

The results of the six scenarios for the propeller wash modeling are presented in this section.

4.1 Erosion and Scour Potential

The erosion potential was approximated based upon the sediment characteristics within each of the model domains and the bed shear stress / bed shear velocities developed during the simulations. The sediment sizes for each of the model domains was determined from the borehole logs presented in Terracon Consultants Inc. (2018) and summarized in Table 4.1. Based on Table 4.1, a very fine sand of grain size 0.12 mm (0.005 in) was chosen to represent the sediment in each of the domains. For this analysis the dry density of the very fine sand is assumed to be 1600 kg/m^3 (100 lb/ft^3). Following Soulsby (1997), the dimensionless sediment size for this sediment is 3.00 with a critical bed shear stress of 0.13 Pa (0.0027 psf) and a critical bed shear velocity of 0.011 m/s (0.037 ft/s).

Table 4.1: Grain Size in Each Model Domain

Area	Bore Hole Number	Depth Below Seabed (m) [ft]	D_{50} (mm) [in]
2	BH-34	1.1 [3.5]	0.11 [0.004]
2	BH-34	5.9 [19.5]	0.13 [0.005]
3	BH-37	2.3 [7.5]	0.10 [0.004]
5	BH-36	0.6 [2]	0.13 [0.005]
Alternative Area 1	CB-3	1.6 [5.15]	0.13 [0.005]
Alternative Area 1	CB-3	10.7 [35.15]	0.11 [0.004]
Alternative Area 2	CB-2	2.8 [9.05]	0.13 [0.005]

The scour potential was approximated based upon the analytical formula for the erosion rate (Partheniades, 1965):

$$S_E = E\left(\frac{\tau_b}{\tau_{ce}} - 1\right)^n \qquad \tau_b > \tau_{ce}$$

Where S_E is the erosion rate (mm/hr), E is the erodibility coefficient (mm/hr), τ_b is the bed shear stress (Pa), τ_{ce} is the critical shear stress (Pa), and n is the power of erosion (-). For this study the power of erosion (n) was assumed to be a value of 1.5 for sand. The erodibility coefficient (E) is typically determined from lab experiments which are not available for this study. Utilizing previous Baird studies, the erodibility coefficient for silty sand with a critical shear stress of approximately 0.10 Pa can range from 1.67 to 4.73 mm/hr. To obtain an estimate for the erodibility coefficient for this project, a FLOW-3D® sediment transport model was run for Area 3b (VLCC). The maximum scour hole depth from the numerical simulation was then used as the calibration value for the erodibility coefficient. The erodibility coefficient was iterated between 1.67 to 4.73 mm/hr until the maximum scour hole depth approximated by the analytical formula matched the depth predicted by the numerical model. For Area 3b (VLCC) the numerical model developed a maximum scour hole depth of 3.79 m

(12.43 ft), which resulted in an erodibility coefficient of 3.22. An erodibility coefficient of 3.22 and a power of erosion of 1.5 was used for all other model domains to approximate the scour potential.

4.1.1 Limitations and Simplifications to the Hydrodynamic Modeling and Analytical Approximation of Scour Potential

The approach taken for modeling the propeller wash and analytically calculating the scour potential has certain limitations, some of these limitations are outlined below:

- The vessel is moving with time which would result in eroding new areas and potentially backfilling previous areas. For this study the propeller was modelled as stationary, which is a conservative assumption with respect to scour depth potential. However, with a moving vessel the scour area potential would be larger due to the constant movement of the velocity plume.
- The analytical approach for approximating scour potential only accounts for erosion and not deposition.
  - Bed forms generated by the sediment transport are not captured, which may result in an overestimation of the scour potential area. Based on preliminary coupled hydrodynamic and sediment transport simulations, the propeller wash tends to follow the scour hole path leading to a velocity plume that does not disperse laterally as much when compared to fixed bed simulations.
- The bed shear stress and bed shear velocities are assumed to not be influenced by the development of the scour hole (i.e., not a coupled simulation).
- There is a lack of physical data to calibrate to for propeller velocities and associated scour potential for the vessels being used in this study and in the Corpus Christi area.

4.1.2 Area 2

Figure 4.1 presents the bed shear stress and bed shear velocities maximized over all time steps within the Area 2 model domain. From Figure 4.1, it is apparent that both the bed shear stresses and bed shear velocities result in plots that are very similar. This is due to the bed shear stress (τ_b) being related to the bed shear velocity (u_*) and the density of water (ρ_w) by the following formula:

$$\tau_b = \rho_w u_*^2$$

From Figure 4.1, it is apparent that the areas of highest shear stress are located near the propeller and develop in a cone shape away from the propeller. The areas of the highest shear stress will result in the areas with the highest erosion potential.

For this simulation there is a submerged groin that is currently buried by sediment, which is outlined in Figure 4.1 and Figure 4.2. Observing the potential scour areas in Figure 4.2, it appears that the scour for this simulation will not uncover the submerged groin. Additionally, for this simulation the propeller wash and scour potential did not reach the shoreline which will not result in undermining of the armor stone located on the shore. From Figure 4.2, the maximum scour potential is estimated to be 14.45 mm (0.57 in) and the total scour potential area is approximately 45879 m^2 (11.34 ac).

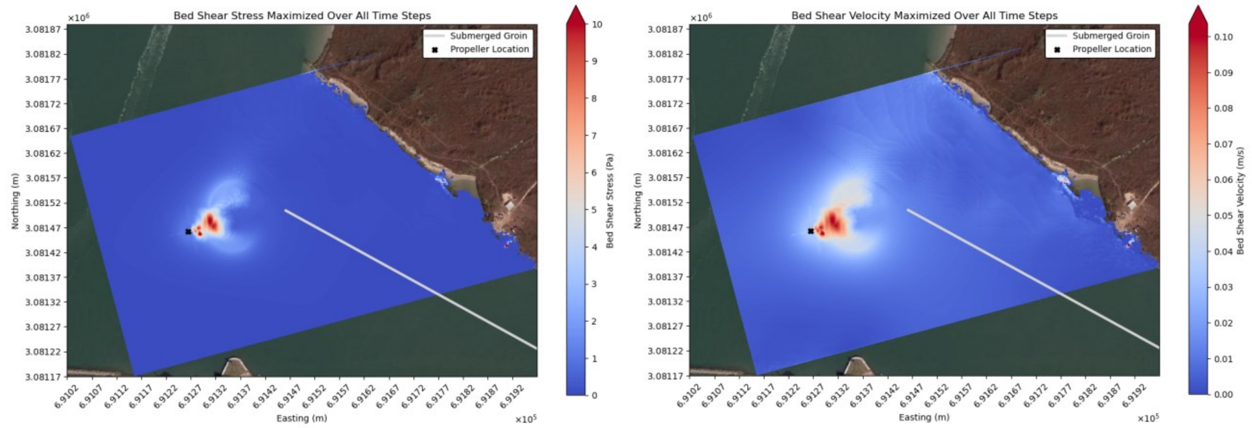

Figure 4.1: Area 2 Bed Shear Stress (Left) and Bed Shear Velocity (Right) Maximized Over All Time Steps

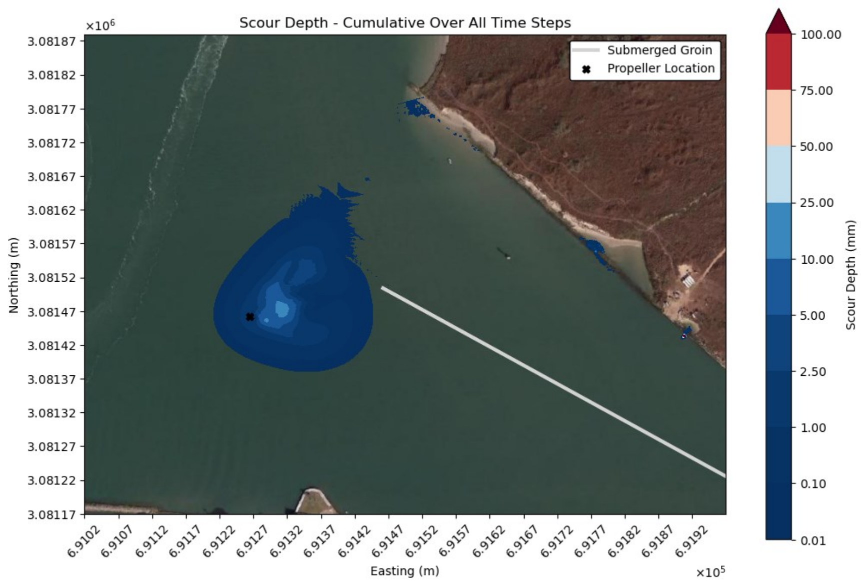

Figure 4.2: Potential Scour Area for Area 2

4.1.3 Area 3a (Tug)

From Figure 4.3, it is apparent that the areas of highest shear stress are located near the propellers and at the shoreline. The propeller wash initial is conical in shape but once it reaches the shoreline it splits to either side. For this simulation there is a wall located at the shoreline, where potential undermining could occur.

Figure 4.4 presents the potential scour areas for this simulation. From Figure 4.4, the maximum scour potential is estimated to be 747.78 mm (2.45 ft) and the total scour potential area is approximately 13028 m^2 (3.22 ac). Furthermore, from Figure 4.4 the scouring starts at the toe of slope and increases as the water depth decreases which may be problematic for slope stability.

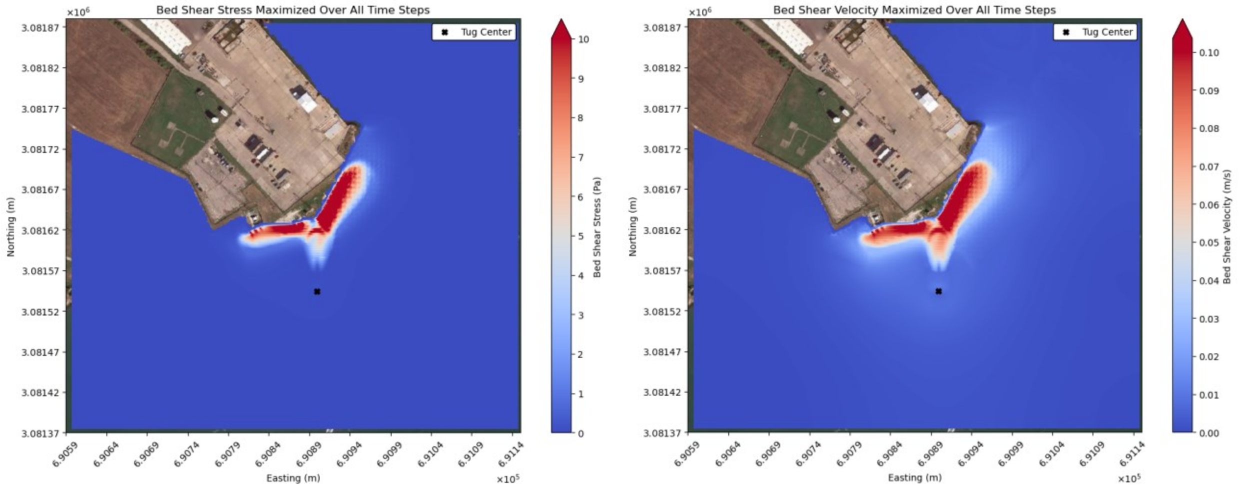

Figure 4.3: Area 3a (Tug) Bed Shear Stress (Left) and Bed Shear Velocity (Right) Maximized Over All Time Steps [Note: maximum bed shear stress and velocity are 47 Pa and 0.2 m/s respectively]

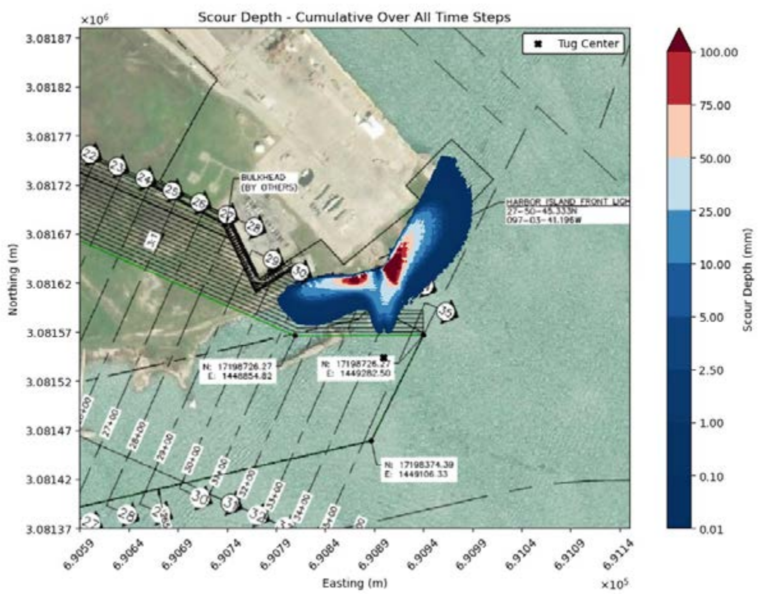

Figure 4.4: Potential Scour Area for Area 3a (Tug)

4.1.4 Area 3b (VLCC)

From Figure 4.5, it is apparent that the areas of highest shear stress are located near the propeller. This simulation represents the worst case for sediment scour potential as the VLCC propeller is located just above the seabed due to the vessel being laden. For this simulation the propeller wash does not reach the shoreline and is contained within the dredged channel and harbor.

Figure 4.6 presents the potential scour areas for this simulation. From Figure 4.6, the maximum scour potential is estimated to be 3787.15 mm (12.43 ft) and the total scour potential area is approximately 37764 m^2 (9.33 ac). Furthermore, as shown in Figure 4.6, the scour potential reaches the toe of slope which may be problematic for slope stability.

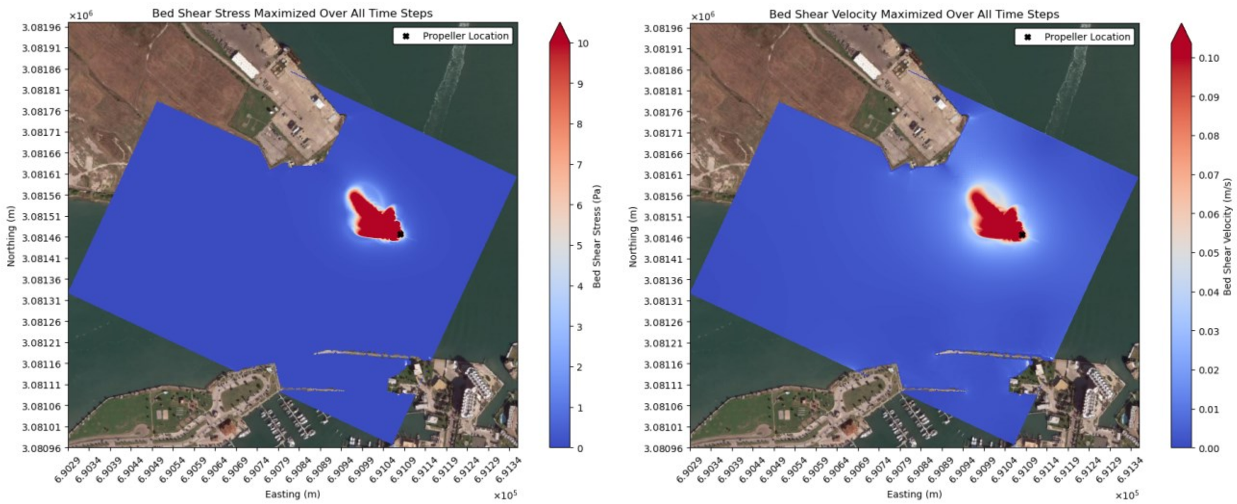

Figure 4.5: Area 3b (VLCC) Bed Shear Stress (Left) and Bed Shear Velocity (Right) Maximized Over All Time Steps [Note: maximum bed shear stress and velocity are 230 Pa and 0.5 m/s respectively]

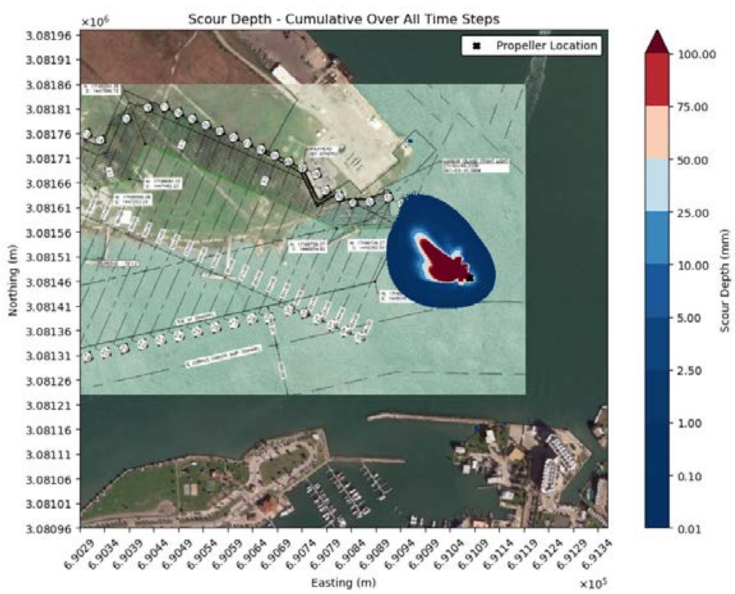

Figure 4.6: Potential Scour Area for Area 3b (VLCC)

4.1.5 Area 5

From Figure 4.7, it is apparent that the areas of highest shear stress are located near the shoreline. The propeller wash is initially conical in shape but once it reaches the shoreline it splits to either side, similar to the results of Area 3a (tug) in Section 4.1.3. There is a revetment located along the shoreline, however, the estimated scour potential is small and likely not a concern for undermining of the structure.

Figure 4.8 presents the potential scour areas for this simulation. From Figure 4.8, the maximum scour potential is estimated to be 29.38 mm (1.16 in) and the total scour potential area is approximately 19391 m^2 (4.79 ac).

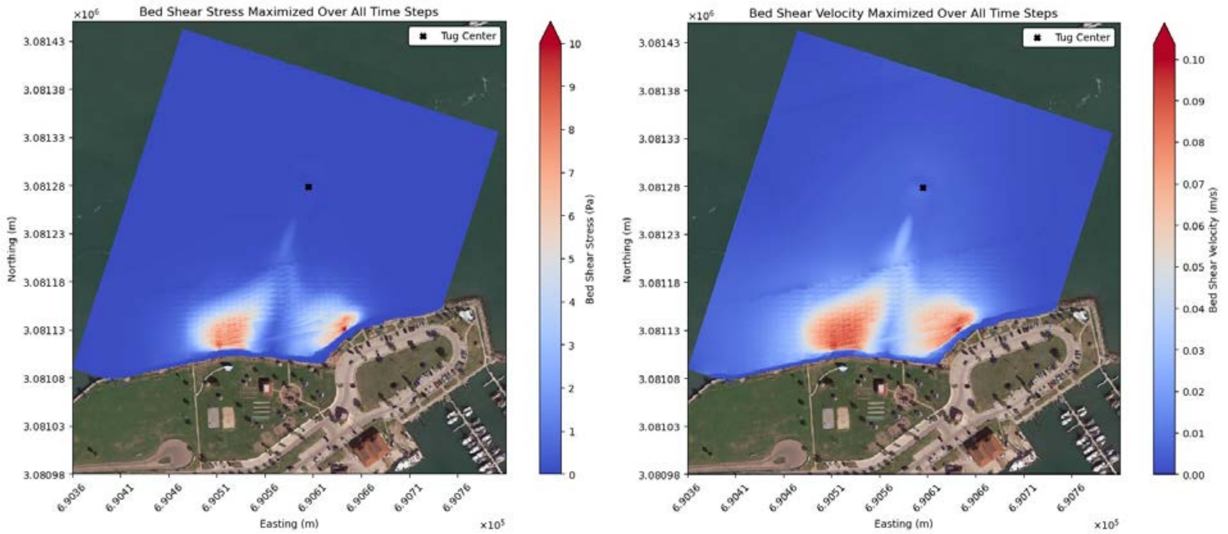

Figure 4.7: Area 5 Bed Shear Stress (Left) and Bed Shear Velocity (Right) Maximized Over All Time Steps

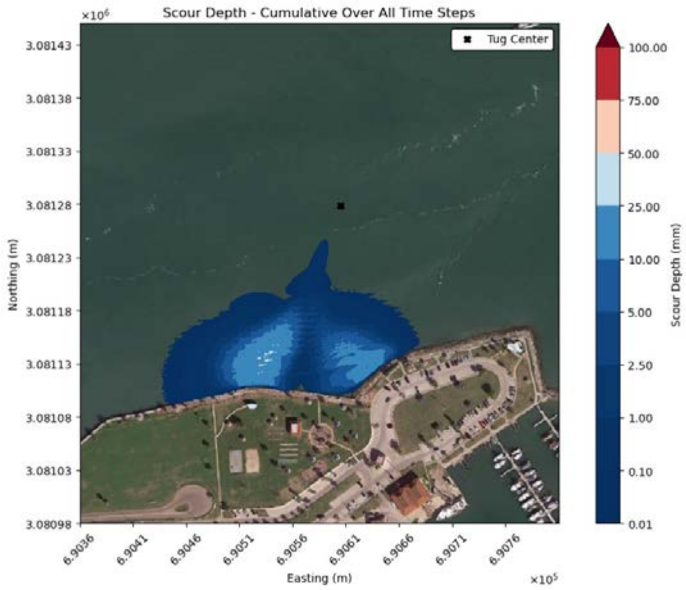

Figure 4.8: Potential Scour Area for Area 5

4.1.6 Alternative Area 1

From Figure 4.9, it is apparent that the areas of highest shear stress are located near the shoreline. This simulation was composed of two tugboats and resulted in the two plumes combining in between the tugs and extending along the shoreline.

Figure 4.10 presents the potential scour areas for this simulation. From Figure 4.10, the maximum scour potential is estimated to be 69.99 mm (2.76 in) and the total scour potential area is approximately 27213 m^2 (6.72 ac). Furthermore, from Figure 4.10 the scouring starts at the toe of slope and increases as the water depth decreases. However, the magnitude of the scour potential is small and likely not a concern for slope stability.

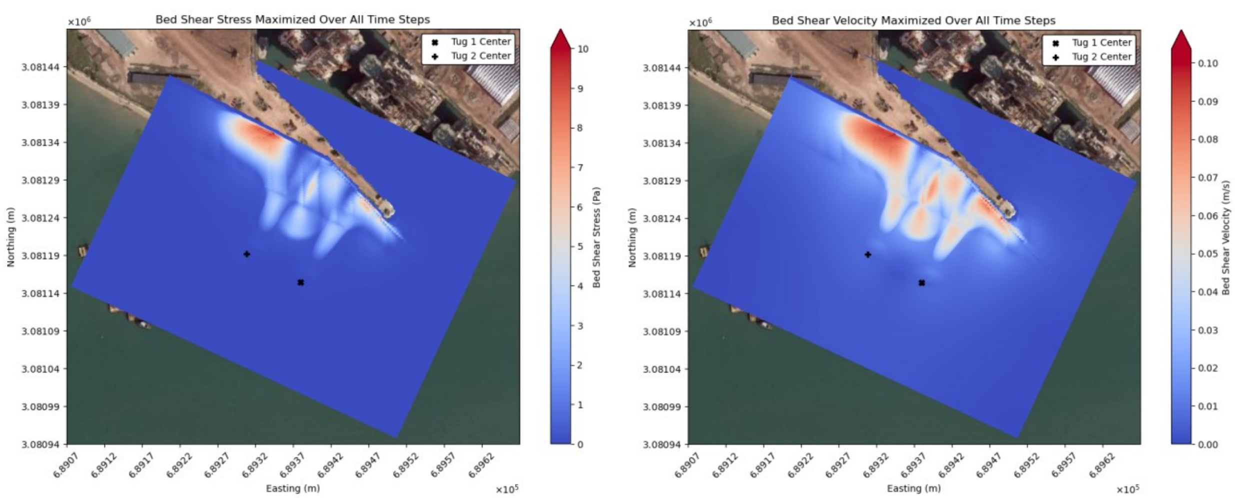

Figure 4.9: Alternative Area 1 Bed Shear Stress (Left) and Bed Shear Velocity (Right) Maximized Over All Time Steps

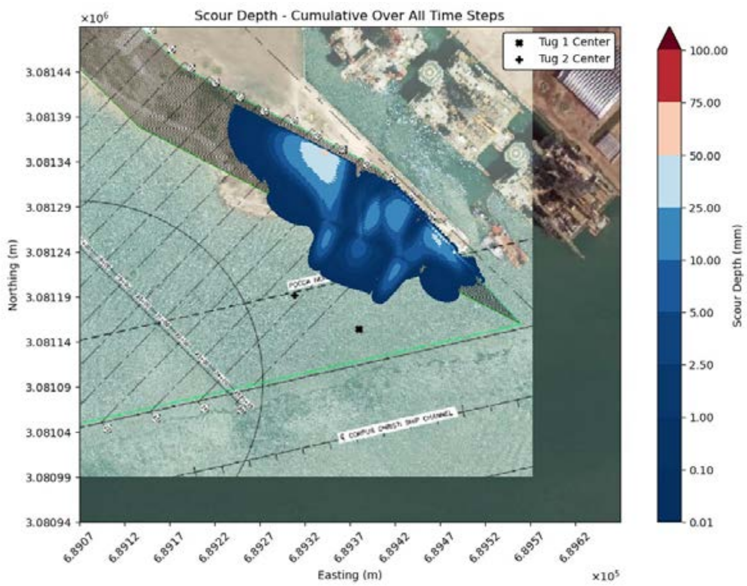

Figure 4.10: Potential Scour Area for Alternative Area 1

4.1.7 Alternative Area 2

From Figure 4.11, it is apparent that the areas of highest shear stress are located near the shoreline. The propeller wash is initially conical in shape but once it reaches the shoreline it splits to either side, similar to the other tug simulations. There is a breakwater located along the shoreline, however, the estimated scour potential is small and likely not a concern for undermining of the structure.

Figure 4.12 presents the potential scour areas for this simulation. From Figure 4.12, the maximum scour potential is estimated to be 10.82 mm (0.43 in) and the total scour potential area is approximately 15501 m^2 (3.83 ac).

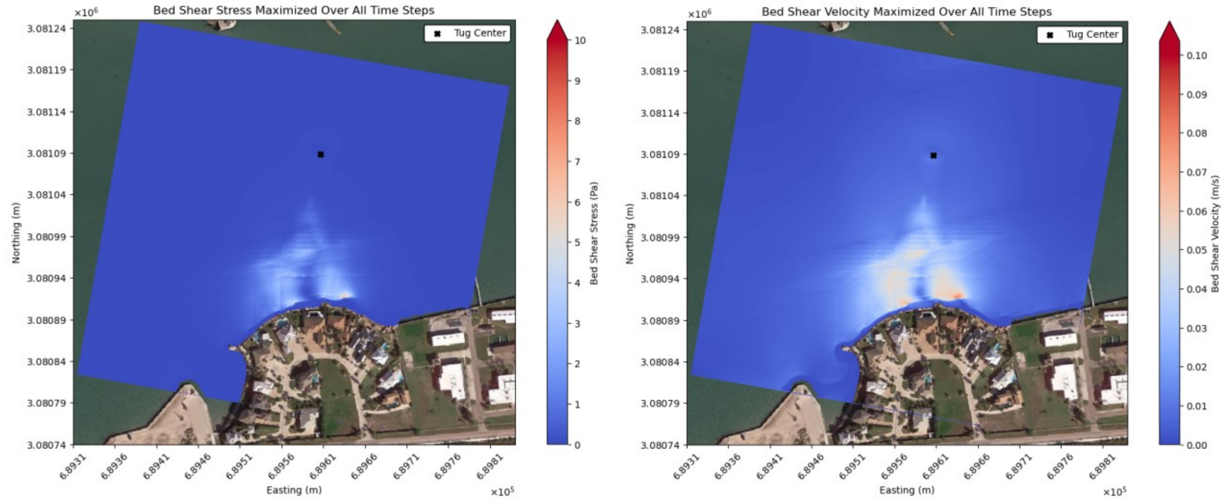

Figure 4.11: Alternative Area 2 Bed Shear Stress (Left) and Bed Shear Velocity (Right) Maximized Over All Time Steps

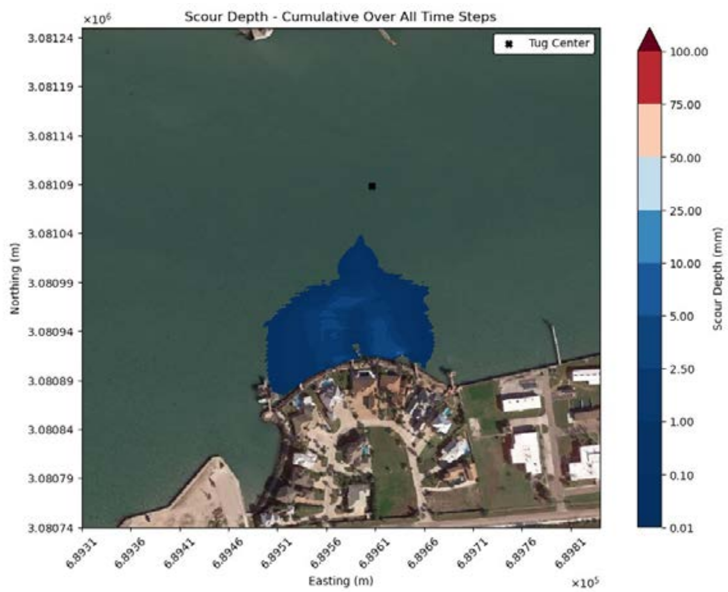

Figure 4.12: Potential Scour Area for Alternative Area 2

5. Conclusions and Recommendations

Baird has conducted a propeller scour study as part of the modeling services for the Corpus Christi Channel Deepening project. The project will be comprised of deepening the Outer and Approach Channels to 77 ft, and the Jetty Channel and seaward-most portion of the Corpus Christi Ship Channel to 75 ft. The channel will be used by vessels including laden VLCC's at a maximum draft of 68 ft departing from the planned Axis and Harbor Island terminals.

The propeller scour study consisted of the following tasks:

- Assessment of vessel maneuvers in the channel
- Model calibration of the VLCC and tug propellers
- Modeling propeller wash hydrodynamics
- Analytically assessing scour potential due to propeller wash

The vessel maneuvers modelled were based on simplified assumptions of vessel position and time, which were developed from the navigation simulations for both Harbor Island and Axis terminals. The presented maneuvers represent the likely scenarios where propeller induced scour might be an issue. If more navigation simulations are completed for these terminals, it is recommended to re-evaluate any new maneuvers that might cause propeller induced scour. Specifically maneuvers that result in a laden VLCC directing its wash towards the shore or structures and maneuvers where tugs are relatively close to the shore for an extended period of time are concerning for propeller induced scour.

The numerical model was calibrated to the analytical solution for propeller centerline velocities developed by Blaauw & van de Kaa (1978) and presented in PIANC (2015). As presented in Section 3, the VLCC propeller and a single tug propeller were both calibrated to the analytical formula in FLOW-3D®. However, Baird is not aware of any physical model data to validate the propeller centerline velocities for these specific propellers.

The propeller wash hydrodynamics was modelled with FLOW-3D® and the scour potential was quantified using an analytical approach. The analytical approach for quantifying scour potential was calibrated to the maximum scour hole depth achieved by a coupled sediment transport and hydrodynamic simulation of Area 3b (VLCC). Using the maximum scour hole depth from the coupled numerical model, the erodibility coefficient was changed in the analytical approach until it resulted in a similar maximum scour hole depth. For the sediment properties assumed in this study, the erodibility coefficient was determined to be 3.22 and the power of erosion was determined to be 1.5. The conclusions drawn for each area are as follows:

- Area 2:
  - For this maneuver, the submerged groin is unlikely to be uncovered due to propeller induced scour.
  - The maximum scour potential is 14.45 mm (0.57 in) and does not reach the shoreline. As such, this maneuver is unlikely to cause scour issues along the revetment at the shoreline.
- Area 3a (tug):
  - This maneuver resulted in scour at the wall located along the shoreline.
  - The maximum scour potential is 747.78 mm (2.45 ft) and is largest at the wall located along the shoreline.
  - This maneuver could result in undermining of the wall.
  - This maneuver may be a concern for slope stability as it scours the toe of slope and increases in scour potential as the water depth decreases.

- Area 3b (VLCC):
  - This maneuver resulted in the largest scour potential due to this simulation being a laden VLCC.
  - The maximum scour potential is 3787.15 mm (12.43 ft) and is largest near the propeller and in the dredged channel.
  - While there doesn't appear to be any risk for structures located along the shore, there could be additional risk for underkeel clearance depending on where the suspended sediment deposits.
  - Additionally, scour near the toe of slope for the dredged channel could be a concern for slope stability.
- Area 5
  - This maneuver resulted in scour at the revetment located along the shoreline.
  - The maximum scour potential is 29.38 mm (1.16 in) and is largest at the revetment.
  - Due to the scour potential being small it is not likely to be a concern for undermining of the revetment.
- Alternative Area 1
  - This maneuver resulted in scour along the shoreline.
  - The maximum scour potential is 69.99 mm (2.76 in) and is largest at the shoreline.
  - Due to the scour potential being small and there being no structures located at the shoreline, this maneuver is not a concern for scour potential.
- Alternative Area 2
  - This maneuver resulted in scour along the shoreline.
  - The maximum scour potential is 10.82 mm (0.43 in) and is largest at the shoreline.
  - There is a breakwater located along the shoreline, however, the estimated scour potential is small and unlikely to cause undermining of the breakwater.

Based on the results of the propeller scour study, the following conclusions can be made about the maneuvers that appear to cause the most scour potential. Additionally, general recommendations are also presented:

- Maneuvers associated with a laden VLCC could result in significant scour potential and sediment transport which may be problematic for underkeel clearance in the dredged channel, structures along the shoreline if the propeller is close to the shoreline (10 propeller diameters away), or slope stability.
- Maneuvers associated with a tug near the shoreline for an extending period of time (> 2mins) could result in significant scour potential and undermining of structures along the shoreline if these events occur frequently. They may also be a concern for slope stability.
- Baird recommends investigating the depth that pipelines and cables are buried to ensure they are not uncovered due to propeller scour.
- As Area 3 developed the largest scour potential, Baird recommends a monitoring program be put in place to monitor wall undermining at the shoreline and slope stability at the toe of slope. If scour is determined to be a potential issue for slope or structure stability, then bed armoring should be investigated as a mitigative solution.

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Appendix M

Underkeel Clearance Study

Note: The Section 508 amendment of the Rehabilitation Act of 1973 requires that the information in Federal documents be accessible to individuals with disabilities. The USACE has made every effort to ensure that the information in this appendix is accessible. However, this appendix is not fully compliant with Section 508, and readers with disabilities are encouraged to contact Mr. Jayson Hudson at the USACE at (409) 766-3108 or at SWG201900067@usace.army.mil if they would like access to the information.

Port of Corpus Christi Authority Channel Deepening Project

Underkeel Clearance Study

October 04 2021 | 13242.102.R1.RevA

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Port of Corpus Christi Authority Channel Deepening Project

Underkeel Clearance Study

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Revision	Date	Status	Comments	Prepared	Reviewed	Approved
A	10/04/2021	Draft	For Client Review	WvdM	SG	LW

Executive Summary

Freese & Nichols, Inc. (FNI) has engaged W.F. Baird & Associates Ltd. to provide coastal engineering and modeling services for the proposed Corpus Christi Channel Deepening project. The project will comprise deepening of the Outer and Approach Channels to 77 ft, and the Jetty Channel and seaward-most portion of the Corpus Christi Ship Channel to 75 ft. The channel will be used by vessels including laden VLCC's at a maximum draft of 68 ft departing from the planned Axis and Harbor Island terminals. A dynamic underkeel clearance (UKC) assessment as described in this report was part of these studies developed for the purposes of assessing project adequacy for the Environmental Impact Statement. The study included an analysis of measured water levels, assessments of modeled currents and waves, and modeling of vessel squat and wave response.

Vessels departing from the Axis terminal would accelerate to a speed of 6-8 knots (kn) in between the jetties. Speeds for departure from the closer Harbor Island terminal would be slightly less. Cruising speeds in the Approach and Outer channels are expected to be in the range of 8-10 kn. Maximum significant wave height for vessel departures was adopted as 10-12 ft, limited by disembarking of the pilot after the channel transit as reported by the Aransas Corpus Christi Pilots Association (ACCPA). Most common wave conditions are from SSE with peak periods of 7-9 s.

Maximum vessel squat was estimated to be 2.7 ft in the Jetty Channel at 6.5 kn speed over ground and against a 1.9 kn flood tide current. However, the maximum flood tide current occurs close to high tide. Ebb tide currents that are maximum around low tide limit the squat to 1.1 ft in the Jetty Channel. Squat at low tide with small current effects in the Approach and Outer Channels at 9 kn speed over ground was estimated at 2.3 ft. The resulting maneuverability margin (safety clearance, not including wave response) with a 10% annual probability (1 in 10 year) low water level condition has a minimum value of 4.7 ft in the Jetty Channel. This is greater than the recommended margin of 3.4 ft suggested by PIANC and greater than the required 2 ft safety clearance by USACE. It is recommended that departure speed profiles be analyzed after the planned navigation simulations and squat re-assessed based on these speed profiles if greater speeds are expected.

The minimum safety clearance for the design operational wave conditions was calculated at 4.5 ft in the Jetty Channel and 5.2 ft in the Approach and Outer Channels, which is compliant with the 2 ft safety clearance criterion established by USACE. Wave response in the Outer Channel increases considerably in longer swells for peak periods greater than 13 s, resulting in 1.9 ft of safety clearance, slightly outside of the USACE criterion. However, peak periods greater than 13 s have only occurred offshore of Corpus Christi infrequently including during hurricanes Katrina, Rita and Ike based on the 1980-2014 wave WIS hindcast of the area. It is recommended that port closure policies be checked for extreme hurricane scenarios to verify whether vessels would depart under extreme wave conditions with large peak periods.

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1. Introduction

1.1 Project Background

W.F. Baird & Associates Ltd. (Baird) was engaged by Freese & Nichols, Inc. (FNI) to provide coastal engineering and modeling services for the Corpus Christi Ship Channel Deepening Project (CDP). The project is the proposed deepening of the Offshore Channel to a nominal depth of 77 ft (Segments 1 and 2 in Figure 1.1), and the Entrance Channel and seaward-most portion of the Corpus Christi Ship Channel to 75 ft (Segments 3 to 6 in Figure 6.1). The channel will service the planned Harbor Island and Axis terminals with laden vessels, including very large crude carriers (VLCC's), departing from these terminals.

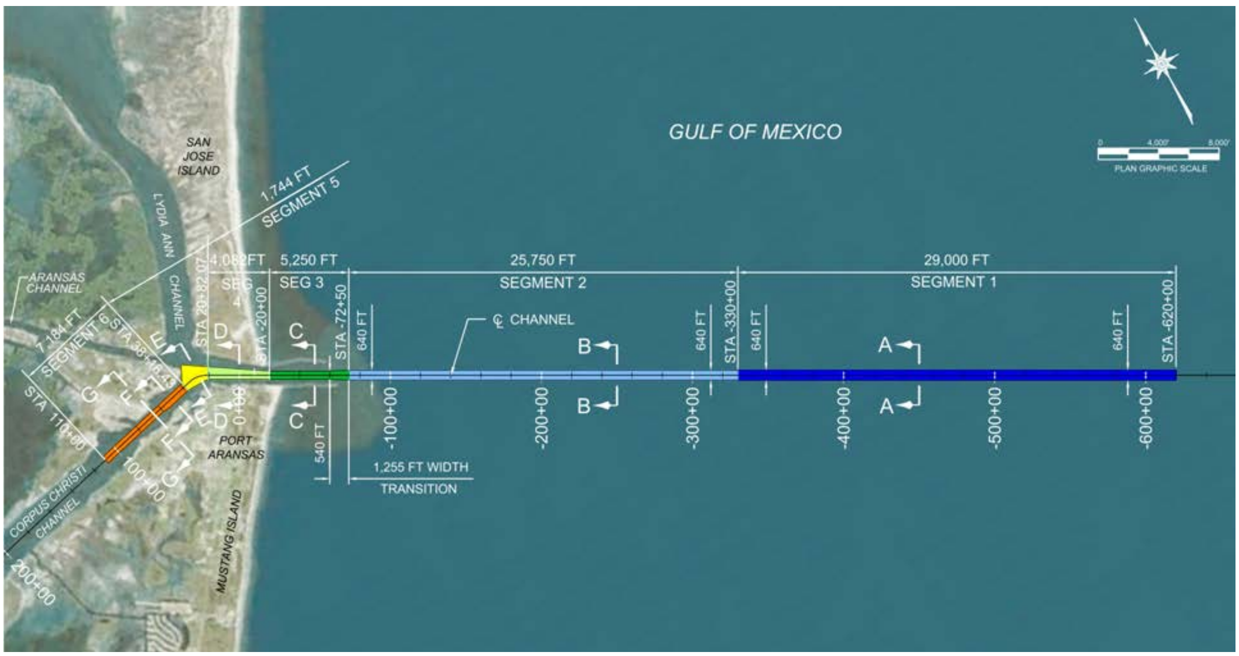

Figure 1.1: Dredging plan for the Corpus Christi Ship Channel Deepening Project

Baird's services include the following tasks:

- Vessel wake analysis
- Dynamic underkeel clearance (UKC) study
- Propeller scour study
- Tidal and hydrodynamic modeling
- Storm surge analysis
- Sediment transport modeling

The dynamic underkeel clearance study is addressed in this Report.

1.2 Study Objectives

The dredged depths for all channel segments have been proposed by the Port of Corpus Christi for the channel design. The objective of the UKC study is to verify adequacy these channel depths using analysis of water levels and the results of wave, hydrodynamic and vessel response modeling. The results of the vessel squat modeling may also be used as input to the planned navigation simulations.

1.3 Report Outline

This report provides a brief description of the numerical model that is used to determine vessel squat and wave response in Section 2. Input data to the UKC assessment are considered in Sections 3 and 4, with channel dimensions, vessel dimensions and vessel speed in Section 3, and water levels, currents and waves in Section 4. UKC criteria are described in Section 5 as set by USACE and adopted in this study. The study results are provided in Sections 6 and 7, with Section 6 focusing on squat and Section 7 considering the wave response and resulting safety clearance between the keel and the channel bed. Conclusions are provided in Section 8.

2. Vessel Response Numerical Model Description

2.1.1 General

Historically, squat was analyzed using squat formulas based on the results of a wide range of physical model test data. Numerical modeling of squat has become more widespread in the last decades with increased computer power. The advantage of numerical modeling is that the model can be better set-up for specific hull shapes, as well as channel geometries and local currents. Nevertheless, calibration and tuning to measurements remains important to account for limitations in the model.

The most common types of numerical models for squat predictions are (in order of complexity):

- slender body models,
- panel models,
- Computational Fluid Dynamics (CFD) models.

Slender body models compute the potential flow around the hull assuming that the vessel length is much greater than its width and draft. Limitations of these models exist when applied to relatively wide ships and for irregular shaped channel banks.

Panel models approximate the submerged vessel hull and channel geometry by a large number of flat quadrilateral panels. Similar to slender body models, the method is based on potential flow, but including 3D effects of both the vessel and channel geometry. The main limitation of panel models is that turbulent flow and propeller wash near the stern are not represented.

CFD models are potentially most accurate as it includes modeling of turbulent flows with the inclusion of propeller wash. However, it is difficult to generate and modify specific hull shapes and computationally demanding. Use of CFD models for squat predictions is at the moment mostly used in the research sphere.

2.1.2 Wavescat Model

Baird's in-house numerical model for squat and wave response "Wavescat" is a panel model. As such, it includes and can be easily set-up for various 3D hull shapes. Hull shapes of ships are usually provided as "body plans" describing the outline of the hull at several cross-sections along the ship from stern to bow. The body plan is transformed into a 3D panel mesh for input in Wavescat. An example of the body plan and hull mesh for a VLCC at 68 ft draft in Wavescat as used in this study is shown in Figure 2.1.

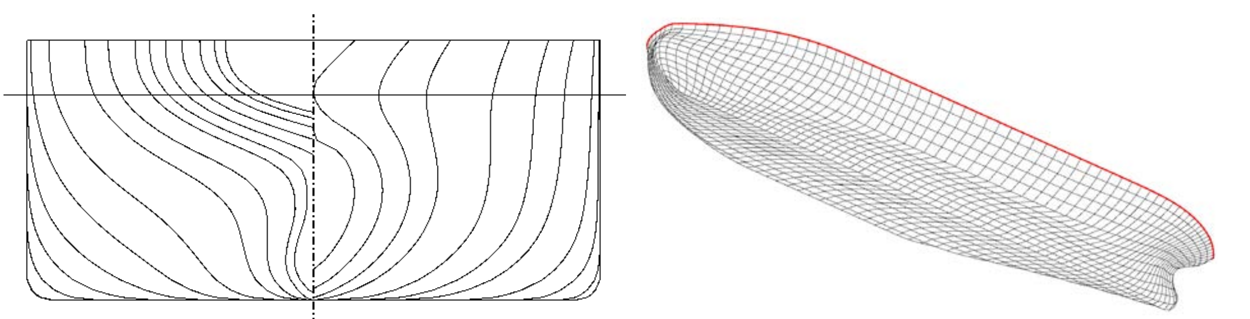

Figure 2.1: Body plan (left) and Wavescat hull mesh (right) for a VLCC

Wacescat is a 3D potential flow and diffraction model based on the free surface Green function. Aside from the hull mesh, panels can be placed on bathymetric features such as channel banks to model bank suction effects on maneuvering forces and squat. The channel bed is assumed horizontal elsewhere. The vessel speed in the model is the speed through water.

Model results include (relevant components for this study in bold):

- **squat,**
- **wave Response Amplitude Operators (RAO's),**
- wave forces,
- drift forces,
- hydrodynamic coefficients (added mass and damping).

The squat result is a midship squat and dynamic trim angle. The squat at bow and stern can be obtained from these two values. The vessel response to a certain sea state can be obtained from the RAO's in 6 degrees of freedom and wave spectrum for all wave frequencies and directions. The sinkage of keel points (bow, stern, port and starboard sides) can be obtained from the response in heave, roll and pitch at the center of gravity.

3. Physical Data Overview

3.1 Vessel Dimensions

The design vessel for the project is a 306k DWT VLCC laden to a draft of 68 ft. The vessel dimensions used in the UKC modelling are in accordance with the data of the vessel used during the navigation simulations provided in Table 1.

Table 3.1: Dimensions of VLCC at 68 ft draft

Designation	(m)	(ft)
Length Over All	332.00	1089.2
Width	58.00	190.3
Draft (Scantling)	22.50	73.8
Draft (Modeled)	20.73	68.0
Deadweight (at Scantling Draft)	306,200 MT	337,500 ST
Displacement (at Modeled Draft)	321,000 MT	353,800 ST

3.2 Channel Dimensions

The assessment of squat and wave response in the channel was done for four channel segments, the Harbor Island Transition Flare (HITF), Jetty Channel, Approach Channel and Outer Channel. These are channel segments 1-4 in Figure 1.1, ordered outward from the port, i.e. in the departing sailing direction. The channel dimensions as provided in the Project Description (Port Corpus Christi, 2019) are given in Table 3.2. The stated bed level that is assumed in the modeling and analysis is the authorized bed level. The channel will be dredged deeper to accommodate sedimentation that is expected to occur up to the guaranteed bed level before subsequent maintenance dredging occurs (i.e,, advanced maintenance dredging).

Table 3.2: Channel Depth and Width for the considered channel sections

Seg.	Name	Length (ft)	Bed Width (ft)	Depth (ft MLLW)	Side Slopes (V:H)
4	Harbor Island Transition Flare	4,082	540*	−75	1:3
3	Jetty Channel	5,250	540	−75	1:3
2	Approach Channel	25,750	640	−77	1:10
1	Outer Channel	29,000	540	−77	1:10

* Minimum width – channel widens to the Harbor Island turning basin

The actual channel in between the jetties is wider due to scour that has occurred on the southern side of the channel. The channel profiles used for the squat modelling presented here are the “typical sections” provided in the Project Description and shown in Figure 3.1 for the Jetty Channel. The section for the Harbor Island Transition Flare was narrowed to a 540 ft bed width representing a section on the eastern side of this segment.

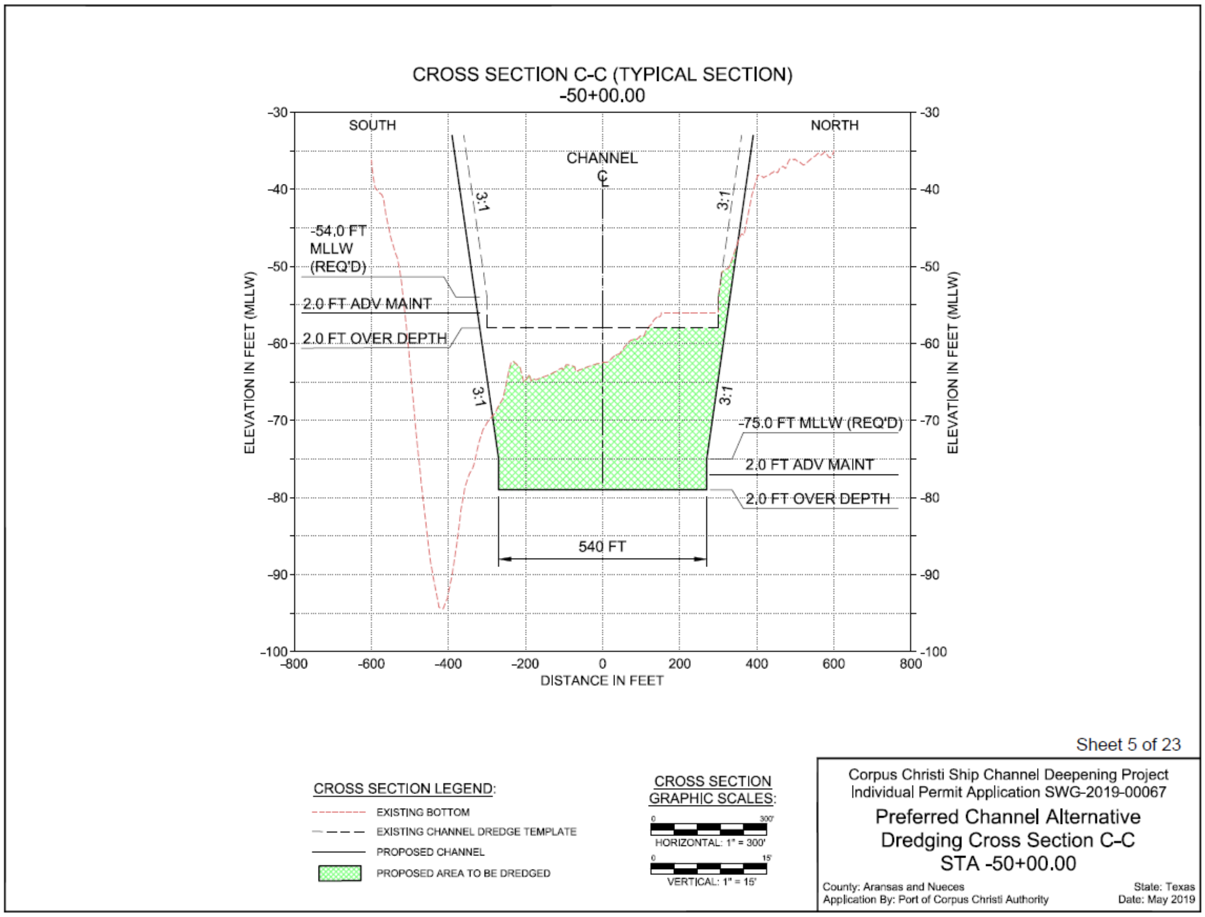

Figure 3.1: Typical channel cross-section in between the jetties (Port Corpus Christi, 2019)

3.3 Vessel Speed

3.3.1 Navigation Simulations

Navigation simulations were conducted as part of the project for the Harbor Island (SCI, 2019; WST & MITAGS-PMI, 2020) and Axis terminals (SCI, 2020). Several departure runs were conducted in these studies with the VLCC at 70 ft draft, sailing from the Harbor Island or Axis terminals to sea following the channel between the jetties. Speed profile data are provided for some of these runs and are summarized in Table 3.3.

The speed in between the jetties is generally around 9 kn but can be larger in an ebb tide when the vessel accelerates faster. Flood tide conditions are governing for speed through water (i.e., against an opposing current) which is most relevant to this study. The vessel continues accelerating in the approach channel.

Table 3.3: Summary of navigation simulation results in between the jetties with vessel speed over ground from the run data and estimates of current speed and vessel speed through water between the jetties

Facility	Terminal	Run #	Current		Speed between Jetties (kn)		Speed (kn)
			Condition	Speed (kn)	Over Ground	Through Water	Approach Ch.
SCI	Harbor Island	9	Flood	2	7.9	9.9	11.6
SCI	Harbor Island	11_2	Flood	2	9.2	11.2	-
SCI	Harbor Island	14	Ebb	2	12.0	10.0	-
SCI	Axis	10	Flood	2	9.6	11.6	-
WST	Harbor Island	13	Ebb	1	9.1	8.1	9.3
WST	Harbor Island	14	Flood	1	9.4	10.4	12.0
WST	Harbor Island	15	Ebb	2	10.6	8.6	12.0

3.3.2 AIS Analysis

Automatic Identification System (AIS) data of 50 VLCC departures from the terminal at Ingleside were also analyzed to verify vessel speeds during existing operations. Since these are historic departures the maximum draft would be 45 ft. The departure tracks are shown in Figure 3.2. The analyzed stretch of the tracks is from the bend in the channel at Harbor Island beyond the end of the existing channel up to a distance of 8.1 nm away from the bend, marked with a red line in Figure 3.2.

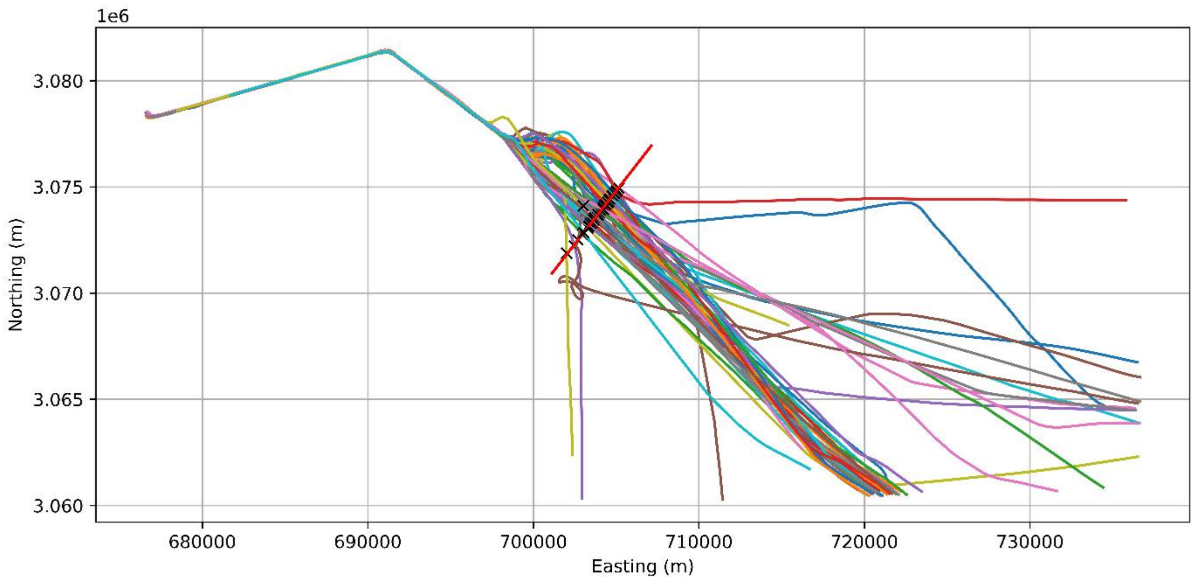

Figure 3.2: Tracks of 50 departures in the AIS data from the Ingleside terminal to sea; 8.1 nm distance away from the bend at Harbor Island marked in red

The speed profiles of the departures are plotted in Figure 3.3 according to the percentiles in the dataset. The head of the jetties are located approx. 1.4 nm away from the bend. The vessels reach a speed of 9-10 kn on average at the end of the jetties and continue to accelerate to an average speed of 11 kn before the end of the existing channel. The drop in speed after the end of the channel is assumed to be to allow a safe drop-off of the pilot to the pilot boat.

The speed in the Jetty Channel is affected by currents. This was analyzed by estimating the speed through water for the 50 AIS transits using the measured current data at Aransas Pass in the Jetty Channel. The results are summarized in Table 3.4. The probability distribution of the speed through water is narrower (more confined) than the distribution of the speed over ground, meaning that the speed over ground is lower in flood currents and higher in ebb currents. However, the difference is not fully due to current speeds. The difference in vessel speed is approx. 0.5 kn, while the current speeds are 1-2 kn. Hence, the variability in speed over ground is more due to other effects than due to current speeds and the speed through water is usually larger in flood currents.

Table 3.4: Probability distribution of speed over ground, speed through water and current velocity (positive for flood currents) in the Jetty Channel

Percentile	Speed over Ground (kn)	Speed through Water (kn)	Current Vel. (kn)
10	7.0	7.5	−1.8
20	7.5	8.0	−1.1
50	9.1	9.2	+0.4
80	10.4	10.1	+1.6
90	10.8	10.5	+2.1

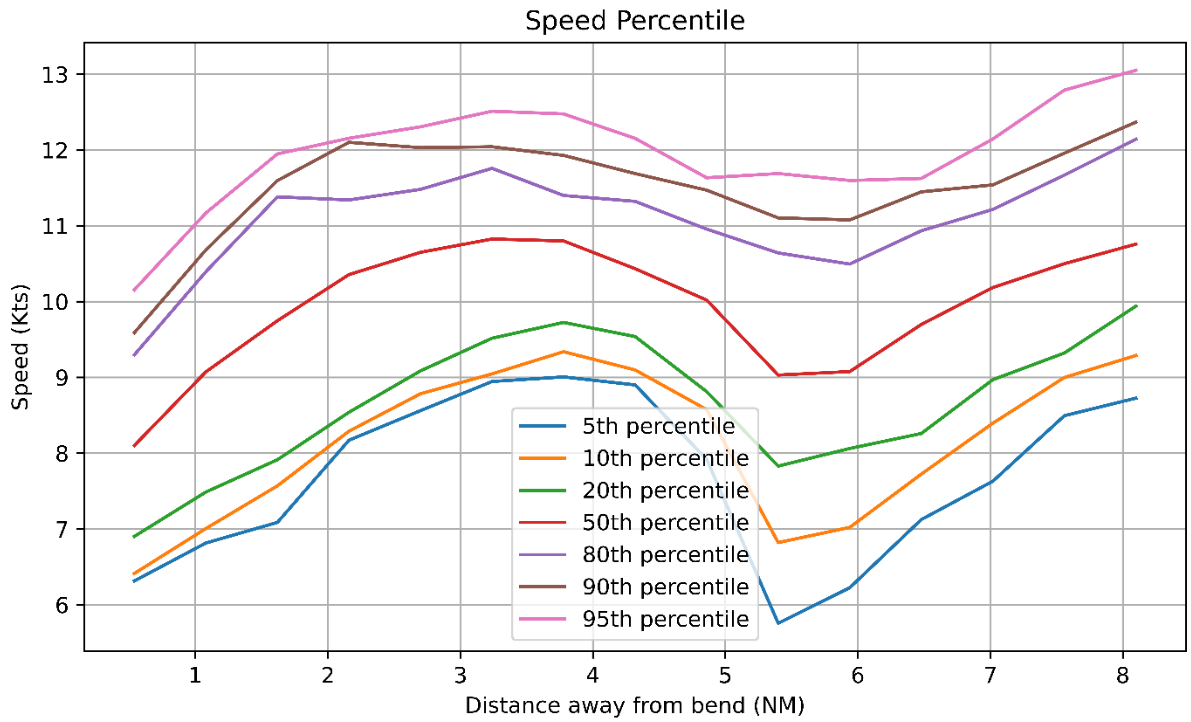

Figure 3.3: Percentile plot of speed profiles from the 50 VLCC departures in the AIS data from the bend near Harbor Island out to sea

3.3.3 Discussion

The vessel speeds observed in the navigation simulations and AIS data agree reasonably well. The vessel reaches a speed of about 9 kn in between the jetties and accelerates to a speed of about 11 kn further down the approach channel. However, based on knowledge and experience of the pilots, it is expected that VLCC's laden to a draft of 68 ft will accelerate much slower than the present vessels at 45 ft draft. Expected speeds over ground in the Jetty Channel are 6-8 kn when departing from the Axis Terminal and 5-7 kn when departing from the Harbor Island terminal. Cruising speeds in the Approach and Outer Channels would also be lower than the existing fleet with a speed of 8-10 kn expected.

Based on the assessment of speed through water from the AIS data, it is estimated that vessels will sail approx. 0.5 kn slower over ground in flood currents and 0.5 kn faster in ebb currents, compared to departures around slack tide with no currents present.

4. Metocean Conditions

4.1 Water Levels

Measured water level data are available from the Port Aransas (8775237) and Aransas Pass (8775241) stations. The Port Aransas station is located opposite the planned Axis terminal and the Aransas Pass station is located on the north slopes of the Jetty Channel. Near-continuous records are available from both stations from January 2017 through May 2021. The Mean Lower Low Water (MLLW) datums relative to NAVD88 at both stations are:

- Port Aransas: −0.15 ft
- Aransas Pass: −0.59 ft

The water levels are influenced by a combination of tidal and meteorological effects. Tides are dominated by a diurnal signal with a range in the order of 1-2 ft. Meteorological effects are in the same order of magnitude. The tides were removed from the records by taking a moving average over a period of 25 hours to analyze the meteorological effects. The time series of these averaged water levels for the Aransas Pass station are given in Figure 4.1. Water levels are usually lowest in January with another episode of low water levels in July and August. The monthly average water levels are given in Table 4.1.

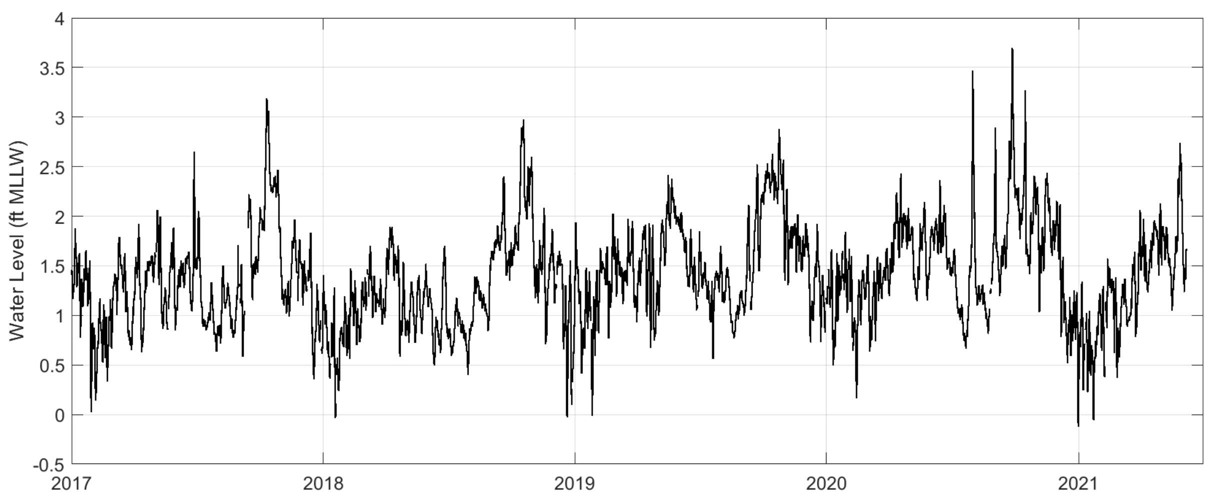

Figure 4.1: Measured water levels at Aransas Pass with tides removed

Table 4.1: Monthly average water levels (ft MLLW)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Port Aransas	0.81	0.81	1.02	1.32	1.41	1.29	0.94	1.00	1.58	1.98	1.49	1.02
Aransas Pass	0.99	1.07	1.27	1.52	1.54	1.45	1.12	1.16	1.73	2.22	1.62	1.15

Extreme low water levels were estimated from the five yearly lowest water levels in the measurements. A Gumbel fit was applied to provide estimates for different return periods provided in Table 4.2. The instantaneous water levels were obtained from the raw water level records, i.e. including tidal and meteorological effects. The mean-tide water levels were obtained from the records with the tides removed.

Table 4.2: Extreme low water levels (ft MLLW) obtained from the measured wave data from 2017-2021

Return Period (Years)		1	2	5	10	20
Instantaneous Water Level	Port Aransas	−1.00	−1.11	−1.27	−1.38	−1.50
	Aransas Pass	−1.08	−1.22	−1.41	−1.55	−1.69
Mean-tide Water Level	Port Aransas	−0.18	−0.24	−0.32	−0.39	−0.45
	Aransas Pass	+0.04	−0.02	−0.09	−0.15	−0.21

4.2 Currents

The current conditions along the channel were taken from the results of hydrodynamic modeling using the hydrodynamic model developed for this project for the sedimentation analysis (reported separately) which is forced on the offshore boundaries by the HYCOM model (Chassignet et al., 2007). A period of 19 days was modeled, January 5-23, 2020, to cover at least one spring-neap cycle. The resulting time series of water levels and current velocities for the Jetty Channel are provided in Figure 4.2. The plotted current velocities are the longitudinal current velocities (along the channel), positive for inward flowing (flood tide) currents. The peak of flood tide currents occurs close to high tide and the peak of ebb tide currents occurs close to low tide. This has a positive effect on the UKC of departing ships as the peak flood currents that enhance squat occur at higher water levels.

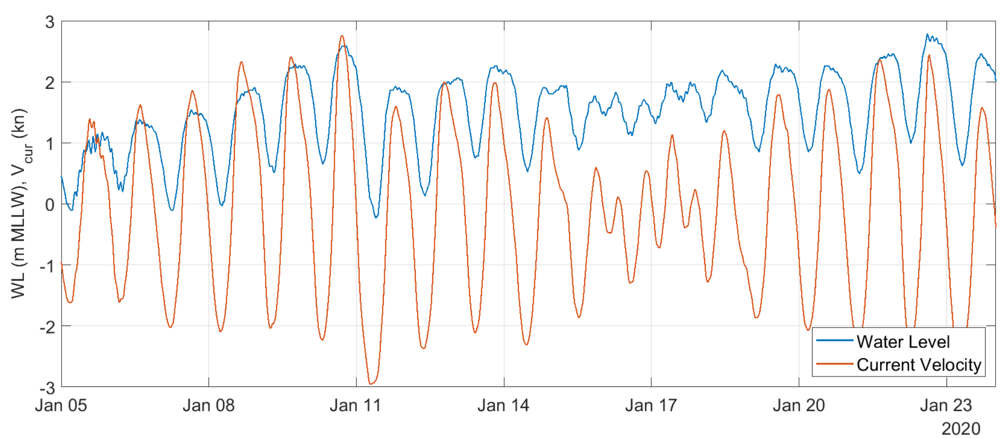

Figure 4.2: Modeled water levels and longitudinal current velocities in the Jetty Channel; outward flowing (ebb) currents negative, inward flowing (flood) currents positive

Three tide conditions were selected for the UKC assessment from January 7. This tide cycle was selected as an average spring tide condition with a relatively low low water. The three conditions are defined as follows:

- Ebb tide – Ebb currents coinciding with the minimum water level
- Slack tide – instance between low and high water closest to the moment when the current direction changes

- Flood tide – strongest flood current (occurring close to high tide)

The ebb and flood tide longitudinal current speeds along the channel are presented in Figure 4.3. The water level and current velocities at the four channel segments are given in Table 4.3 and Table 4.4, respectively.

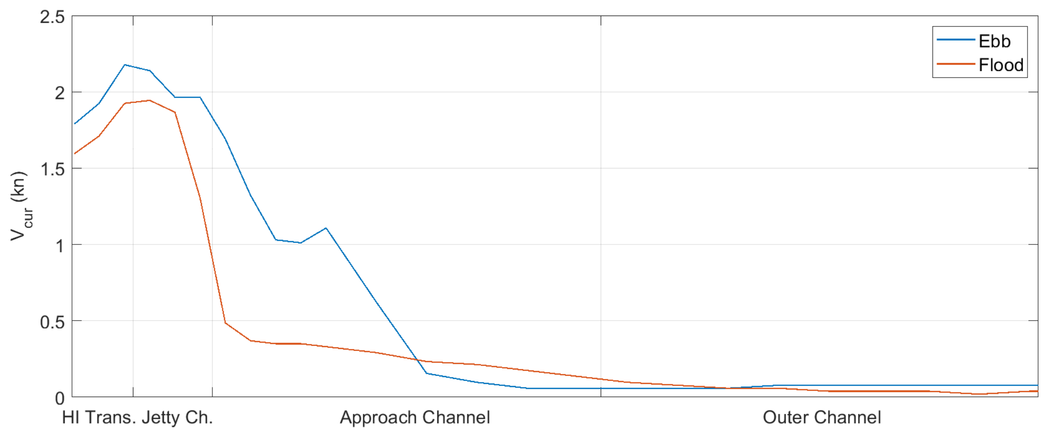

Figure 4.3: Longitudinal Current speeds along the channel at the considered ebb and flood conditions

Table 4.3: Water levels relative to mean tide (ft) for the three considered tide conditions

	HI Transition	Jetty Channel	Approach Channel	Outer Channel
Ebb	−1.05	−1.02	−0.98	−0.95
Slack	+0.07	+0.10	+0.13	+0.16
Flood	+0.56	+0.59	+0.82	+0.82

Table 4.4: Longitudinal current velocities; outward flowing (ebb) currents negative, inward flowing (flood) currents positive

	HI Transition	Jetty Channel	Approach Channel	Outer Channel
Ebb	−2.17	−1.96	−0.08	+0.01
Slack	−0.03	−0.04	+0.03	+0.05
Flood	+1.92	+1.86	+0.19	+0.02

4.3 Wave Conditions

The wave conditions along the Port of Corpus Christi channel were determined using near-shore wave transformation modelling for specific offshore wave conditions. A set of design and operational offshore wave conditions is provided in this Section from analysis of the 35-year (1980-2014) WIS model (Hubertz, 1992) hindcast data at 30 m water depth. These conditions were used as input for wave transformation modeling.

4.3.1 Extreme Wave Conditions

WIS hindcast data are available from Station 73040 (27.75° N, 96.8° W) at 30 m water depth. Significant wave height (H_{m0}) is less than 6 ft for approx. 90% of the time. Larger wave conditions with H_{m0} greater than 10 ft occur in advance of landfall of hurricanes during the hurricane season (June through October) and during strong cold fronts in the fall and winter (November through March). A list of 107 storms with peak significant wave heights greater than 10 ft was compiled from the 35-year hindcast. 25 storms occurred during the hurricane season and 82 storms outside the hurricane season. However, the largest wave events coincide with hurricanes.

Vessels will not depart from Port Corpus Christi in very large wave conditions, particularly due to constraints with pilot disembarking in open water after departure. Largest wave heights for departure are typically 10-12 ft as indicated by the pilots. It is further expected that departures will not occur in severe wind conditions. It is expected that vessels will not depart in gale force winds with a 34 kn wind speed or higher. These assumptions were verified using a list of historic channel closures from mid-2016 until the end of 2019. The closure periods are overlayed on the wave height and wind speed time series from offshore WIS hindcast data (2015-2019 extended dataset). Many closures occur for wave heights less than 10 ft and wind speeds less than 34 kn. However, there are four occurrences of wave heights of 10-12 ft when the channel was open (in Nov. and Dec. 2016, Oct. 2017 and Dec. 2018), and similarly several occurrences of wind speeds close to 34 kn.

The storm list was developed to include the peak of the storm for storms with H_{m0} of 10-12 ft and wind speeds less than 34 kn, and a time before or after the peak for storms with H_{m0} greater than 12 ft or wind speed greater than 34 kn. A scatter plot of peak period and mean wave direction for all storms is provided in Figure 4.4. Most events are outside the hurricane season with a SSE wave direction and peak period of 8 s. Some NE events also occurred, mainly outside the hurricane season, and longer-period events occurred in conjunction with hurricanes. Three events with peak periods close to 16 s are interesting outliers as these would result in a significantly larger response for departing ships. The three events were caused by the well-known hurricanes Katrina, Rita and Ike, all of which had landfall locations considerably north and east of Port Aransas. Data for these three hurricanes are indicated in Table 4.5. Hurricane Harvey is not in the list as it occurred after the end of the WIS data in 2014.

Table 4.5: Summary data for three hurricanes causing long swells with T_p > 15 s; hurricane Saffir-Simpson category, minimum pressure and maximum sustained wind speed are the data at the peak in the Gulf of Mexico; wave height and period data are at the peak of the event at the Corpus Christi WIS wave hindcast location

Date	Name	Cat.	Landfall	Press. (mbar)	Wind Spd. (kn)	H_{m0} (ft)	T_p (s)
Aug 29, 2005	Katrina	5	Louisiana	902	150	11.8	16.3
Sep 23, 2005	Rita	5	Louisiana	895	155	11.7	15.4
Sep 12, 2008	Ike	2	Texas	950	95	11.8	15.9

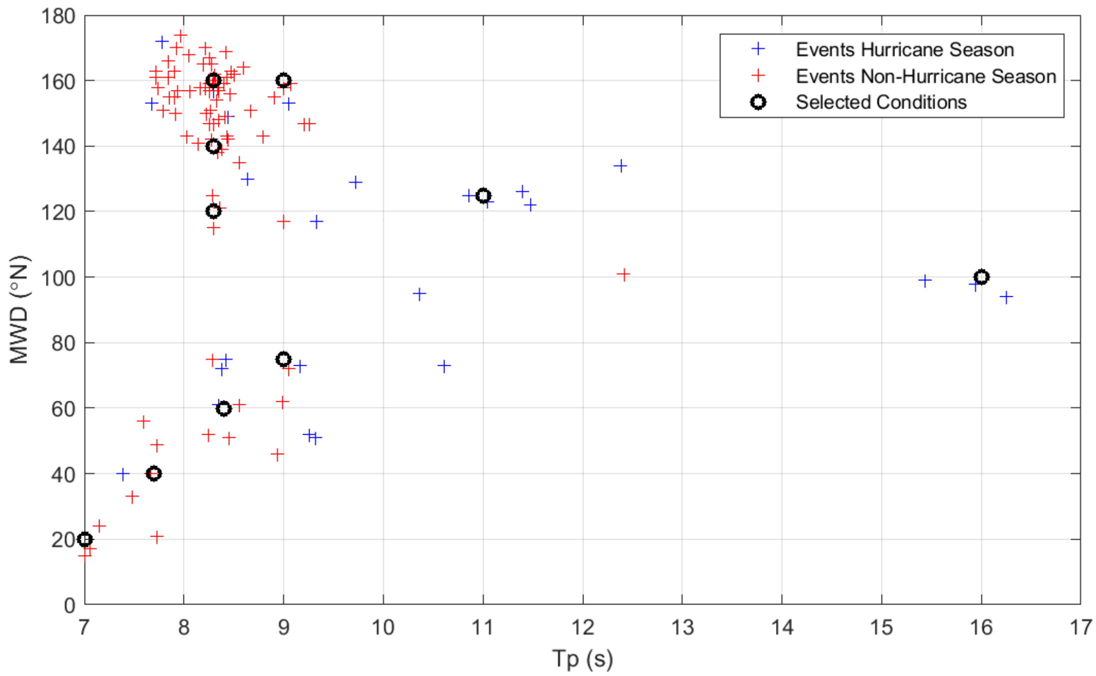

Figure 4.4: Scatter plot of mean wave direction against peak period for all storms with H_{m0} of 10-12 ft and wind speed < 34 kn from the 1980-2014 WIS hindcast at Station 73040

Table 4.6: Wave parameters for the ten selected conditions for input in the wave transformation modelling at 30 m water depth; sensitivity conditions are shaded

#	H_{m0} (ft)	T_p (s)	MWD (°N)	Spreading (°)	γ_0
1	12	7.0	20	30	2
2	12	7.7	40	30	2
3	12	8.4	60	30	2
4	12	9.0	75	30	2
5	12	8.3	120	25	1
6	12	8.3	140	25	1
7	12	8.3	160	25	1
8	12	9.0	160	25	1
9	12	11.0	125	30	1
10	12	16.0	100	10	3

Ten wave conditions were selected for input in the underkeel clearance modelling and as such for input in the near-shore wave transformation modeling. These wave conditions are highlighted as circles in Figure 4.4 and the wave parameters are given in Table 4.6. These wave conditions cover most relevant storms in the hindcast. Although the hurricane cases do not represent day-to-day operational conditions, they were used as sensitivity analyses for the model.

The significant wave height was chosen at the upper-bound of the 10-12 ft threshold for pilot disembarking. The peak period and mean wave direction were selected from the scatter plot. The conditions with peak periods of 7-9 s are considered as design operational events, while the longer-period conditions are added for sensitivity. Directional spreading was estimated from the average spreading in the related storm events and the JONSWAP peak enhancement factor γ_0 was estimated from the ratio between the peak and mean period (Tm01). The SSE events are generally more developed with a spectral shape close to Pierson-Moskowitz, while the longer-period events are due to swells from distant hurricanes with narrower spectra.

4.3.2 Operational Wave Conditions

Less extreme operational wave conditions are considered for UKC modelling combined with extreme low water levels. From the assessment of extreme low water levels, it appeared that there is no or no strong relationship between wave conditions and low water levels. Therefore, less extreme operational wave conditions will be considered than the extreme wave conditions for departure.

The occurrence of wave height against peak period for the entire 35-year WIS hindcast data is given in Table 4.7. The peak period is less than 8 s for approx. 93% of the time. The most probable peak period increases slightly for larger wave heights.

Table 4.7: Occurrence table of significant wave height against peak period from the 1980-2014 WIS hindcast

	Wave Period (s)											
Wave Height (m)	2.00-3.00	3.00-4.00	4.00-5.00	5.00-6.00	6.00-7.00	7.00-8.00	8.00-9.00	9.00-10.00	10.00+	Total	C(%)	Maximum Period (s)
0.00-0.30	0.14	0.70	1.07	0.33	0.43	0.35	0.29	0.18	0.11	3.61	100.00	16.03
0.30-0.61	0.21	2.34	6.98	5.44	1.62	0.59	0.27	0.08	0.07	17.59	96.39	18.68
0.61-0.91	0.00	1.31	7.69	9.11	5.78	1.69	0.41	0.08	0.05	26.13	78.80	16.96
0.91-1.22		0.17	3.70	7.93	5.81	2.57	0.76	0.17	0.09	21.20	52.68	16.39
1.22-1.52		0.02	1.01	5.20	4.73	2.34	0.87	0.29	0.08	14.54	31.47	15.35
1.52-1.83		0.00	0.28	1.69	3.61	1.58	0.52	0.19	0.10	7.95	16.93	16.48
1.83-2.13			0.05	0.51	2.06	1.27	0.46	0.12	0.08	4.56	8.98	15.20
2.13-2.44			0.00	0.19	0.75	0.90	0.30	0.07	0.06	2.28	4.42	15.27
2.44-2.74				0.05	0.19	0.54	0.22	0.05	0.06	1.11	2.14	15.87
2.74-3.05				0.00	0.05	0.24	0.18	0.04	0.03	0.54	1.04	16.16
3.05-3.35					0.01	0.06	0.14	0.03	0.02	0.27	0.49	16.41
3.35-3.66					0.00	0.01	0.07	0.02	0.01	0.12	0.23	16.59
3.66+					0.00	0.00	0.02	0.02	0.06	0.11	0.11	17.30
Totals	0.36	4.54	20.78	30.45	25.04	12.17	4.50	1.34	0.82	100.00		

Based on the occurrence table in Table 4.7, ten operational wave conditions were selected as input conditions for wave transformation modeling as shown in Table 3. Eight wave conditions are for wave heights of 2-9 ft combined with the median occurrence peak period with each wave height. The last two conditions for longer swell events that occur infrequently but may lead to larger vessel response and will be used for a sensitivity analysis in the UKC assessment.

Table 4.8: Wave parameters for the ten selected conditions for input in the wave transformation modelling at 30 m water depth; sensitivity conditions are shaded

#	Exceeedance	H_{m0} (ft)	T_p (s)	MWD (°N)	Spreading (°)	γ_0
11	79%	2	5.0	130	25	1.2
12	53%	3	5.5	130	25	1.2
13	31%	4	6.0	140	25	1.2
14	17%	5	6.4	140	25	1.2
15	9%	6	6.7	140	25	1.2
16	4%	7	7.0	150	25	1.2
17	2%	8	7.3	150	25	1.2
18	1%	9	7.6	150	25	1.2
19	-	5	8.5	110	25	1.0
20	-	6	10.0	90	20	1.0

4.3.3 Wave Modeling Results

Significant wave height and mean wave direction were extracted from the wave transformation model results along the channel centerline. The significant wave height along the channel for four of the prominent wave conditions is presented in Figure 4.5. The wave height along the channel declines more rapidly along the Outer and Approach channels for the longer-period events (9 and 10) than the for the events with more common peak periods, as the longer swells refract more away on the channel side slopes. Moreover, a wave direction more in line with the channel orientation enhances this refraction effect.

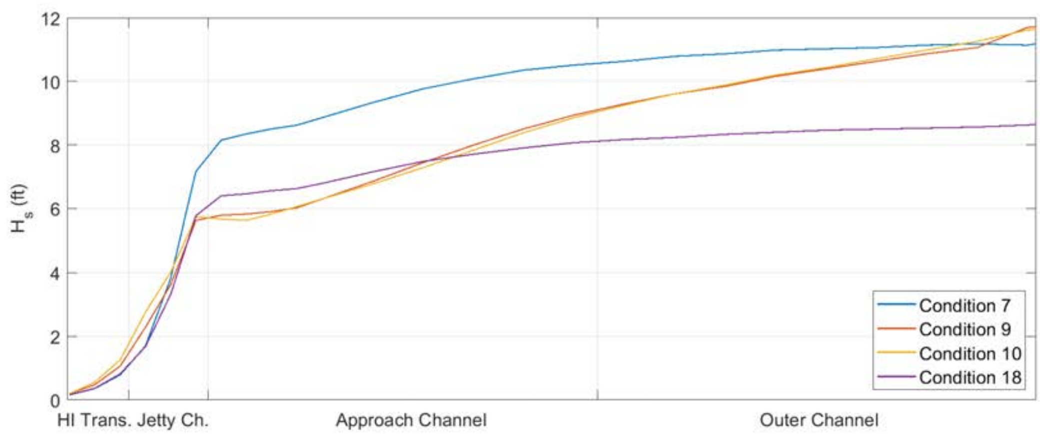

Figure 4.5: Significant wave height along the channel for three extreme wave conditions (7, 9 and 10) and one operational wave condition (18)

Wave modeling results for input to the UKC calculations were obtained from characteristic locations in the four channel segments:

- Harbor Island Transition Flare: STA −2,000 ft
- Jetty Channel: STA −6,000 ft
- Approach Channel: STA −25,000 ft
- Outer Channel: STA −55,000 ft

The significant wave height and mean wave directions at these locations are given in Table 4.9.

Table 4.9: Significant wave height and mean wave direction for all wave conditions; sensitivity conditions are shaded

Cond.	Sign. Wave Height (ft)				Mean Wave Dir. (°N)			
#	HITF	Jetty Ch.	Appr. Ch.	Outer Ch.	HITF	Jetty Ch.	Appr. Ch.	Outer Ch.
Extreme Wave Conditions								
1	1.1	3.1	3.8	4.7	113	87	70	55
2	1.9	5.3	6.2	7.0	113	96	82	67
3	2.4	6.8	8.4	9.2	113	96	90	79
4	2.6	7.1	9.2	10.4	113	99	95	88
5	2.1	6.2	9.1	11.2	116	118	121	121
6	1.5	6.0	9.5	11.2	121	136	142	140
7	1.1	6.3	10.1	11.1	128	144	153	156
8	1.0	5.9	9.8	11.1	128	143	152	156
9	1.5	5.1	8.0	10.9	117	124	128	126
10	1.8	5.3	7.8	11.0	115	106	107	106
Operational Wave Conditions								
11	0.8	1.7	2.0	2.0	116	127	130	130
12	1.0	2.4	3.0	3.0	116	127	130	130
13	1.0	2.9	3.8	3.9	119	136	140	140
14	1.1	3.4	4.7	4.9	119	136	140	140
15	1.1	3.9	5.5	5.8	120	136	141	140
16	1.0	4.4	6.4	6.7	124	142	149	149
17	1.1	4.8	7.2	7.6	124	142	149	149
18	1.1	5.1	7.9	8.5	124	141	149	149
19	1.0	2.7	4.0	4.7	115	110	112	111
20	1.2	3.3	4.7	5.5	114	102	100	97

5. Underkeel Clearance Criteria

The design of the Corpus Christi channel is recommended to be in accordance with USACE (2006) guidelines. The water level, draft, UKC and bed level components in the depth design of the navigation channel are shown in Figure 5.1 and defined as follows:

- Water level: indicated at Mean Lower Low Water (MLLW) but chosen at more extreme low waters in combination with operational wave conditions for the Corpus Christi channel due to the effect of seasonal and meteorological conditions on the water levels.
- Draft of the design ship: 68 ft.
- Effect of freshwater: ignored here as the draft is determined prior to departure in water with the same. density as in the channel.
- Wave response: according to wave response modeling for the selected wave conditions.
- Squat: according to vessel squat modelling.
- Safety clearance: USACE (2006) recommends a minimum of 2 ft clearance for regular sandy or silty channel bed types as present in the Corpus Christi channel.
- Authorized channel level: according to the channel design parameters listed in Table 3.2.
- Advance maintenance: 2 ft according to the Project Description (Port Corpus Christi, 2019).
- Dredging tolerance: 2 ft according to the Project Description (Port Corpus Christi, 2019).

PIANC (2014) also provides a recommendation for a maneuverability margin, which is defined as the clearance between the lowest point of the keel including effects from squat and heeling and the maneuverability bed level (equal to the authorized channel level here). A clearance of at least 5% of the draft is recommended for maneuverability, i.e. 3.4 feet for the VLCC at 68 feet draft. Heeling is ignored as this is negligibly small for laden VLCC's that are very stable and have relatively small windage areas.

It is assessed here that the design of the Corpus Christi channel is required to be in accordance with USACE (2006) guidelines, while accordance with PIANC (2014) guidelines would be recommended.

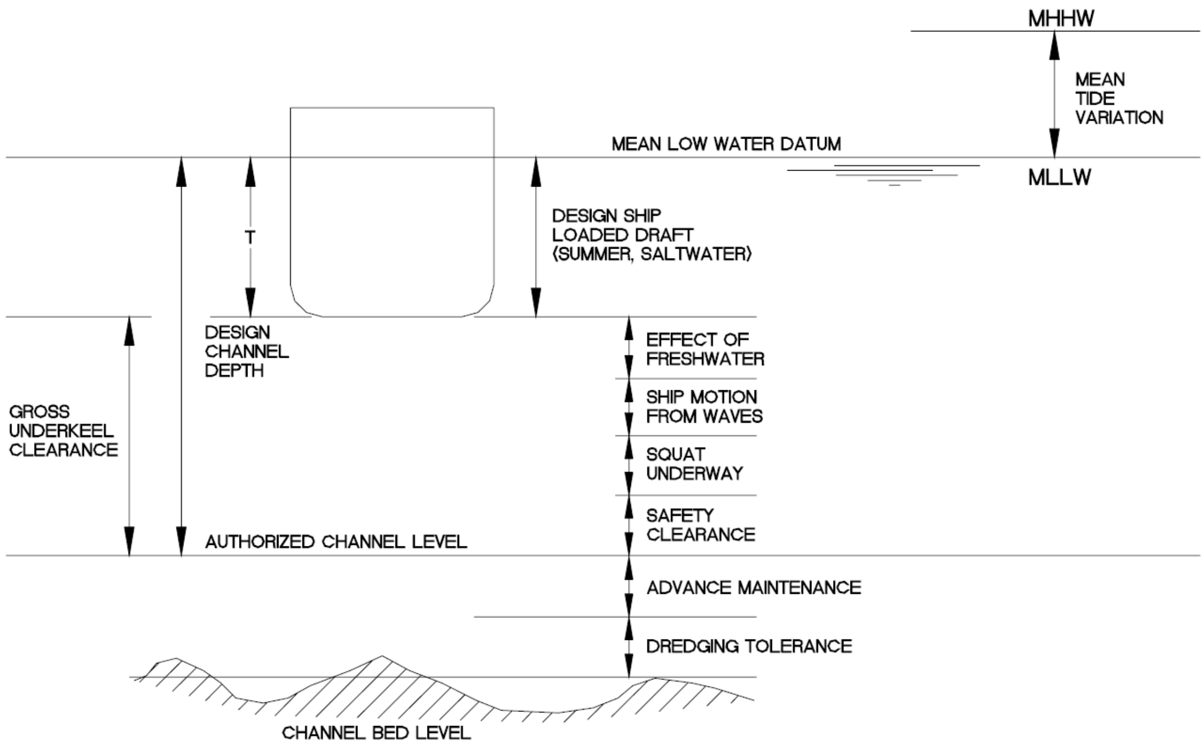

Figure 5.1: Channel depth allowances (source: USACE, 2006)

6. Squat and Maneuverability Margin

Squat was modeled in Wavescat for four channel segments. The water level was adopted at MLLW for ebb currents, +1 ft MLLW during slack tide and +2 ft MLLW for flood currents. The bed level is uniform at −77 ft MLLW in the approach channel and −75 ft MLLW between the jetties. Squat is related to the vessel speed through water with the current speeds according to Table 4.4. The resulting maximum (bow) squat is provided in Figure 6.1 for the Jetty and Outer Channels. The squat is largest in the Jetty Channel due to the effects of a confined channel and a strong counter current. The channel side slopes are included as arrays of panels to model the confined flow effects on squat.

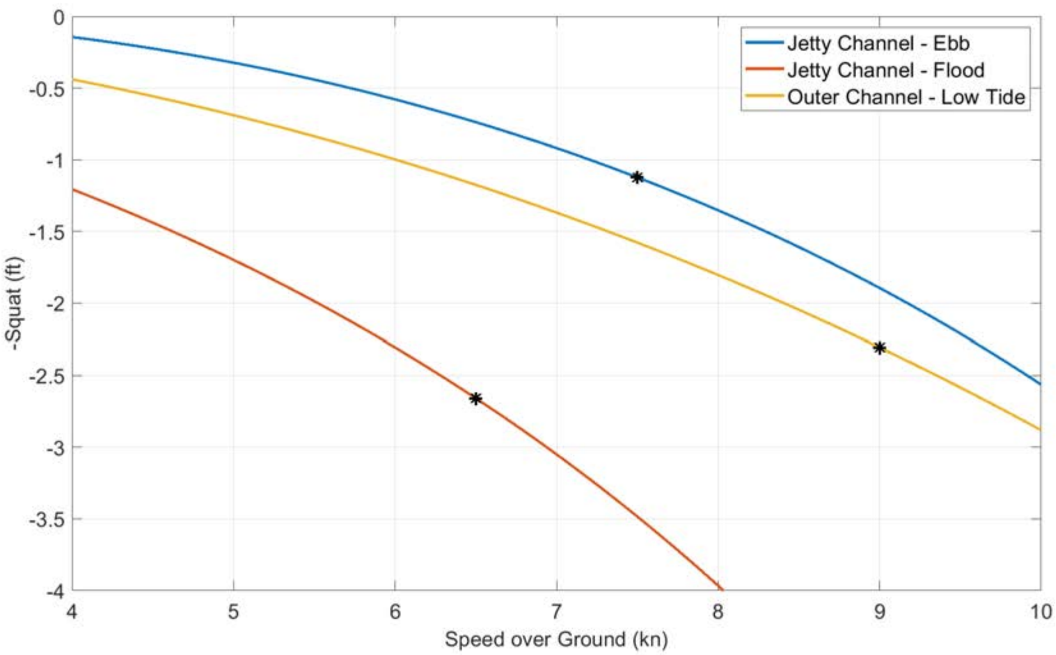

Figure 6.1: Modeled squat in the Jetty and Outer Channels; values used in the UKC assessment indicated with asterisks (*)

The modeled squat for the projected range of vessel speeds is provided in Table 6.1. For validation of the modelling, squat formula results were also determined for the Approach and Outer Channels according to the ICORELS formula (as recommended for the estimation of squat in USACE (2006), albeit with a different reference):

$$z_{squat} = 2.4 \frac{\nabla}{L^2} \frac{F_h^2}{\sqrt{1-F_h^2}}$$

where z_{squat} is the sinkage at the bow, ∇ is the volume displacement, L is the length between perpendiculars and F_h is the depth-related Froude number. Water level was assumed at MLLW and ignoring the effects of currents in the ICORELS results. The modeled results agree well with the ICORELS results for low water (ebb). The small difference may be due to the fact that the ICORELS formula was derived more conservatively to be also applicable to fuller shaped tanker hulls with cylindrical bows compared to the more streamlined bulbous bow shape of the modelled VLCC.

Table 6.1: Squat (ft) in the four channel segments for different speeds over ground and at ebb (low water), slack tide (mid-tide) and flood (high water) conditions; note that considered speeds in the HI Transition Flare and Jetty Channel are 0.5 kn higher during ebb and 0.5 kn lower during flood; estimates using the ICORELS formula at low water are added for reference

Segment	HI Transition Fl.			Jetty Channel			Approach Channel			Outer Channel		
Speed (kn)	5	6	7	6	7	8	8	9	10	8	9	10
Ebb	0.3	0.5	0.7	0.7	1.1	1.6	1.8	2.3	2.9	1.8	2.3	2.9
Slack	0.6	0.9	1.3	1.3	1.8	2.4	1.8	2.3	2.9	1.8	2.3	2.8
Flood	1.0	1.4	1.9	2.0	2.7	3.5	1.9	2.4	2.9	1.7	2.2	2.8
ICORELS	-	-	-	-	-	-	*1.9*	*2.4*	*3.0*	*1.9*	*2.4*	*3.0*

The maneuverability margin, i.e. a safety clearance ignoring wave response, is defined according to the following assumptions:

- Water level according to 10 year return period estimate of the lowest mean tide level at Aransas Pass (−0.15 ft MLLW) and tidal variation according to the ebb, slack and flood tide levels of the reference tide.
- Vessel draft at 68 ft
- Squat according to mid-range speed estimates in Table 6.1.
- Channel depth at authorized bed level (75 ft and 77 ft)

The resulting maneuverability margins are given in Table 6.2. The results are compliant both with the 2 ft safety clearance (USACE, 2006) and the 3.4 ft maneuverability margin (PIANC, 2014) criteria. The ebb tide (low water) condition is governing in all four channel segments, although the flood tide conditions is close in the Jetty Channel due to the enhancement of squat in a counter current.

It is recommended that departure speed profiles be analyzed after the planned navigation simulations and squat reassessed based on any updates to the speed profiles. This will determine whether the transition between the deeper dredged Approach Channel (77 ft) and the Jetty Channel (75 ft) is at the most optimal location.

Table 6.2: Maneuverability Margin Results

	HITF	Jetty Ch.	Approach Ch.	Outer Ch.
Ebb	5.3	4.7	5.5	5.6
Slack	6.0	5.1	6.6	6.7
Flood	6.0	4.8	7.3	7.4

7. Wave Response and Safety Clearance

The wave response allowance was calculated for the 20 wave conditions and at the four channel segments. The resulting wave response allowance is listed in Table 7.1.

The Safety clearance was calculated using the following assumptions:

- Mean water levels according to:
  - Non-hurricane season extreme wave conditions 1-8 according to mean water level in January at Aransas Pass: +0.99 ft MLLW
  - Hurricane season extreme wave conditions 9 and 10 according to mean water level in July-August at Aransas Pass: +1.14 ft MLLW
  - Operational wave conditions 11-20 according to 10 year return period extreme mean water level at Aransas Pass: −0.15 ft MLLW
- Ebb tide (low water) condition for tidal water level variation and current condition
- Vessel draft at 68 ft
- Squat according to mid-range speed estimates in Table 6.1
- Channel depth at authorized bed level (75 ft and 77 ft)

The safety clearance results are also included in Table 7.1. The long-swell extreme condition 10 is governing for all segments except in the HITF where waves have diminished. The safety clearance is marginally non-compliant in the Outer Channel for this condition. Operational wave condition 18 (1% exceedance) combined with an extreme 10 year return period water level is governing between the design conditions. The safety clearance is compliant for this condition.

Wave response is relatively small for all except the 16 s swell condition, such that an extreme low water level combined with an operational wave condition is governing for the safety clearance except for this condition. Wave response increases beyond a peak period of 11 s (Condition 9) causing this.

It is recommended that port closure policies be checked for extreme hurricane scenarios to verify whether vessels would depart under extreme wave conditions with peak periods of 12 s or greater.

Table 7.1: Wave response and safety clearance results (ft); sensitivity (not-design) conditions are shaded grey; values less than the 2 ft criterion are highlighted in orange.

Cond.	Wave Response				Safety Clearance			
#	HITF	Jetty Ch.	Appr. Ch.	Outer Ch.	HITF	Jetty Ch.	Appr. Ch.	Outer Ch.
1	0.02	0.10	0.26	0.45	6.4	5.7	6.4	6.3
2	0.05	0.21	0.47	0.77	6.4	5.6	6.2	5.9
3	0.10	0.39	0.72	1.07	6.4	5.4	6.0	5.6
4	0.15	0.53	0.91	1.27	6.3	5.3	5.8	5.4
5	0.07	0.19	0.31	0.39	6.4	5.6	6.4	6.3
6	0.05	0.22	0.48	0.55	6.4	5.6	6.2	6.2
7	0.04	0.28	0.72	0.89	6.4	5.5	5.9	5.8
8	0.05	0.38	0.99	1.25	6.4	5.4	5.7	5.5
9	0.21	0.70	1.36	1.83	6.4	5.3	5.5	5.1
10	0.65	2.13	3.47	5.03	6.0	3.8	3.4	**1.9**
11	0.00	0.00	0.01	0.01	5.3	4.6	5.5	5.6
12	0.00	0.01	0.01	0.01	5.3	4.6	5.5	5.6
13	0.01	0.02	0.04	0.04	5.3	4.6	5.5	5.5
14	0.01	0.03	0.06	0.06	5.3	4.6	5.5	5.5
15	0.01	0.05	0.09	0.10	5.3	4.6	5.4	5.5
16	0.01	0.08	0.18	0.19	5.3	4.6	5.3	5.4
17	0.02	0.11	0.24	0.26	5.3	4.5	5.3	5.3
18	0.02	0.14	0.32	0.35	5.3	4.5	5.2	5.2
19	0.04	0.10	0.17	0.20	5.3	4.5	5.4	5.4
20	0.08	0.24	0.42	0.53	5.2	4.4	5.1	5.0
Minimum Over All					5.2	3.8	3.4	**1.9**
Minimum Design Conditions					5.3	4.5	5.2	5.2

8. Conclusions

Baird has conducted an underkeel clearance (UKC) study as part of the modeling services for the Corpus Christi Channel Deepening project. The project will comprise deepening of the Outer and Approach Channels to 77 ft, and the Jetty Channel and seaward-most portion of the Corpus Christi Ship Channel to 75 ft. The channel will be used by laden VLCC's at a maximum draft of 68 ft departing from the planned Axis and Harbor Island terminals.

The UKC study consisted of the following tasks:

- Assessment of vessel speeds in the channel
- Analysis of measured water levels with focus on extreme and operational low water levels
- Assessment of tidal current velocities from hydrodynamic modeling results
- Assessment of wave conditions from wave hindcast data and wave transformation modeling results
- Modeling and assessment of squat for selected vessel speeds and current conditions
- Modeling and assessment of response of the vessel in waves for selected wave conditions

The vessel speed is expected to be in the range of 6-8 kn in between the jetties and the vessel would accelerate to a cruising speed of 8-10 kn in the Approach and Outer channels. This is slower than current practice as it is expected that the VLCC's at a larger draft are more sluggish and will not reach the same cruising speed due to additional drag effects. It is recommended that departure speed profiles be analyzed after the planned navigation simulations and squat assessed based on these speed profiles.

The design water level was assessed from a mean level from measured data at Aransas Pass as a 10 year return period lowest level at −0.15 ft MLLW and a regular spring tide low water at −1.02 ft relative to mean tide in the Jetty Channel. Ebb current velocities peak close to low tide and cause a reduction of the vessel squat. Maximum flood currents that enhance squat occur close to high tide. The resulting maneuverability margin (safety clearance, not including wave response) has a minimum of 4.7 ft in the Jetty Channel. This is greater than the recommended margin of 3.4 ft suggested by PIANC (2014) and greater than the required 2 ft safety clearance by USACE (2006).

Maximum significant wave height for vessel departures was chosen at 10-12 ft limited by disembarking of the pilot after the channel transit. These events occur mostly due to winter depressions but can also be associated with swells from advancing hurricanes. Most common conditions are from SSE with peak periods of 7-9 s, and were selected as design wave events. Maximum wave response allowance is limited to 1.3 ft in the Outer Channel due to the relatively small wave period and since the vessel is advancing against the waves.

The minimum safety clearance for the design wave conditions was calculated at 4.5 ft in the Jetty Channel and 5.2 ft in the Approach and Outer Channels, which is compliant with the 2 ft safety clearance criterion by USACE (2006). Wave response in the Outer Channel increases considerably in longer swells with peak periods greater than 11 s. Swells with periods close to 16 s have only occurred offshore of Corpus Christi in the 1980-2014 wave hindcast associated with hurricanes Katrina, Rita and Ike. A safety clearance of 1.9 ft was calculated in the Outer Channel for a departure at low tide in such a long-period swell condition with a significant wave height of 12 ft and 16 s peak period. It is recommended that port closure policies be checked for extreme hurricane scenarios to verify whether vessels could depart under extreme wave conditions with peak periods of 12 s or greater.

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Appendix A

Historic Channel Closures

Plots of significant wave height and wind speed with historic channel closures highlighted in red. Wave and wind data obtained from the WIS hindcast Station 73040 offshore of Corpus Christi (27.75° N, 96.8° W) at 30 m water depth.

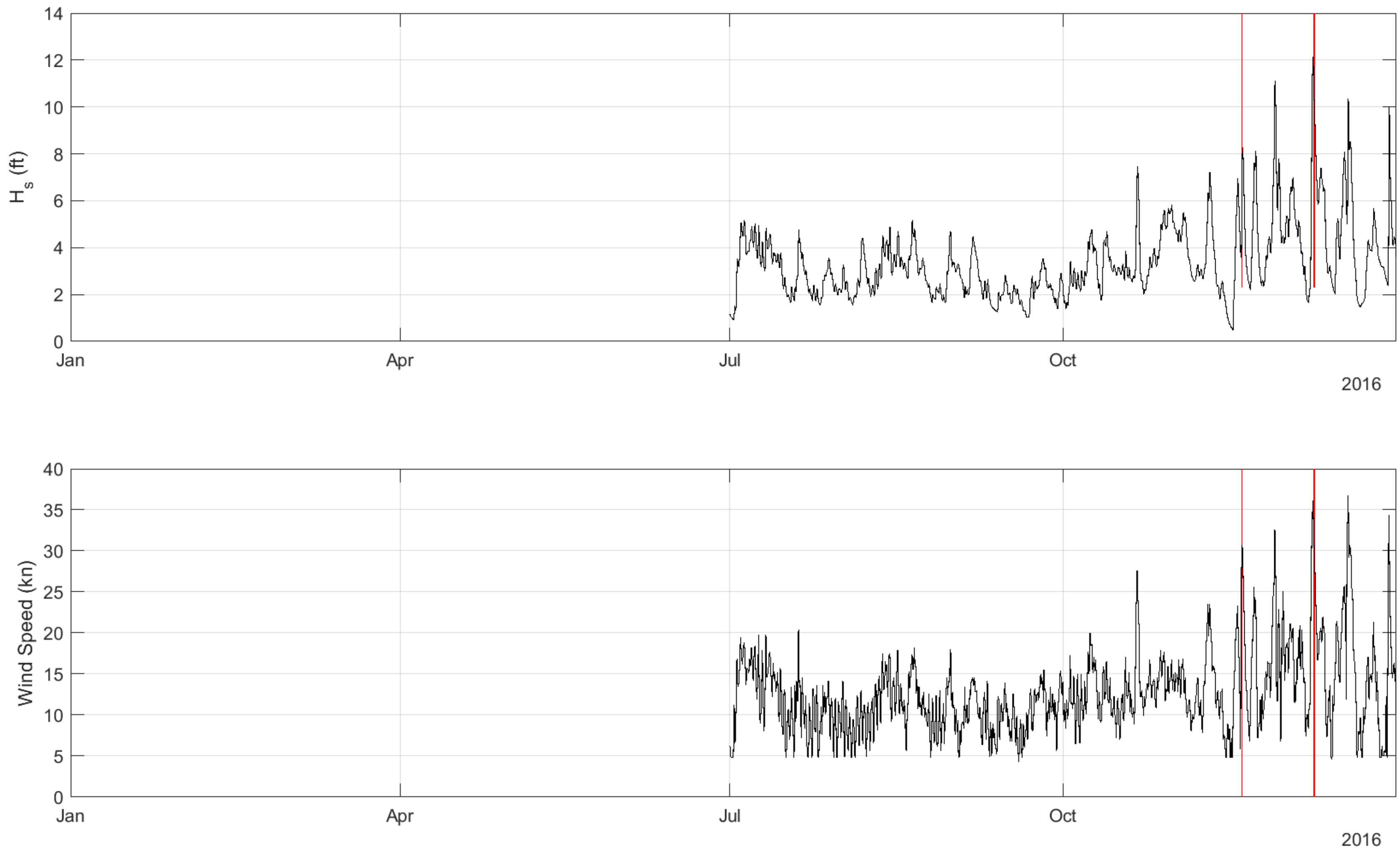

Figure A.1: Significant wave height and wind speed for 2016 with channel closures highlighted in red

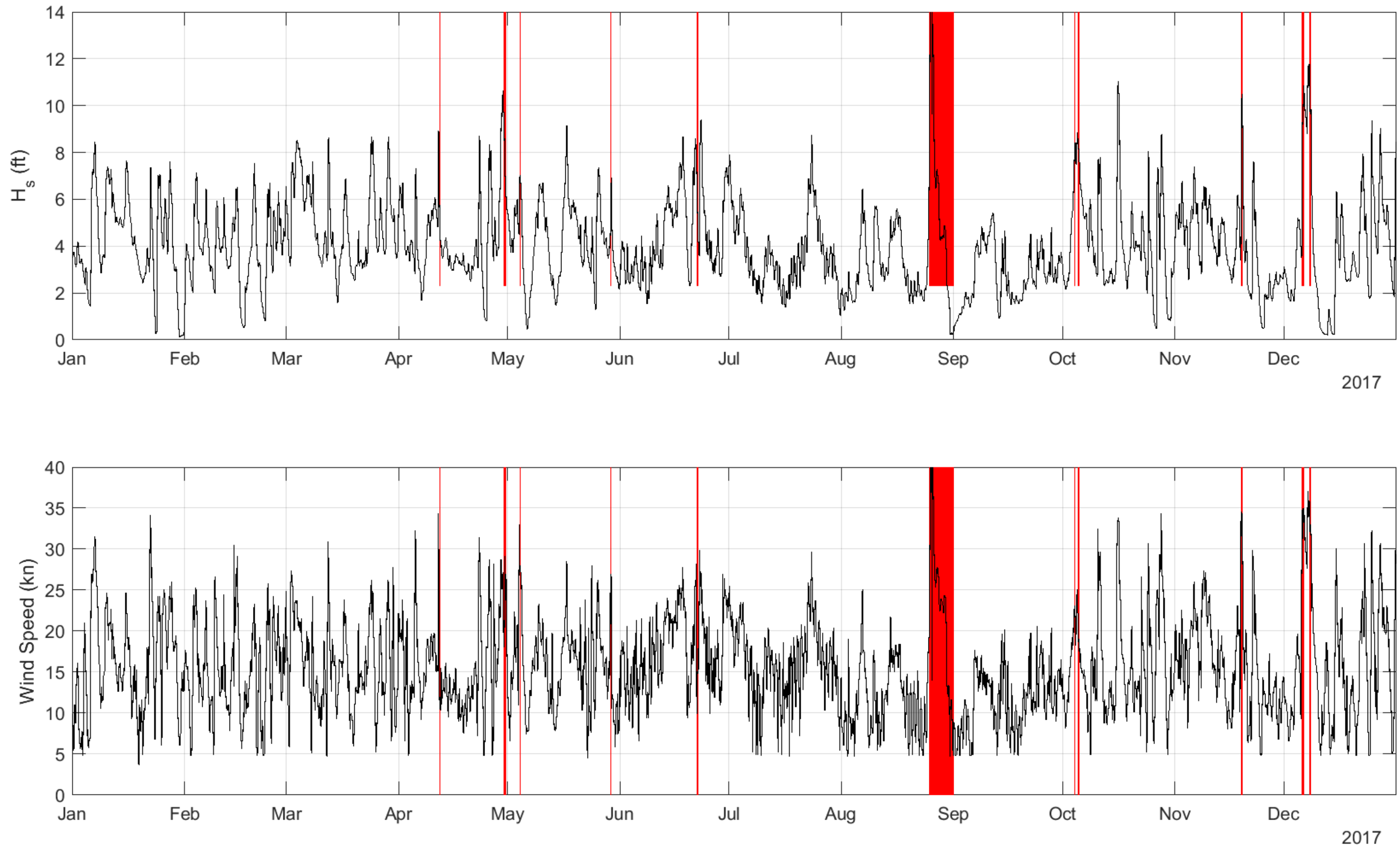

Figure A.2: Significant wave height and wind speed for 2017 with channel closures highlighted in red

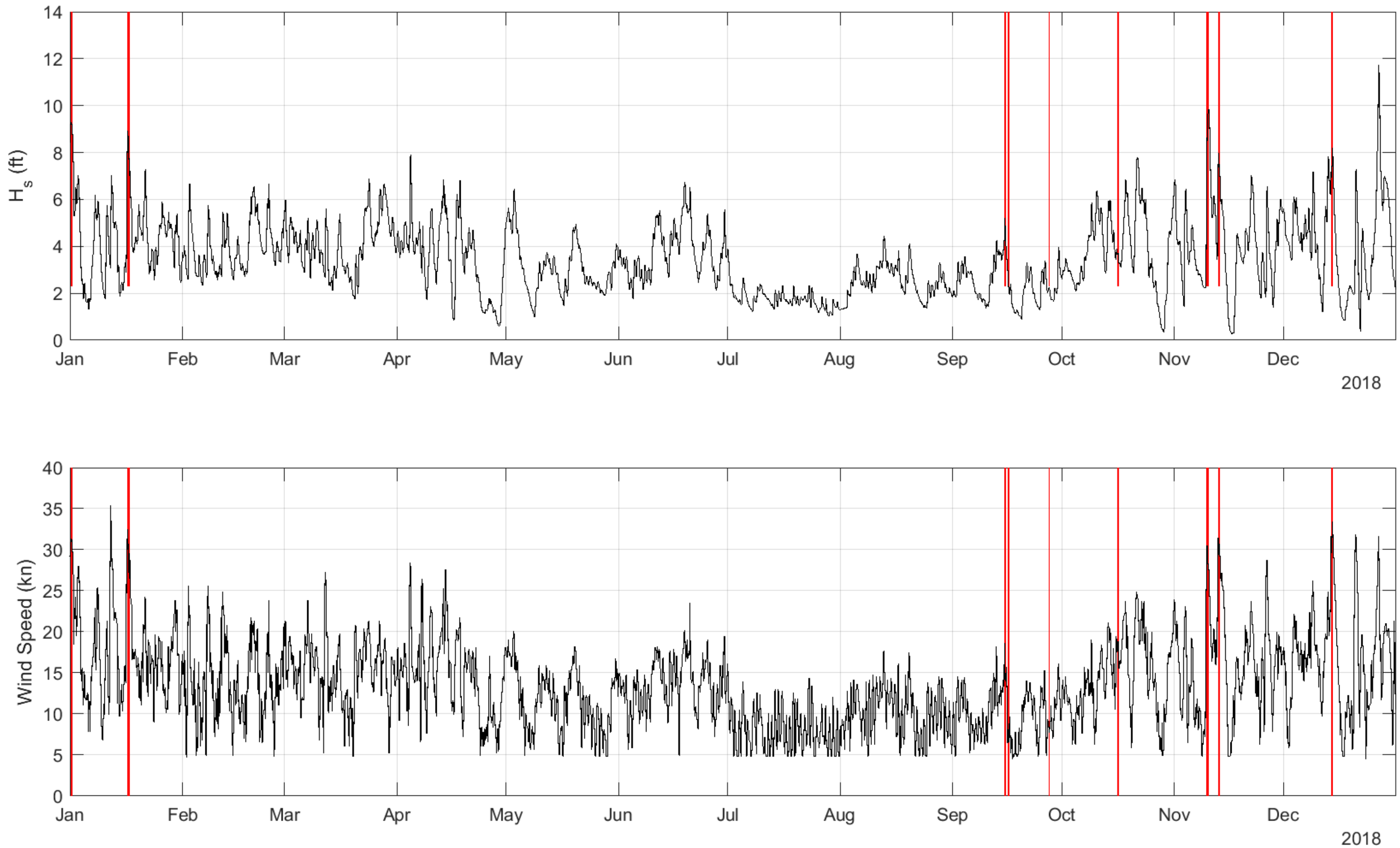

Figure A.3: Significant wave height and wind speed for 2018 with channel closures highlighted in red

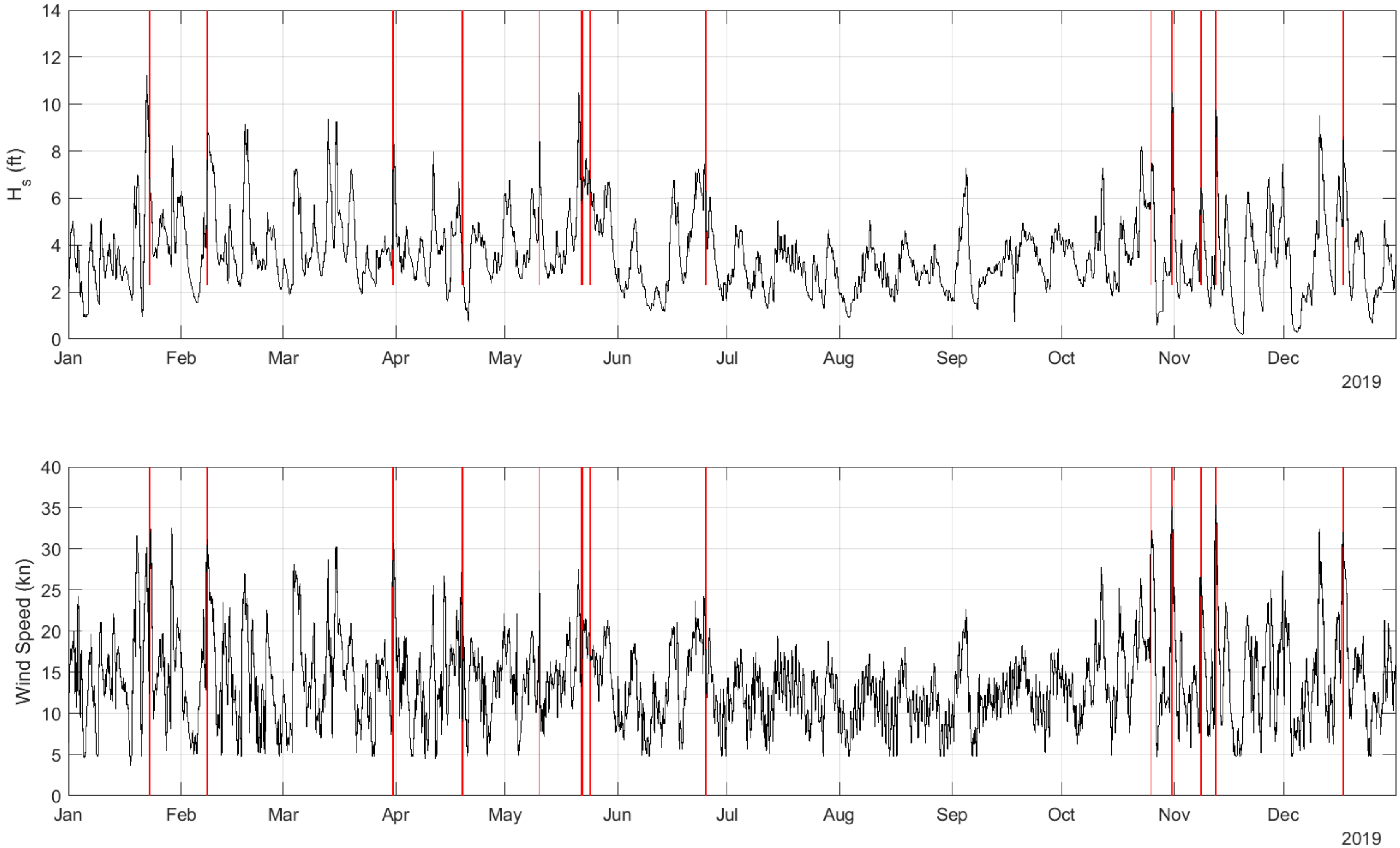

Figure A.4: Significant wave height and wind speed for 2019 with channel closures highlighted in red

Appendix N

Clean Water Act Section 404(b)(1) Evaluation

Job No. PCA20166

APPENDIX N

DRAFT
SECTION 404(B)(1) EVALUATION
FOR THE
PROPOSED CORPUS CHRISTI SHIP
CHANNEL DEEPENING PROJECT

Prepared for:

U.S. Army Corps of Engineers

Prepared by:

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June 2022

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Acronyms and Abbreviations

BU	beneficial use
CCSC	Corpus Christi Ship Channel
CSD	cutter suction dredge
cy	cubic yards
DEIS	Draft Environmental Impact Statement
Gulf	Gulf of Mexico
mcy	million cubic yards
MLLW	mean lower low water
MSL	mean sea level
ODMDS	Ocean Dredged Material Disposal Site
PA	placement area
PCCA or Applicant	Port of Corpus Christi Authority
Port	Port of Corpus Christi
ppt	parts per thousand
USACE	U.S. Army Corps of Engineers
VLCC	Very Large Crude Carriers

1.0 PROJECT DESCRIPTION

1.1 LOCATION

The Proposed Action is in the Gulf of Mexico (Gulf) and the Corus Christi Ship Channel (CCSC). The CCSC is in Corpus Christi Bay on the south-central portion of the Texas coast, 200 miles southwest of Galveston and 150 miles north of the mouth of the Rio Grande River. The coastal counties included within the study area are Aransas, Nueces, Refugio, and San Patricio. The CCSC provides deepwater access from the Gulf to the Port of Corpus Christi (Port), via Port Aransas, through Redfish Bay and Corpus Christi Bay. The waterway extends from deep water in the Gulf through the Port Aransas jettied entrance and connects to marine terminals along the Inner Harbor and La Quinta Channel. The Inner Harbor starts at Harbor Bridge and includes five turning basins. The La Quinta Channel extends from the CCSC near Ingleside, Texas, and runs parallel to the eastern shoreline of Corpus Christi Bay for 6.9 miles to the San Patricio Turning Basin. The Proposed Action will be completed within the limits of the CCSC from the Gulf to Harbor Island. The study area extends offshore from the San José, Mustang, and North Padre islands beyond the proposed CCSC extension, approximately 17 miles.

1.2 GENERAL DESCRIPTION

The CCSC is currently authorized by the U.S. Army Corps of Engineers (USACE) to project depths of –54 feet and –56 feet mean lower low water (MLLW) from Station 110+00 to Station –330+00 as part of the CCSC Improvement Project. The current authorized width of the CCSC is 600 feet inside the jetties and 700 feet in the entrance channel.

The Port of Corpus Christi Authority (PCCA or Applicant) proposes to deepen the channel from Station 110+00 to Station –72+50 to a maximum depth of –79 feet MLLW (–75 feet MLLW plus two feet of advanced maintenance and two feet of allowable overdredge), and from Station –72+50 to Station –330+00, the channel would be deepened to a maximum depth of –81 feet MLLW (–77 feet MLLW plus two feet of advanced maintenance and two feet of allowable overdredge). The Proposed Action includes a 29,000-foot extension of the CCSC from Station–330+00 to Station –620+00 to a maximum depth of –81-foot MLLW (–77 feet MLLW plus two feet of advanced maintenance and two feet of allowable overdredge) to reach the –80-foot MLLW bathymetric contour in the Gulf. The Proposed Action would span approximately 13.8 miles from a location near the southeast side of Harbor Island to the –80-foot MLLW bathymetric contour in the Gulf.

The Proposed Action consists of the following:

- Deepening a portion of the CCSC from the current authorization of –54 and –56 feet MLLW to final constructed deepened channel ranging from –75 to –77 feet MLLW;
- Extending the existing terminus of the authorized channel an additional 29,000 feet into the Gulf to reach the –80-foot MLLW bathymetric contour;

- Expanding the existing Inner Basin at Harbor Island as necessary to accommodate Very Large Crude Carriers (VLCC) turning.
- Straightening the northeast channel limits of the Harbor Island Transition Flare.
- Placement of new work dredged material into an existing upland dredged material placement area at Harbor Island;
- Placement of new work dredged material within the Corpus Christi New Work Ocean Dredged Material Disposal Site (ODMDS).
- Placement intended as beneficial use (BU) at:
  - Harbor Island and Port Aransas to restore eroded shorelines adjacent the CCSC;
  - Harbor Island to restore the eroded bluff and shoreline;
  - Gulf-facing shoreline of San José Island for dune and beach restoration;
  - Gulf-facing shoreline of Mustang Island for beach restoration; and
  - Nearshore berms offshore San José and Mustang islands.

The total length of the CCSC proposed for deepening is approximately 13.8 miles. The Proposed Action would generate an estimated 46.3 million cubic yards (mcy) of new work material. The newly generated material would consist of approximately 37 percent clays (17.1 mcy) and 63 percent sand (29.1 mcy). The clay portion of the new work dredged material located in the offshore reaches (Station –620+00 to –72+50) would be placed at the Corpus Christi New Work ODMDS located approximately 2.9 miles southeast of the Aransas Pass South Jetty and adjacent to the CCSC. The clay portion of new work dredged material from Stations –72+50 to Station 110+00 would be used beneficially where possible to create perimeter dikes.

The new proposed depth for the applicable sections of the channel would be approximately –79 feet to –81 feet MLLW to account for underkeel clearances and includes 2 feet of advanced maintenance and 2 feet of allowable overdredge depth. The design depth was based on a detailed review of the dimensions of VLCCs expected to call at the Port's existing and proposed crude oil export terminals; the predominant density of crude oil to be exported and associated vessel draft; environmental effects due to winds, waves, and currents; required underkeel clearances, plus 2 feet of advanced maintenance; and 2 feet of allowable overdredge depth. The Proposed Action does not include widening the channel. Deepening activities will be completed within the footprint of the authorized CCSC channel width. Incidental widening may be needed however to maintain side slope requirements and are expected to be minor.

1.3 AUTHORITY AND PURPOSE

The project purpose, as determined by the USACE after concurrence with the Cooperating Agencies, is to export safely, efficiently, and economically current and forecasted crude oil inventories via VLCC, a common vessel in the world fleet. Crude oil is delivered via pipeline from the Eagle Ford and Permian Basins to multiple locations at the Port. Crude Oil inventories exported at the Port have increased from

280,000 barrels per day in 2017 to 1,650,000 barrels in January 2020 with forecasts increasing to 4,500,000 barrels per day by 2030. Current facilities require vessel lightering to fully load a VLCC which increases cost and effects safety.

To address the purpose and need, PCCA proposes to deepen portions of the CCSC beyond the current authorized project depth of –54 feet and –56 feet MLLW, from the Gulf (approximate Station –620+00) to Harbor Island (approximate Station 110+00), to allow berthing of VLCCs which can then be fully laden, with drafts of up to 70 feet. This is a length of approximately 13.8 miles.

The purpose of the Proposed Action, as provided by the Applicant, is to construct a channel with the capability to accommodate transit of fully laden VLCCs from multiple locations on Harbor Island into the Gulf. Factors influencing the Applicant's need for the project include:

- The ability for more efficient movement of U.S. produced crude oil to meet current and forecasted demand in support of national energy security and national trade objectives,
- Enhancement of the PCCA's ability to accommodate future growth in energy production, and
- Construction of a channel project that the PCCA can readily implement to accommodate industry needs.

1.4 GENERAL DESCRIPTION OF DREDGED OR FILL MATERIAL

1.4.1 General Characteristics of Material

The sediment within the dredge template varies from very fine sand to high plasticity clays. The outer portions of the ship channel transition from a soft clay dominated Outer Channel (Station –330+00 to –620+00) to a sand dominated Approach Channel (Station –72+50 to –330+00). The interior portions of the ship channel, including the Corpus Christi Channel segment (Station 110+00 to 38+16.43), Harbor Island Junction segment (Station 38+16.43 to 20+82.07), Harbor Island Transition Flare segment (Station 20+82.07 to –20+00), and Jetties to Harbor Island Transition Flare (Station –20+00 to –72+50) are comprised of loose clay and silty sands with some clays. A summary is provided in Table 1.

Table 1
Sediment Characterization for Corpus Christi Ship Channel by Segment

Segment	Description	Begin Station	End Station	Approximate Composition
1	Outer Channel	–620+00	–330+00	82.5% Soft Clay 17.5% Sand
2	Approach Channel	–330+00	–72+50	18% Soft Clay 4% Stiff Clay 78% Sand

Segment	Description	Begin Station	End Station	Approximate Composition
3	Jetties to Harbor Island Transition Flare	–72+50	–20+00	1% Soft Clay 13% Stiff Clay 86% Sand
4	Harbor Island Transition Flare	–20+00	20+82.07	2% Soft Clay 28% Stiff Clay 70% Sand
5	Harbor Island Junction	20+82.07	38+16.43	<1% Soft Clay 27% Stiff Clay 72% Sand
6	CCSC	38+16.43	110+00	43.5% Stiff Clay 56.5% Sand

1.4.2 Quantity of Material

Although quantity estimates are still in progress, approximately 46.3 mcy of material would need to be dredged. Table 2 provides a breakdown of material volumes by dredging location.

Table 2
Dredged Material Volumes per Channel Segment for the Proposed Action

Dredging Location	Dredged Material Quantity (cy) for Proposed Action
Outer Channel	9,617,390
Approach Channel	20,308,762
Jetties to Harbor Island Transition Flare	2,105,041
Harbor Island Transition Flare	2,851,897
Harbor Island Junction	2,951,614
Corpus Christi Ship Channel	8,448,886
Total	46,283,590

cy = cubic yards

1.5 DESCRIPTION OF THE PROPOSED DISCHARGE

1.5.1 Location

Discharges are proposed at several placement areas (PAs) and other locations along the CCSC, San José Island, Mustang Island, and offshore at the New Work ODMDS. The inshore locations were chosen for PA levee improvements and fill, shoreline restoration or repair, dune and beach restoration, and beach nourishment. Placement locations are outlined in Table 3.

Table 3
Placement Locations

Placement Site	Description
PA6	5-foot levee raise and fill (no environmental benefit)
SS1	Restore eroded and washed-out shoreline at Harbor Island
SS2	Restore shoreline washouts along Port Aransas Nature Preserve
SS1 Extension	Reestablish eroded shoreline and land loss in front of PA4
PA4	Upland placement
HI-E	Bluff and shoreline restoration with site fill
SJI	Dune and beach restoration San José Island
New Work ODMDS	Place New Work ODMDS
B1–B9	Nearshore berms offshore of San José Island and Mustang Island
MI	Beach Nourishment for Gulf side of Mustang Island

1.5.2 Size

Total area of discharges may cover approximately 4,663 acres. Details regarding acreage and placement capacity for each BU site is included in Table 4.

Table 4
Size and Capacity of Placement Locations

Placement Site	Placement Capacity (cy)
PA6	1,796,400
SS1	2,793,000
SS2	250,000
PA4	4,537,400
HI-E	1,825,000
SJI	4,000,000
New Work ODMDS	38,888,600
B1–B9	8,100,000
MI	2,000,000

1.5.3 Type of Site and Habitat

The sites and types of habitats that could be directly impacted are outlined in Table 5.

1.5.4 Time and Duration of Discharge

Construction is expected to occur from 2023 until 2026. Maintenance will be ongoing; estimates for the CCSC deepening include a 50-year project life. Table 6 provides a breakdown anticipated construction start and completion dates by task.

Table 5
Habitat Types of Placement Sites

Placement Site	Habitat Cover Type(s)
PA6	N/A – Existing Levee
SS1	Bare Land; Estuarine Aquatic Bed; Estuarine Emergent Wetland; Grassland/Herbaceous; Open Water; Palustrine Aquatic Bed; Unconsolidated Shore
SS2	Bare Land; Deciduous Forest; Estuarine Emergent Wetland; Grassland/Herbaceous; Open Water; Palustrine Emergent Wetland; Scrub/Shrub Wetland; Scrub/Shrub; Unconsolidated Shore
PA4 (includes SS1 Extension)	Bare Land; Deciduous Forest; Estuarine Emergent Wetland; Grassland/Herbaceous; Open Water; Palustrine Emergent Wetland; Scrub/Shrub; Unconsolidated Shore
HI-E	Bare Land; Deciduous Forest; Estuarine Emergent Wetland; Grassland/Herbaceous; Open Water; Palustrine Emergent Wetland; Scrub/Shrub Wetland; Unconsolidated Shore
SJI	Bare Land; Grassland/Herbaceous; Open Water; Palustrine Emergent Wetland; Unconsolidated Shore
New Work ODMDS	Open Water
B1–B9	Open Water
MI	Bare Land; Developed Low Intensity; Estuarine Emergent Wetland; Grassland/Herbaceous; Open Water; Palustrine Emergent Wetland; Scrub/Shrub; Unconsolidated Shore

Source: NOAA (2010).

1.5.5 Description of Disposal Method

It is anticipated that most materials would be used for PA improvements and fill, or beneficially for restoration or for beach nourishment, with the remaining materials to be placed in the Maintenance ODMDS. For placement actions targeting restoration, fill discharges may consist of thin-layer placement or confined placement, depending on the target restoration elevations. Direct placement with dredged pipeline is anticipated for larger restoration actions including beach and dune restoration. Hopper dredge would likely be used for ODMDS discharges.

Table 6
Preliminary Construction Schedule Plan*

Task ID	Task Description	Start Date	End Date	Duration (Days)
1	CSD via Scow to ODMDS (7,213,043 cy)	7/1/2023	9/11/2024	438
2	CSD via Pipe to ODMDS (2,404,347 cy)	9/11/2024	12/28/2024	108
3	CSD via Pipe to ODMDS (4,182,610 cy)	12/28/2024	7/4/2025	188
4	CSD via Scow to B9 (1,200,000 cy)	7/4/2025	9/7/2025	65
5	CSD via Scow to B8 (1,200,00 cy)	9/7/2025	11/11/2025	65
6	CSD via Pipe to B7 (1,200,000 cy)	11/11/2025	1/4/2026	54
7	CSD via Pipe to B1 (750,000 cy)	1/4/2026	2/7/2026	34
8	CSD via Pipe to B2 (750,000 cy)	2/7/2026	3/12/2026	34
9	CSD via Pipe to B3 (750,000 cy)	3/12/2026	4/15/2026	34
10	CSD via Pipe to B4 (750,000 cy)	4/15/2026	5/20/2026	35
11	CSD via Scow to B5 (750,000 cy)	5/20/2026	6/30/2026	41
12	CSD via Scow to B6 (750,000 cy)	6/30/2026	8/9/2026	41
13	CSD via Pipe to SJI Shore (2,000,000 cy)	7/1/2023	10/4/2023	95
	CSD via Pipe to SJI Dune (2,000,000 cy)	10/4/2023	1/2/2024	90
14	CSD via Pipe to MI (2,000,000 cy)	1/2/2024	4/1/2024	90
15	CSD via Pipe to PA4 (2,026,152 cy)	4/1/2024	7/1/2024	91
16	CSD via Pipe to PA4 (993,848 cy)	7/1/2024	8/15/2024	45
17	CSD via Pipe to SS1 (1,111,193 cy)	8/15/2024	10/4/2024	50
18	CSD via Pipe to SS1 (2,851,897 cy)	10/4/2024	2/9/2025	128
19	CSD via Pipe to SS1 (836,910 cy)	2/9/2025	3/19/2025	38
20	CSD via Pipe to M10 (2,114,704 cy)	3/19/2025	6/22/2025	95
21	CSD via Pipe to M10 (4,020,764 cy)	6/22/2025	12/20/2025	181

* This table represents a preliminary construction schedule from 08/17/2020; since this time the PAs have changed. Assumptions also include that the timeframe assumes the use of two cutter suction dredges (CSD) during the duration of the contract. Tasks 1 to 12 will be performed by one CSD while tasks 13 to 21 will be performed by another working simultaneously, and one dredge will do the majority of the offshore portion of work with open water disposal while the second dredge will perform the majority of the inshore work with beach and upland placement area disposal.

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2.0 FACTUAL DETERMINATIONS

2.1 PHYSICAL SUBSTRATE DETERMINATIONS

2.1.1 Substrate Elevation and Slope

Marsh and restoration actions target elevations ranging from below mean sea level (MSL) to about +2 feet MSL with generally flat slopes. For beach nourishment and dune restoration, dune elevations typically range from +4 to +12 feet (top of dune), with a common slope of 1:3; beach nourishment could range from –4 to +4 feet, and slopes can range from 1:50 for subaerial portions and 1:25 for intertidal portions.

At SS2, the Proposed Action involves restoration of approximately 1,085 linear feet of an eroded shoreline by an armored berm constructed with approximately 250,000 cy of dredge material hydraulically pumped to the site. Berm elevation design is +7 feet MLLW at a 4:1 slope with a crest width of approximately 20 feet. Construction of the interior levee, via hydraulic pumping and mechanical placement, at a 10:1 slope will meet the existing sand flats and wetlands at an elevation of approximately +1.5 feet MLLW. Some portions will include a bulkhead built to up to +9.5 feet MLLW.

At PA4 and SS1, a levee would be constructed via hydraulic pumping. Mechanically placed stiff clay will provide incremental exterior levee raising for dredge material placed between the proposed SS1 Extension levee and the existing PA4 levee to an approximate elevation of +20 feet MLLW; other parts of PA4 include a levee up to +12 feet MLLW, with incremental fills indicated up to +24 feet MLLW. The backside containment levee may be up to +5 feet MLLW.

At HI-E, exterior shoreline levee design will raise the existing elevation to +15 feet MLLW at a 4:1 slope and a crest width of 15 feet. Mechanical placement of approximately 23,400 cy of riprap at a 4:1 slope to +7 feet MLLW will armor the exterior shoreline levee and provide erosion control. The exterior upland levee design is to a +3 feet over grade at a 4:1 slope.

2.1.2 Sediment Type

It is assumed that stiffer clays would be used for containment levees and sands would be used for beach nourishment and other fills targeting restoration.

2.2 DREDGED/FILL MATERIAL MOVEMENT

In most instances, project actions would use a containment structure to hold materials in situ; in other instances, thin layer placement would be performed where some material movement throughout the marsh is intended. Last, any beach and dune nourishments would result in erosion into the surf zone over time. Modeling of beach nourishment (W.F. Baird and Associates, 2022) indicated up to a 5 percent loss of sediment from Mustang Island and up to a 2 percent loss from San José Island; negligible to no movement of nearshore berms are expected. ODMDS modeling indicated a relatively stable bathymetry following discharges, but channel sedimentation in the outer channel is 2.25 times greater when comparing the Proposed Action condition versus the No-Action condition (W.F. Baird and Associates, 2022).

2.3 PHYSICAL EFFECTS ON BENTHOS

There would be direct impacts to benthic organisms, which would be buried or removed during construction. Excavation of sediments removes and buries benthic organisms, whereas placement of dredged material and structures smothers or buries benthic communities. Dredging and placement activities may cause ecological damage to benthic organisms due to physical disturbance, mobilization of sediment contaminants, and increasing concentrations of suspended sediments (Montagna et al., 1998). Placement, however, can also release nutrients that can enhance species diversity and population densities of benthic organisms outside the immediate dredge placement area as long as the dredged material is not contaminated (Newell et al., 1998).

Recolonization of areas impacted by dredging and dredged material placement occurs through vertical migration of buried organisms through the dredged material, immigration of organisms from the surrounding area, recruitment from the water column, and/or sediments slumping from the side of the dredged area (Bolam and Rees, 2003; Newell et al., 1998). The response and recovery of the benthic community from dredged material placement is affected by many factors, including environmental (e.g., water quality, water stratification), sediment type and frequency, and timing of disposal. Communities in these dynamic ecosystems are dominated by opportunistic species tolerant of a wide range of conditions (Bolam et al., 2010; Bolam and Rees; 2003, Newell et al., 2004; Newell et al., 1998). Although changes in community structure, species composition, and guild function may occur, these impacts would be temporary in some dredging and disposal areas (Bolam and Rees, 2003). Shallower, higher energy estuarine habitats can recover as fast as 1 to 10 months from perturbation, while deeper, more-stable habitats can take up to 8 years to recover (Bolam et al., 2010; Bolam and Rees, 2003; Newell et al., 1998; Sheridan, 1999, 2004; VanDerWal et al., 2011; Wilber et al., 2006).

2.3.1 Other Effects

Construction activities, particularly beach and dune restoration and offshore sediment source dredging, may affect, but are unlikely to adversely affect, Federally listed sea turtles. Beach and dune restoration actions are anticipated to benefit sea turtles by increasing available nesting habitat. Beach and dune restoration activities may also have temporary and localized disturbances to the Federally listed Piping Plover (*Charadrius melodus*) and Rufa Red Knot (*Calidris canutus rufa*); however, long-term benefits to these species are anticipated due to beach nourishment and tidal habitat restoration.

2.3.2 Actions Taken to Minimize Impacts

Some of the project features were developed as a result of stakeholder coordination and placement discharges will take place on existing PAs, eroding shorelines, storm-damaged shorelines, or eroding beach.

Best management practices will be in place to avoid and minimize impacts during discharge such as use of turbidity curtains to protect seagrass.

2.4 WATER CIRCULATION, FLUCTUATION, AND SALINITY DETERMINATIONS

2.4.1 Water

2.4.1.1 Salinity

Short-term modeling indicates that construction of the Proposed Action could slightly decrease bay salinities, less than 1 part per thousand (ppt) on average in the Corpus Christi Bay system. Some localized changes in salinity of less than ±3 ppt in the proposed dredge area and connected navigation channels may occur. Secondary long-term modeling also showed that channel deepening would not cause significant salinity change on average, but it may cause short-term changes in the range of ±3 ppt in the proposed dredge area and connected navigation channels (W.F. Baird and Associates, 2022).

2.4.1.2 Water Chemistry

Dredging and placement actions would result in short-term and localized impacts and would not be expected to degrade the long-term water quality within the project area. These patterns would return to their previous condition following completion of discharges. Temporary changes to dissolved oxygen, nutrients, and turbidity may occur due to sediment disturbance and mixing during construction.

2.4.1.3 Clarity

There would be some temporary increase in local turbidity during dredging and placement operations. Water clarity is expected to return to normal background levels shortly after operations are completed.

2.4.1.4 Color

Water immediately surrounding the construction area would become discolored temporarily due to disturbance of the sediment during dredging and placement actions but would be expected to return to normal after operations cease.

2.4.1.5 Odor

Negligible amounts of hydrogen sulfide may be expected during excavation and placement activities, which would be temporary and localized.

2.4.1.6 Taste

It is anticipated that no drinking water sources would be impacted by the Proposed Action; no effects to taste are anticipated.

2.4.1.7 Dissolved Gas Levels

Negligible amounts of hydrogen sulfide may be expected. Hydrogen sulfide and other gases like methane are associated with high amounts of decaying organic matter, which are not expected to be present in excavated and placed materials. Offshore sediments may be very low in total organic carbon, an indicator of organic content. Dissolved gases have not been identified as a problem with maintenance material of the current channels. Temporary dissolved oxygen decreases associated with extended periods of construction and dredged material placement may also happen from aerobic decomposition from short-term increases in organic matter suspended within the water column.

2.4.1.8 Nutrients

Temporary changes to nutrient levels may occur due to sediment disturbance and mixing during construction. Changes in ratios of nitrogen and phosphorus may change plankton communities in the bay, particularly in areas with oysters that rely on plankton as their primary food source.

2.4.1.9 Eutrophication

Nutrients are not expected to reach levels high enough for periods long enough to lead to eutrophication of the surrounding waters.

2.4.1.10 Others as Appropriate

No other potential impacts to water quality have been identified; additional information can be found in the Draft Environmental Impact Statement (DEIS).

2.4.2 Current Patterns and Circulation

2.4.2.1 Current Patterns and Flow Velocity

Discharges associated with placement would not alter typical current patterns and flow velocities. Since some of the PAs will include levees (including some armored levees of heights up to +20 feet MLLW or more), storm surges could be altered.

Channel deepening would not result in significant impacts on currents in Corpus Christi Bay, Redfish Bay, and Nueces Bay. Modeling predicted that the Proposed Action would reduce current speeds through the deepened navigation channel. The mean current speed at Aransas Pass is reduced by about 0.213 feet per second and the maximum current speed is reduced up to 0.614 feet per second. The current speed increases in the CCSC from Port Aransas to Ingleside where the water depth remains unchanged. The current speed at the Inner Channel near Port Aransas increases about 0.09 to 0.13 feet per second, up to 0.36 feet per second (W.F. Baird and Associates, 2022).

Secondary long-term modeling also demonstrates no significant impact on currents in Corpus Christi Bay, Redfish Bay, and Nueces Bay. Channel deepening would reduce current speeds through the proposed dredge area and increase the current speed in the Corpus Christi Channel from Port Aransas to Port Ingleside where the water depth remains unchanged. (W.F. Baird and Associates, 2022).

2.4.2.2 Stratification

Relatively minor amounts of vertical salinity stratification may result from the Proposed Action.

2.4.2.3 Hydrologic Regime

Deepening of navigation channels can alter circulation patterns and increase the tidal range and tidal prism within bay systems (USACE, 1987). Alternative 1 would result in these types of local bathymetric changes within and adjacent to the existing CCSC. These changes would be small compared to the scale of regional bathymetry.

2.4.3 Normal Water Level Fluctuations

Short-term modeling indicates that channel deepening is unlikely to change mean water levels in the bay. However, the model predicted that high tide would increase by less than 0.79 inches in Corpus Christi and Redfish Bay. The maximum increase of high tide occurs at Humble Basin which is about 1.57 inches. The model predicted that low tide would drop by less than 1.57 inches in Corpus Christi and Redfish Bay. The maximum drop of low tide occurs in the Inner Channel near Humble Basin which is 3.94 inches (W.F. Baird and Associates, 2022).

Short-term modeling predicted tidal amplitude increases of about 11 percent in Redfish Bay, 8 percent in Corpus Christi Bay, 7 percent in Nueces Bay, and 3 percent at Rockport. The tidal amplitude at the Inner Channel near Port Aransas has the largest increase, which is about 17 percent. There is no major change in tidal amplitudes in Aransas Pass and the Outer Channel. The model predicted that the average tidal range increase is about 1.57 inches at the Inner Channel near Port Aransas, ranging from 0.12 to 0.35 inches. The average tidal range increase at Corpus Christi Bay and Redfish Bay is less than 0.79 inches, ranging from –0.04 to 1.57 inches. A noticeable impact on the tidal range is limited to the Navigation Channel from Point Mustang to the inner basin (W.F. Baird and Associates, 2022).

Secondary long-term modeling indicates similar impacts to mean water levels as predicted by the short-term model. The model predicted that the tidal amplitude at the Inner Channel near Port Aransas had the largest increase of about 15 percent. The increase in tidal amplitudes were found to be approximately 10 percent in Redfish Bay, 9 precent in Corpus Christi Bay, 7 percent in Nueces Bay, and 3 percent in Rockport. The model predicted that the average increase in tidal range is approximately 1.38 inches at the inner channel near Port Aransas, and the average tidal range increase at Corpus Christi Bay and Redfish Bay is less than 0.79 inches. These were consistent with the short-term model (W.F. Baird and Associates, 2022).

2.4.4 Salinity Gradients

Short-term modeling was conducted to assess the impact of channel deepening on salinity by comparing the salinity predicted for the Proposed Action to existing conditions. The results indicate that channel deepening would increase average salinity by less than 1 ppt along the navigation channel. Channel deepening may result in small instantaneous changes in salinity (about ±3 ppt) in proposed dredge area and connected navigation channels. Channel deepening may also cause some small change in salinity (about ±3 ppt) at the outlet of Nueces Bay during high flow periods from the Nueces River (W.F. Baird and Associates, 2022).

Secondary long-term modeling also showed that channel deepening would not cause significant salinity change on average, but it may cause short-term changes in the range of ±3 ppt in the proposed dredge area and the connected navigation channels (W.F. Baird and Associates, 2022).

Activities associated with offshore placement and the BU of dredged material are not anticipated to impact salinity levels in the project area. Localized impacts may occur in areas where new work material is used to develop or expand bird islands in Corpus Christi Bay. These impacts would be limited to short-term changes in salinity resulting from freshwater runoff during rain events.

2.4.5 Actions that Will Be Taken to Minimize Impacts

Some of the project features were developed because of stakeholder coordination and placement discharges will take place on existing PAs, eroding shorelines, storm-damaged shorelines, or eroding beach. Best management practices will be in place to avoid and minimize impacts during discharge such as use of turbidity curtains to protect seagrass.

2.5 SUSPENDED PARTICULATE/TURBIDITY DETERMINATION

2.5.1 Expected Changes in Suspended Particulates and Turbidity Levels in Vicinity of Disposal Site

There will be some temporary increase in local turbidity during dredging and placement operations. Water clarity is expected to return to normal background levels shortly after operations are completed. Turbidity increases also may occur during dewatering.

2.5.2 Effects on Chemical and Physical Properties of the Water Column

2.5.2.1 Light Penetration

The temporary and localized turbidity increases during dredging and placement actions would also have temporary and localized impacts to light penetration. Conditions are anticipated to return to normal levels of light penetration following construction.

2.5.2.2 Dissolved Oxygen

Temporary dissolved oxygen decreases associated with extended periods of construction and dredged material placement may happen from aerobic decomposition from short-term increases in organic matter suspended within the water column. Additional information can be found in Section 4.1.4 of the DEIS.

2.5.2.3 Toxic Metals and Organics

Sediments are not expected to contain toxic metals and organics.

2.5.2.4 Pathogens

Sediments are not expected to contain or influence pathogens.

2.5.2.5 Aesthetics

Placement areas that target restoration or beach nourishment may improve aesthetics. Placement areas with levee improvement and fill may detract from aesthetics.

2.5.2.6 Others as Appropriate

No other potential impacts to water quality have been identified; additional information can be found in the DEIS.

2.5.3 Effects on Biota

Long-term effects to biota are expected to be beneficial due to restoration actions; negative effects to biota are expected to be temporary and localized.

2.5.4 Actions Taken to Minimize Impacts

Some of the project features were developed because of stakeholder coordination and placement discharges will take place on existing PAs, eroding shorelines, storm-damaged shorelines, or eroding beach. Best management practices will be in place to avoid and minimize impacts during discharge such as use of turbidity curtains to protect seagrass.

2.6 CONTAMINANT DETERMINATIONS

Although additional sediment sampling is pending, prior sampling for the –54 foot authorized depth did not indicate any concern for contaminants. A Sampling Analysis Plan for the Marine Protection, Research and Sanctuaries Act Section 103 evaluation of sediment was developed to determine if the new work material sediments proposed to be dredged are acceptable for disposal in the New Work ODMDS. Included in that plan is the biological testing of sediment, including sediment toxicity and bioaccumulation (Freese and Nichols, Inc., 2021). This testing is currently being conducted by PCCA.

Measurable impacts from chemical contaminants such as heavy metals, synthetic organic compounds, and nutrients are not expected to present in sediments. This conclusion is based on pre-dredging bulk analyses and toxicity and bioaccumulation assessments conducted from 1980 to 2002, whose results show that no extensive or severe contamination occurs in the sediments within the CCSC, and that dredged material was suitable for offshore placement without special management conditions (EPA and USACE, 2008; USACE, 2003). Most of the material to be dredged will be new work material, which is unlikely to have been exposed to contaminants or pollution.

2.7 AQUATIC ECOSYSTEM AND ORGANISM DETERMINATIONS

2.7.1 Effects on Plankton

During construction of the Proposed Action, temporary disturbances and impacts to plankton assemblages would occur. Turbidity from total suspended solids tends to reduce light penetration and thus reduce photosynthetic activity by phytoplankton (Wilber and Clarke, 2001). Such reductions in primary productivity would be localized around the immediate area of the dredging and placement operations. This reduced productivity may be offset by an increase in nutrients released into the water column during dredging activities that can increase productivity in the area surrounding the dredging activities (Newell et al., 1998; Wilber and Clarke, 2001). In past studies of impacts of dredged material placement from turbidity and nutrient release, the effects are both localized and temporary (May 1973). Due to the capacity and natural variation in phytoplankton populations, the impacts to phytoplankton from project construction, dredging within the project area, and dredged material placement of material would be temporary.

2.7.2 Effects on Benthos

Impacts to benthos would be localized and temporary; however, benthic organisms are expected to quickly rebound following construction activities since the majority of the project is in shallower, high energy estuarine habitats (Bolam et al., 2010; Bolam and Rees, 2003; Newell et al., 1998; Sheridan, 1999, 2004; VanDerWal et al., 2011; Wilber et al., 2006). There would be direct impacts to benthic organisms, which would be buried or removed during construction of the Proposed Action. Excavation of sediments removes and buries benthic organisms, whereas placement of dredged material and structures smothers or buries benthic communities. Dredging and placement activities may cause ecological damage to benthic organisms due to ecosystem physical disturbance, mobilization of sediment contaminants making them more bio-available, and increasing concentrations of suspended sediments (Montagna et al., 1998).

2.7.3 Effects on Nekton

During construction of the Proposed Action, temporary disturbances and impacts to nekton assemblages would occur. Although there may be temporary and localized effects to nekton due to dredging and placement operations, long-term benefits may result from restoration actions.

2.7.4 Effects on Aquatic Food Web

The effects on benthic biota (such as infauna) and nekton (e.g., plankton) that form the base of the aquatic food web would be localized, temporary, and not result in substantial adverse impacts to populations. Long-term benefits to ecological functions, including trophic dynamics, may result from restoration actions that benefit biota.

2.7.5 Effects on Special Aquatic Sites

Direct impacts to Special Aquatic Sites are anticipated, but the overall action is intended to restore Special Aquatic Sites. The Port Aransas Nature Preserve should benefit from placement of sediment at proposed placement site SS2. Placement of dredged material for BU should restore two shoreline breaches and land at the Port Aransas Nature Preserve.

2.8 PROPOSED DISPOSAL SITE DETERMINATIONS

2.8.1 Mixing Zone Determination

It is assumed that there would be no discharge quality concerns and that no mixing zones would be required.

2.8.2 Determination of Compliance with Applicable Water Quality Standards

Project actions would be performed in compliance with State and Federal regulations and would adhere to applicable water quality standards.

2.8.3 Potential Effects on Human Use Characteristics

2.8.3.1 Municipal and Private Water Supply

There are municipal and private water supplies located within the project area, but water quality of water supplies and drinking water would not be impacted.

2.8.3.2 Recreational and Commercial Fisheries

Although the Proposed Action is anticipated to have minor impacts on salinity, tidal amplitude, tidal velocities, freshwater retention time, and tidal prism (all of which may result in effects to recreational and commercial fisheries), some placement actions targeting restoration may result in the provision of additional habitats for recreational and commercial fisheries.

2.8.3.3 Water-related Recreation

Some placement actions targeting restoration may result in the provision of additional habitats for recreational and commercial fisheries. Bird watching opportunities may also be enhanced with some of the placement actions.

2.8.3.4 Aesthetics

Placement areas that target restoration or beach nourishment may improve aesthetics by restoring natural habitat features. Placement areas with levee improvement and fill may detract from aesthetics.

2.8.3.5 Parks, National and Historic Monuments, National Seashores, Wilderness Areas, Research Sites, and Similar Preserves

No Federal lands would be affected by the Proposed Action. The Port Aransas Nature Preserve should benefit from placement of sediment at proposed placement site SS2. Placement of dredged material for BU should restore two shoreline breaches and land at the Port Aransas Nature Preserve. State-owned lands include beaches, and beach nourishment may benefit those areas on Mustang and San José islands.

2.9 DETERMINATION OF CUMULATIVE EFFECTS ON THE AQUATIC ECOSYSTEM

The Proposed Action is expected to contribute to cumulative effects on tidal amplitude. For example, with the Proposed Action, the tidal amplitude at the Inner Channel near Port Aransas may experience up to a 15 percent increase. When considering the impacts of tidal amplitude of the No-Action condition (–54 feet MLLW authorized depth) over previous condition (–48 feet MLLW authorized depth), modeling indicates that the –54 feet depth also increased the tidal amplitude over the –48 feet depth, by up to 18 percent at the Inner Channel. These modeling results indicate that the CDP would result in a direct cumulative impact to tidal range, particularly at the Inner Channel near Port Aransas where cumulative increases of tidal amplitude approach 36 percent (W.F. Baird and Associates, 2022).

The Proposed Action would result in temporary and localized increases in turbidity which can affect the aquatic ecosystem. The impacts are expected to be minor. Where past, present, or reasonably foreseeable actions may have simultaneous construction and similar impacts, there could be a chance of cumulative effects (although they would be minor, localized, and temporary). Beneficial cumulative effects may result from placement actions that target restoration in conjunction with other ecosystem restoration actions in the region.

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Appendix O

Coastal Zone Management Consistency Determination

Job No. PCA20166

APPENDIX O

DRAFT
TEXAS COASTAL ZONE MANAGEMENT PROGRAM CONSISTENCY DETERMINATION FOR THE PROPOSED CORPUS CHRISTI SHIP CHANNEL DEEPENING PROJECT

Prepared for:

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June 2022

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Acronyms and Abbreviations

BMP	best management practice
BU	beneficial use
CCSC	Corpus Christi Ship Channel
CDP	channel deepening project
CNRA	Coastal Natural Resource Area
CNRA	Coastal Natural Resource Areas
DA	Department of Army
EIS	Environmental Impact Statement
GLO	Texas General Land Office
Gulf	Gulf of Mexico
LEDPA	least environmentally damaging practicable alternative
mcy	million cubic yards
MLLW	mean lower low water
NEPA	National Environmental Policy Act
PA	Placement Area
PCCA or Applicant	Port of Corpus Christi Authority
SAV	submerged aquatic vegetation
SWC	USACE, Galveston District
TCEQ	Texas Commission on Environmental Quality
TxDOT	Texas Department of Transportation
USACE	U.S. Army Corps of Engineers
VLCC	Very Large Crude Carrier

1.0 INTRODUCTION

The Port of Corpus Christi Authority (PCCA or Applicant) applied to the U.S. Army Corps of Engineers (USACE), Galveston District (SWG), for a Department of Army (DA) permit. The DA permit application is for deepening of the Corpus Christi Ship Channel (CCSC). The application was originally submitted on January 3, 2019. Based on comments provided by the USACE on May 23, 2019, the application was revised June 4, 2019. The DA permit action is governed under the following statutes:

- **Section 10 of the Rivers and Harbors Act of 1899:** Section 10 of the Rivers and Harbors Act prohibits the construction of structures or obstructions in navigable waters without consent of Congress (33 USC 403). Structures include wharves, piers, jetties, breakwaters, bulkheads, etc. The Rivers and Harbors Act also considers any changes to the course, location, condition, or capacity of navigable waters and includes dredge and fill projects in those waters. The USACE oversees implementation of this law. The proposed action would include construction of structures and/or work that may affect navigable waters.
- **Section 14 of the Rivers and Harbors Act of 1899:** Section 14 of the Rivers and Harbors Act authorizes the USACE to approve alterations to public works projects operated and maintained by non-Federal sponsors known as Section 408 (33 USC 408). Any modification to a Federally maintained USACE project requires a 408 approval from the Chief of Engineers. The proposed action would constitute a major modification to a Federal navigation channel which will require a more comprehensive review and evaluation.
- **Section 404 of the Clean Water Act:** Section 404 of the Clean Water Act (33 USC 1344) normally requires a USACE permit for the discharge or deposition of dredged or fill material and for the building of structures in all waters of the United States. The proposed action would include the discharge of dredged or fill material into waters of the United States. This is responsible for ensuring "no net loss" of wetlands by requiring permit applicants to make every effort to avoid and minimize aquatic resource impacts and provide compensatory mitigation to offset any permitted impacts. The USACE can only permit the least environmentally damaging practicable alternative (LEDPA) as it pertains to regulated fill discharges. For this proposed project the LEDPA only applies to the Dredged Material Management Plan.
- **Section 103 of the Marine Protection, Research, and Sanctuaries Act:** Section 103 of the Marine Protection, Research, and Sanctuaries Act prescribes regulations, procedures, and evaluations applicable to Federal projects for the placement of dredged material in offshore waters. The proposed action would include construction of structures and/or work that may affect ocean disposal of dredged material.

Based on the DA permit application submitted by PCCA, the USACE determined that the permitting action for the proposed project constitutes a major Federal action. The USACE published a Notice of Intent to prepare a Draft Environmental Impact Statement (EIS), which was published in the *Federal Register* on April 7, 2020.

Pursuant to the National Environmental Policy Act (NEPA) of 1969, as amended (42 USC 4323 et seq.), the USACE serves as the Lead Agency for the preparation of the EIS. A Draft EIS has been prepared to analyze and disclose the potential impacts of the PCCA Channel Deepening Project (CDP) and reasonable alternatives on the natural and human environment. It is intended to be sufficient in scope to address Federal, State, and local requirements with respect to the proposed activities and permit approvals. As part of the NEPA process, the U.S. Environmental Protection Agency, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, the U.S. Fish and Wildlife Service, and the U.S. Coast Guard are cooperating agencies. The Texas Commission on Environmental Quality (TCEQ) and the Texas Parks and Wildlife Department are commenting agencies.

1.1 PROJECT LOCATION

The Proposed Action Alternative is located within the existing channel bottom of the CCSC starting at Station 110+00 near the southeast side of Harbor Island, traversing easterly through the Aransas Pass, and extending beyond the currently authorized terminus Station –330+00 an additional 29,000 feet terminating out into the Gulf of Mexico (Gulf) at the proposed new Terminus Station –620+00, an approximate distance of 13.8 miles, in Port Aransas, Nueces County, Texas. This segment is currently maintained to the Federally authorized depth of –54.0 feet mean lower low water (MLLW) along the Entrance Channel and to –46.4 feet MLLW between the Entrance Channel to 0.5 mile east of Harbor Bridge. The Federally authorized Corpus Christi Ship Channel Improvement Project has deepened the offshore section outside the jetties from –49 feet MLLW to –56 feet MLLW and will widen the CCSC from 500 to 530 feet in the reach from Port Aransas to Ingleside and from 400 to 530 feet in Corpus Christi Bay with the addition of barge lanes.

1.2 APPLICANT'S PROPOSED ACTION ALTERNATIVE

The CCSC is currently authorized by the USACE to project depths of –54 feet and –56 feet MLLW from Station 110+00 to Station –330+00 as part of the CCSC Improvement Project. The current authorized width of the CCSC is 600 feet inside the jetties and 700 feet in the entrance channel.

The Applicant's Proposed Action Alternative would deepen the channel from Station 110+00 to Station –72+50 to a maximum depth of –79 feet MLLW (–75 feet MLLW plus two feet of advanced maintenance and two feet of allowable overdredge), and from Station –72+50 to Station –330+00, the channel would be deepened to a maximum depth of –81 feet MLLW (–77 feet MLLW plus two feet of advanced maintenance and two feet of allowable overdredge). The proposed project includes a 29,000-foot extension of the CCSC from Station–330+00 to Station –620+00 to a maximum depth of –81-foot MLLW (–77 feet MLLW plus two feet of advanced maintenance and two feet of allowable overdredge) to reach the –80-foot MLLW bathymetric contour in the Gulf. The proposed project would span approximately 13.8 miles from a location near the southeast side of Harbor Island to the –80-foot MLLW bathymetric contour in the Gulf. The proposed project would cover approximately 1,778 acres, creating approximately 46 million cubic yards (mcy) of new work dredged material (17.1 mcy of clay and 29.2 mcy of sand).

The proposed project consists of the following:

- Deepening a portion of the CCSC from the current authorization of –54 and –56 feet MLLW to final constructed deepened channel ranging from –75 to –77 feet MLLW to accommodate fully-laden Very Large Crude Carriers (VLCC) transiting from Harbor Island to the Gulf from Stations 110+00 to –620+00;
- Extending the existing terminus of the authorized channel an additional 29,000 feet into the Gulf to reach the –80-foot MLLW bathymetric contour to accommodate fully-laden VLCCs transiting from Harbor Island to the Gulf;
- Expanding the existing Inner Basin at Harbor Island as necessary to accommodate VLCCs turning;
- Placement of new work dredged material into waters of the United States for beneficial use (BU) sites located in and around Corpus Christi and Redfish bays;
- Placement of dredged material on San José Island for dune restoration;
- Placement of dredged material nearshore berms for beach restoration along San José and Mustang islands; and
- Transport of new work dredged material to the Corpus Christi New Work Ocean Dredged Material Disposal Site.

1.3 PROJECT PURPOSE

The overall project purpose, as determined by the USACE after concurrence with the Cooperating Agencies is: To safely, efficiently, and economically export current and forecasted crude oil inventories via VLCC, a common vessel in the world fleet. Crude oil is delivered via pipeline from the Eagle Ford and Permian Basins to multiple locations at the Port. Crude oil inventories exported at the Port have increased from 280,000 barrels per day in 2017 to 1,650,000 barrels in January 2020 with forecasts increasing to 4,500,000 barrels per day by 2030. Current facilities require vessel lightering to fully load a VLCC which increases cost and effects safety.

The purpose of the proposed project, as provided by the Applicant, is to construct a channel with the capability to accommodate transit of fully laden VLCCs from multiple locations on Harbor Island into the Gulf. Factors influencing the Applicant’s need for the project include:

- The ability for more efficient movement of U.S. produced crude oil to meet current and forecasted demand in support of national energy security and national trade objectives,
- Enhancement of the PCCA’s ability to accommodate future growth in energy production, and
- Construction of a channel project that the PCCA can readily implement to accommodate industry needs.

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2.0 IMPACTS ON COASTAL NATURAL RESOURCE AREAS

The following coastal natural resource areas, as listed in Texas Natural Resources Code, §33.203(1), are included for their relevance to the PCCA CDP:

- Waters of the open Gulf
- Waters under tidal influence
- Submerged lands
- Coastal wetlands
- Submerged aquatic vegetation (SAV)
- Tidal sand and mud flats
- Oyster reefs
- Coastal barriers
- Coastal shore areas
- Gulf Beaches
- Critical Dune Areas
- Special Hazard Areas
- Critical Erosion Areas
- Coastal Preserves

2.1 WATERS OF THE OPEN GULF OF MEXICO

A portion of the Applicant's Proposed Action Alternative would be constructed within water of the open Gulf and would alter bathymetry to accommodate the deeper channel. Additionally, some dredged materials would be discharged in an Ocean Dredged Material Disposal Site. The release of sediment during dredging increases turbidity in the water column, which creates a sediment plume, the extent of which is determined by the direction and strength of the currents and particle size. Due to the capacity and natural variation in phytoplankton and algal populations, the impacts to phytoplankton and algae from project construction, dredging within the project area, dredged material placement of new work and maintenance material, and placement of material for BU project features would be temporary. Impacts to zooplankton from project construction and dredging within the project area, dredged material placement of new work and maintenance material, and placement of material for BU project features would be temporary.

2.2 WATERS UNDER TIDAL INFLUENCE

The majority of the Applicant's Proposed Action Alternative would be constructed within waters under tidal influence. Although there would be direct impacts from dredging and placement activities, placement areas (PAs) include BU to improve eroded or damaged shorelines.

The Applicant's Proposed Action Alternative may have the following impacts to waters under tidal influence in Corpus Christi Bay based on modeling (W.F. Baird and Associates, 2022):

- Salinity modeling predicts that channel deepening would increase salinity in the project area by less than 1 parts per thousand (W.F. Baird and Associates, 2022). At less than 1 parts per thousand, the magnitude of change is negligible and would be less than significant given the wide salinity tolerances of estuarine species.

- The velocity magnitudes in the CCSC entrance channel are expected to be lower with the deeper channel compared to current conditions (W.F. Baird and Associates, 2022). This slight decrease in velocity at the entrance channel is not anticipated to impact fauna.
- The tidal range/amplitude is expected to increase with channel deepening (W.F. Baird and Associates, 2022). The model predicted that the tidal amplitude at the Inner Channel near Port Aransas had the largest increase of about 15 percent. The increase in tidal amplitudes were found to be approximately 10 percent in Redfish Bay, 9 precent in Corpus Christi Bay, 7 percent in Nueces Bay, and 3 percent in Rockport.

2.3 SUBMERGED LANDS

The Applicant's Proposed Action Alternative would result in permanent loss of open-bay bottom and tidal habitat through some of the inshore placement actions. Bathymetry changes would also occur through channel deepening. Bathymetric changes would also occur from beach nourishment placement actions (direct placement and nearshore berms).

2.4 COASTAL WETLANDS

Channel deepening would not impact coastal wetlands, but inshore placement areas would impact 16.61 acres of tidal wetlands and 181.22 acres of freshwater wetlands. Some placement actions are intended to create coastal prairie or marsh habitat and would protect adjacent seagrass and wetlands. Short-term localized impacts are expected during restoration activities because of increased turbidity, or thin-layer placement, for example. Although channel modifications can alter erosion and salinity (which could in turn affect wetlands or SAV) no significant change in water exchange, salinity, and inflow patterns would occur with the Applicant's Proposed Action Alternative.

2.5 SUBMERGED AQUATIC VEGETATION

The proposed channel dredging for the Applicant's Proposed Action Alternative would have no direct impacts to SAV as they are not present within the project footprint for proposed channel deepening. Indirect impacts from turbidity would be limited to the area around the dredging, and no significant impacts would be expected to seagrass from temporary turbidity. Although channel modifications can alter erosion and salinity (which could in turn affect wetlands or SAV), no significant change in water exchange, salinity, and inflow patterns would occur with the Applicant's Proposed Action Alternative.

The project footprint associated with proposed BU sites include areas where SAV has been mapped and includes 6.74 acres of impact. SAV would not be affected by dredged material placement unless specifically targeted for restoration or enhancement from BU actions. Although SAV impacts may occur with dredged material placement actions, it should be noted that dredged material would be used at all BU sites to either convert deep open water areas to protect adjacent shallow bathymetry areas that support tidal wetlands or SAV, or restore eroding shorelines that may protect areas of SAV.

2.6 TIDAL SAND AND MUD FLATS

The Applicant's Proposed Action Alternative includes placement areas and actions that would impact tidal sand and mud flats; however, those placement actions are intended as BU to either convert deep open water areas to protect adjacent shallow bathymetry areas that support tidal wetlands or SAV, or restore eroding shorelines that may protect areas of SAV. Placement areas would impact 84.85 acres of flats (Mott MacDonald, 2021, 2022).

2.7 OYSTER REEFS

A total of 0.10 acres of live oyster reef habitat occurs in the footprint of placement site HI-E and would be directly impacted by the CDP. The Texas General Land Office (GLO, 2021) indicates 32 acres of mapped oyster reef habitat occur in the remainder of the project area and 3.17 acres of oysters were mapped within a 500-foot construction buffer of the inshore PAs (Triton Environmental Solutions, 2021, 2022). These oyster areas could be indirectly impacted by increased turbidity during construction of placement site HI-E. Turbidity increases from construction of the Applicant's Proposed Action Alternative would be temporary and local. The slight increase in salinity that is expected resulting from the Applicant's Proposed Action Alternative is not anticipated to cause any long-term impacts to oyster reefs in the project area. Increased nutrients from dredging activities could cause algal blooms that could impact oysters. Water column turbidity would increase during project construction that could affect survival or growth of oysters nearby.

2.8 COASTAL BARRIERS

The Applicant's Proposed Action Alternative includes some placement actions consisting of beach nourishment, dune restoration, and nearshore berms that would have positive impacts in terms of maintaining coastal barriers. Dredged material from channel deepening would be used beneficially for dune restoration on San José Island, and nearshore berms for beach nourishment along San José and Mustang islands. Beach nourishment placement at MI and SJI would result in 323.12 acres of beach/sand flat habitat impacts.

2.9 COASTAL SHORE AREAS

Some portions of the Applicant's Proposed Action Alternative would be constructed within 100 feet landward of the high tide line, which is within coastal shore areas. The Applicant's Proposed Action Alternative includes placement actions that include beach nourishment that would have positive impacts in terms of maintaining coastal barriers. Dredged material from channel deepening would be used beneficially for nearshore berms for potential beach nourishment along San José and Mustang islands.

2.10 GULF BEACHES

The Applicant's Proposed Action Alternative includes placement activities consisting of beach nourishment that would have positive impacts in terms of maintaining coastal barriers and protecting these coastal shore areas during storm surges. Dredged material from channel deepening would be used beneficially for nearshore berms for potential beach nourishment along San José and Mustang islands. Actions include direct placement on dunes and beaches and nearshore berms. Beach nourishment placement at MI and SJI would result in 323.12 acres of beach/sand flat habitat impacts.

2.11 CRITICAL DUNE AREAS

Some portions of the Applicant's Proposed Action Alternative would be constructed on the Gulf shoreline within 1,000 feet of mean high tide, designated as critical dune area. Dredged material from channel deepening would be used beneficially for dune restoration on San José Island that was damaged during Hurricane Harvey.

2.12 SPECIAL HAZARD AREAS

The entirety of the Applicant's Proposed Action Alternative would be constructed within the 100-year floodplain. Dredged material from channel deepening would be used for PA levee improvements and fill, shoreline restoration, and beach and dune nourishment, which should improve the natural storm-buffer functions Dredged material from channel deepening would be used for dune restoration on San José Island, and nearshore berms for potential beach nourishment along San José and Mustang islands. Dredged material from channel deepening would be used beneficially to convert deep open water areas to shallow bathymetry to support the establishment of tidal wetlands or PAs.

2.13 CRITICAL EROSION AREAS

Some of the placement actions for the Applicant's Proposed Action Alternative are intended to repair eroded shorelines near Port Aransas. Dredged material from channel deepening would be used beneficially for nearshore berms for potential beach nourishment along San José and Mustang islands.

2.14 COASTAL PRESERVES

No impact to coastal preserves would result from the Applicant's Proposed Action Alternative. Dredged material from channel deepening would be used beneficially around Redfish Bay, which contains the Redfish Bay State Scientific Area, containing approximately 14,000 acres of seagrasses. "Voluntary No-prop Zones" were established by the Texas Parks and Wildlife Department in this area to protect the five unique species of seagrasses from being damaged by outboard motor propellers. Some placement actions may function as a buffer to seagrass found in Redfish Bay State Scientific Area and would involve: 1) convert deep open water areas to shallow bathymetry to support either establishment of tidal wetlands or SAV, or 2) restore eroding shorelines that would protect large areas of SAV.

3.0 COMPLIANCE WITH GOALS AND POLICIES

The following rules, as outlined under the Texas Administrative Code (Title 31, Part 16), governing the Texas Coastal Management Program were reviewed for compliance:

- §501.15 – Policy for Major Actions
- §501.25 – Policy for Dredging and Dredged Materials and Placement
- §501.26 – Policies for Construction in the Beach/Dune System
- §501.27 – Policies for Development in Coastal Hazard Areas
- §501.28 – Policies for Development Within Coastal Barrier Resource System Units and Otherwise Protected Areas on Coastal Barriers
- §501.31 – Policies for Transportation Projects
- §501.32 – Policies for Emission of Air Pollutants

3.1 SECTION 501.15 – POLICY FOR MAJOR ACTIONS

(a) For purposes of this section, "major action" means an individual agency or subdivision action listed in §505.11 of this title (relating to Actions and Rules Subject to the Coastal Management Program), §506.12 of this title (relating to Federal Actions Subject to the Coastal Management Program), or §505.60 of this title (relating to Local Government Actions Subject to the Coastal Management Program), relating to an activity for which a Federal environmental impact statement under the National Environmental Policy Act, 42 United States Code Annotated, §4321, et seq. is required.

(b) Prior to taking a major action, the agencies and subdivisions having jurisdiction over the activity shall meet and coordinate their major actions relating to the activity. The agencies and subdivisions shall, to the greatest extent practicable, consider the cumulative and secondary adverse effects, as described in the Federal environmental impact assessment process, of each major action relating to the activity.

(c) No agency or subdivision shall take a major action that is inconsistent with the goals and policies of this chapter. In addition, an agency or subdivision shall avoid and otherwise minimize the cumulative adverse effects to coastal natural resource areas of each of its major actions relating to the activity.

Compliance: The Applicant's Proposed Action Alternative is being evaluated by State and Federal agencies, as well as the public, through the NEPA compliance processes associated with an EIS. Potential cumulative effects with past, present, and reasonably foreseeable actions on Coastal Natural Resource Areas (CNRAs) bay be beneficial in nature as the PAs for the Applicant's Proposed Action Alternative include placement activities that target restoration of eroded and storm damaged

CNRAs. Compliance with State and Federal regulations and use of best management practices (BMPs) would avoid and minimize impacts.

3.2 SECTION 501.23 – POLICIES FOR DEVELOPMENT IN CRITICAL AREAS

(a) Dredging and construction of structures in, or the discharge of dredged or fill material into, critical areas shall comply with the policies in this section. In implementing this section, cumulative and secondary adverse effects of these activities will be considered.

(1) The policies in this section shall be applied in a manner consistent with the goal of achieving no net loss of critical area functions and values.

(2) Persons proposing development in critical areas shall demonstrate that no practicable alternative with fewer adverse effects is available.

(3) In evaluating practicable alternatives, the following sequence shall be applied:

(A) Adverse effects on critical areas shall be avoided to the greatest extent practicable.

(B) Unavoidable adverse effects shall be minimized to the greatest extent practicable by limiting the degree or magnitude of the activity and its implementation.

(C) Appropriate and practicable compensatory mitigation shall be required to the greatest extent practicable for all adverse effects that cannot be avoided or minimized.

Compliance: Discharges within CNRAs are intended to restore eroded and storm-damaged areas. Placement actions include restoration of eroded shorelines, PA levee improvement and fill, repair of storm-damaged shorelines, and potential beach nourishment through direct placement and nearshore berms. These actions target beneficial use and were preferred over offshore disposal or other alternatives with less contribution to CNRA function and value. In the area with the greatest increase in tidal range/amplitude, there is an abundance of developed and industrial shorelines. Existing CNRAs in this area have experienced severe erosion from storms and ship wakes and BU actions are intended to improve these areas.

(7) Development in critical areas shall not be authorized if significant degradation of critical areas will occur. Significant degradation occurs if:

(A) the activity will jeopardize the continued existence of species listed as endangered or threatened, or will result in likelihood of the destruction or adverse modification of a habitat determined to be a critical habitat under the Endangered Species Act, 16 United States Code Annotated, §§1531 – 1544;

Compliance: The Applicant's Proposed Action Alternative was fully evaluated under the Endangered Species Act as part of the NEPA compliance processes associated with an EIS. No listed species continued existence would be jeopardized as a result of the Applicant's Proposed Action Alternative.

(B) the activity will cause or contribute, after consideration of dilution and dispersion, to violation of any applicable surface water quality standards established under §501.21 of this title;

Compliance: The Applicant's Proposed Action Alternative would comply with all State and Federal water quality standards; a 404(b)1 evaluation has been prepared for this project and will be submitted to the agencies for review and concurrence.

(C) the activity violates any applicable toxic effluent standard or prohibition established under §501.21 of this title;

Compliance: The Applicant's Proposed Action Alternative would comply with all State and Federal water quality standards; sediment sampling indicates no constituents of concern are present.

(D) the activity violates any requirement imposed to protect a marine sanctuary designated under the Marine Protection, Research, and Sanctuaries Act of 1972, 33 United States Code Annotated, Chapter 27; or

Compliance: The Applicant's Proposed Action Alternative would not affect any marine sanctuaries.

(E) taking into account the nature and degree of all identifiable adverse effects, including their persistence, permanence, areal extent, and the degree to which these effects will have been mitigated pursuant to subsections (c) and (d) of this section, the activity will, individually or collectively, cause or contribute to significant adverse effects on:

(i) human health and welfare, including effects on water supplies, plankton, benthos, fish, shellfish, wildlife, and consumption of fish and wildlife;

(ii) the life stages of aquatic life and other wildlife dependent on aquatic ecosystems, including the transfer, concentration, or spread of pollutants or their byproducts beyond the site, or their introduction into an ecosystem, through biological, physical, or chemical processes;

(iii) ecosystem diversity, productivity, and stability, including loss of fish and wildlife habitat or loss of the capacity of a coastal wetland to assimilate nutrients, purify water, or reduce wave energy; or

(iv) *generally accepted recreational, aesthetic or economic values of the critical area which are of exceptional character and importance.*

Compliance: Discharges within CNRAs are intended to restore eroded and storm-damaged areas. Placement actions include restoration of eroded shorelines, PA levee improvement and fill, repair of storm-damaged shorelines, and potential beach nourishment through direct placement and nearshore berms. These actions target beneficial use and were preferred over offshore disposal or other alternatives with less contribution to CNRA function and value. Compliance with State and Federal regulations and use of BMPs would avoid and minimize impacts.

(b) *The TCEQ and the RRC shall comply with the policies in this section when issuing certifications and adopting rules under Texas Water Code, Chapter 26, and the Texas Natural Resources Code, Chapter 91, governing certification of compliance with surface water quality standards for federal actions and permits authorizing development affecting critical areas; provided that activities exempted from the requirement for a permit for the discharge of dredged or fill material, described in Code of Federal Regulations, Title 33, §323.4 and/or Code of Federal Regulations, Title 40, §232.3, including but not limited to normal farming, silviculture, and ranching activities, such as plowing, seeding, cultivating, minor drainage, and harvesting for the production of food, fiber, and forest products, or upland soil and water conservation practices, shall not be considered activities for which a certification is required. The GLO and the SLB shall comply with the policies in this section when approving oil, gas, or other mineral lease plans of operation or granting surface leases, easements, and permits and adopting rules under the Texas Natural Resources Code, Chapters 32, 33 and 51–53, and Texas Water Code, Chapter 61, governing development affecting critical areas on state submerged lands and private submerged lands, and when issuing approvals and adopting rules under Texas Natural Resources Code, Chapter 221, for mitigation banks operated by subdivisions of the state.*

Compliance: The Applicant's Proposed Action Alternative would comply with all State and Federal water quality standards. This project does not involve agricultural actions, oil and gas activities, or establishment of a mitigation bank.

(c) *Agencies required to comply with this section will coordinate with one another and with federal agencies when evaluating alternatives, determining appropriate and practicable mitigation, and assessing significant degradation. Those agencies' rules governing authorizations for development in critical areas shall require a demonstration that the requirements of subsection (a)(1)–(7) of this section have been satisfied.*

Compliance: The Applicant's Proposed Action Alternative is being evaluated by state and federal agencies, as well as the public, through the NEPA compliance processes associated with an EIS. Potential cumulative effects with past, present, and reasonably foreseeable actions on CNRAs bay be beneficial in nature as the PAs for the Applicant's Proposed Action Alternative include placement

activities that target restoration of eroded and storm damaged CNRAs. Compliance with State and Federal regulations and use of BMPs would avoid and minimize impacts.

(d) For any dredging or construction of structures in, or discharge of dredged or fill material into, critical areas that is subject to the requirements of §501.15 of this title (relating to Policy for Major Actions), data and information on the cumulative and secondary adverse effects of the project need not be produced or evaluated to comply with this section if such data and information is produced and evaluated in compliance with §501.15(b)–(c) of this title.

Compliance: The Applicant's Proposed Action Alternative is a Federal action that includes the preparation of an EIS under NEPA. All plan formulations included coordination with an interagency team consisting of State and Federal agencies. The project would comply with the goals and policies of this chapter. Cumulative and secondary impacts were evaluated in Section 501.15(b)–(c) of this compliance document.

3.3 SECTION 501.24 – POLICIES FOR CONSTRUCTION OF WATERFRONT FACILITIES AND OTHER STRUCTURES ON SUBMERGED LANDS

(a) Development on submerged lands shall comply with the policies in this section.

(14) Nonstructural erosion response methods such as beach nourishment, sediment bypassing, nearshore sediment berms, and planting of vegetation shall be preferred instead of structural erosion response methods.

(17) Erosion of Gulf beaches and coastal shore areas caused by construction or modification of jetties, breakwaters, groins, or shore stabilization projects shall be mitigated to the extent the costs of mitigation are reasonably proportionate to the benefits of mitigation. Factors that shall be considered in determining whether the costs of mitigation are reasonably proportionate to the cost of the construction or modification and benefits include, but are not limited to, environmental benefits, recreational benefits, flood or storm protection benefits, erosion prevention benefits, and economic development benefits.

(b) To the extent applicable to the public beach, the policies in this section are supplemental to any further restrictions or requirements relating to the beach access and use rights of the public.

Compliance: The Applicant's Proposed Action Alternative is being evaluated by State and Federal agencies, as well as the public, through the NEPA compliance processes associated with an EIS. Placement areas for the Applicant's Proposed Action Alternative include placement activities that target restoration of eroded and storm damaged CNRAs. Compliance with State and Federal regulations and use of BMPs would avoid and minimize impacts.

3.4 SECTION 501.25 – DREDGING AND DREDGED MATERIAL DISPOSAL AND PLACEMENT

(a) *Dredging and the disposal and placement of dredged material shall avoid and otherwise minimize adverse effects to coastal waters, submerged lands, critical areas, coastal shore areas, and Gulf beaches to the greatest extent practicable. The policies of this section are supplemental to any further restrictions or requirements relating to the beach access and use rights of the public. In implementing this section, cumulative and secondary adverse effects of dredging and the disposal and placement of dredged material and the unique characteristics of affected sites shall be considered.*

Compliance: Discharges within CNRAs are intended to restore eroded and storm-damaged areas. Placement actions include restoration of eroded shorelines, PA levee improvement and fill, repair of storm-damaged shorelines, and potential beach nourishment through direct placement and nearshore berms. These actions target BU and were preferred over offshore disposal or other alternatives with less contribution to CNRA function and value. Compliance with State and Federal regulations and use of BMPs would avoid and minimize impacts. Although there may be temporary and localized impacts to access during direct beach nourishment activities, long-term impact is beneficial to beach users.

(1) *Dredging and dredged material disposal and placement shall not cause or contribute, after consideration of dilution and dispersion, to violation of any applicable surface water quality standards established under §501.21 of this title.*

Compliance: The Applicant's Proposed Action Alternative would comply with all State and Federal water quality standards; a 404(b)1 evaluation has been prepared for this project and will be submitted to the agencies for review and concurrence. Sediment sampling showed no cause for concern. Additional sampling is pending.

(2) *Except as otherwise provided in paragraph (4) of this subsection, adverse effects on critical areas from dredging and dredged material disposal or placement shall be avoided and otherwise minimized, and appropriate and practicable compensatory mitigation shall be required, in accordance with §501.23 of this title.*

Compliance: Discharges within CNRAs are intended to restore eroded and storm-damaged areas. Placement actions include restoration of eroded shorelines, PA levee improvement and fill, repair of storm-damaged shorelines, and potential beach nourishment through direct placement and nearshore berms. These actions target BU and were preferred over offshore disposal or other alternatives with less contribution to CNRA function and value. Compliance with State and Federal regulations and use of BMPs would avoid and minimize impacts.

(3) *Except as provided in paragraph (4) of this subsection, dredging and the disposal and placement of dredged material shall not be authorized if:*

(A) *there is a practicable alternative that would have fewer adverse effects on coastal waters, submerged lands, critical areas, coastal shore areas, and Gulf beaches, so long as that alternative does not have other significant adverse effects;*

(B) *all appropriate and practicable steps have not been taken to minimize adverse effects on coastal waters, submerged lands, critical areas, coastal shore areas, and Gulf beaches; or*

(C) *significant degradation of critical areas under §501.23(a)(7)(E) of this title would result.*

Compliance: Discharges within CNRAs are intended to restore eroded and storm-damaged areas. Placement actions include restoration of eroded shorelines, PA levee improvement and fill, repair of storm-damaged shorelines, and potential beach nourishment through direct placement and nearshore berms. These actions target BU and were preferred over offshore disposal or other alternatives with less contribution to CNRA function and value. Compliance with State and Federal regulations and use of BMPs would avoid and minimize impacts.

(4) *A dredging or dredged material disposal or placement project that would be prohibited solely by application of paragraph (3) of this subsection may be allowed if it is determined to be of overriding importance to the public and national interest in light of economic impacts on navigation and maintenance of commercially navigable waterways.*

Compliance: Discharges within CNRAs are intended to restore eroded and storm-damaged areas. Placement actions include restoration of eroded shorelines, PA levee improvement and fill, repair of storm-damaged shorelines, and potential beach nourishment through direct placement and nearshore berms. These actions target BU and were preferred over offshore disposal or other alternatives with less contribution to CNRA function and value. Compliance with State and Federal regulations and use of BMPs would avoid and minimize impacts.

(b) *Adverse effects from dredging and dredged material disposal and placement shall be minimized as required in subsection (a) of this section. Adverse effects can be minimized by employing the techniques in this subsection where appropriate and practicable.*

(1) *Adverse effects from dredging and dredged material disposal and placement can be minimized by controlling the location and dimensions of the activity. Some of the ways to accomplish this include:*

(A) *locating and confining discharges to minimize smothering of organisms;*

(B) *locating and designing projects to avoid adverse disruption of water inundation patterns, water circulation, erosion and accretion processes, and other hydrodynamic processes:*

(C) *using existing or natural channels and basins instead of dredging new channels or basins, and discharging materials in areas that have been previously disturbed or used for disposal or placement of dredged material;*

(D) *limiting the dimensions of channels, basins, and disposal and placement sites to the minimum reasonably required to serve the project purpose, including allowing for reasonable overdredging of channels and basins, and taking into account the need for capacity to accommodate future expansion without causing additional adverse effects;*

(E) *discharging materials at sites where the substrate is composed of material similar to that being discharged;*

(F) *locating and designing discharges to minimize the extent of any plume and otherwise control dispersion of material; and*

(G) *avoiding the impoundment or drainage of critical areas.*

Compliance: Discharges within CNRAs are intended to restore eroded and storm-damaged areas. Placement actions include restoration of eroded shorelines, PA levee improvement and fill, repair of storm-damaged shorelines, and potential beach nourishment through direct placement and nearshore berms. These actions target BU and were preferred over offshore disposal or other alternatives with less contribution to CNRA function and value. Compliance with State and Federal regulations and use of BMPs would avoid and minimize impacts.

(2) *Dredging and disposal and placement of material to be dredged shall comply with applicable standards for sediment toxicity. Adverse effects from constituents contained in materials discharged can be minimized by treatment of or limitations on the material itself. Some ways to accomplish this include:*

(A) *disposal or placement of dredged material in a manner that maintains physiochemical conditions at discharge sites and limits or reduces the potency and availability of pollutants;*

(B) *limiting the solid, liquid, and gaseous components of material discharged;*

(C) *adding treatment substances to the discharged material; and*

(D) adding chemical flocculants to enhance the deposition of suspended particulates in confined disposal areas.

<u>Compliance: The Applicant's Proposed Action Alternative would comply with all State and Federal water quality standards and sediment sampling has not indicated any constituents of concern.</u>

(3) Adverse effects from dredging and dredged material disposal or placement can be minimized through control of the materials discharged. Some ways of accomplishing this include:

(A) use of containment levees and sediment basins designed, constructed, and maintained to resist breaches, erosion, slumping, or leaching;

(B) use of lined containment areas to reduce leaching where leaching of chemical constituents from the material is expected to be a problem;

(C) capping in-place contaminated material or, selectively discharging the most contaminated material first and then capping it with the remaining material;

(D) properly containing discharged material and maintaining discharge sites to prevent point and nonpoint pollution; and

(E) timing the discharge to minimize adverse effects from unusually high water flows, wind, wave, and tidal actions.

<u>Compliance: Containment and other BMPs would be used when possible to avoid and minimize impacts.</u>

(4) Adverse effects from dredging and dredged material disposal or placement can be minimized by controlling the manner in which material is dispersed. Some ways of accomplishing this include:

(A) where environmentally desirable, distributing the material in a thin layer;

(B) orienting material to minimize undesirable obstruction of the water current or circulation patterns;

(C) using silt screens or other appropriate methods to confine suspended particulates or turbidity to a small area where settling or removal can occur;

(D) using currents and circulation patterns to mix, disperse, dilute, or otherwise control the discharge;

(E) *minimizing turbidity by using a diffuser system or releasing material near the bottom;*

(F) *selecting sites or managing discharges to confine and minimize the release of suspended particulates and turbidity and maintain light penetration for organisms; and*

(G) *setting limits on the amount of material to be discharged per unit of time or volume of receiving waters.*

Compliance: Containment and other BMPs (including potentially turbidity curtains) would be used to avoid and minimize impacts.

(5) *Adverse effects from dredging and dredged material disposal or placement operations can be minimized by adapting technology to the needs of each site. Some ways of accomplishing this include:*

(A) *using appropriate equipment, machinery, and operating techniques for access to sites and transport of material, including those designed to reduce damage to critical areas;*

(B) *having personnel on site adequately trained in avoidance and minimization techniques and requirements; and*

(C) *designing temporary and permanent access roads and channel spanning structures using culverts, open channels, and diversions that will pass both low and high-water flows, accommodate fluctuating water levels, and maintain circulation and faunal movement.*

Compliance: Appropriate equipment, personnel training, and consideration of flows and circulation patterns would be involved with construction practices and behaviors.

(6) *Adverse effects on plant and animal populations from dredging and dredged material disposal or placement can be minimized by:*

(A) *avoiding changes in water current and circulation patterns that would interfere with the movement of animals;*

(B) *selecting sites or managing discharges to prevent or avoid creating habitat conducive to the development of undesirable predators or species that have a competitive edge ecologically over indigenous plants or animals;*

(C) *avoiding sites having unique habitat or other value, including habitat of endangered species;*

(D) *using planning and construction practices to institute habitat development and restoration to produce a new or modified environmental state of higher ecological value by displacement of some or all of the existing environmental characteristics;*

(E) *using techniques that have been demonstrated to be effective in circumstances similar to those under consideration whenever possible and, when proposed development and restoration techniques have not yet advanced to the pilot demonstration stage, initiating their use on a small scale to allow corrective action if unanticipated adverse effects occur;*

(F) *timing dredging and dredged material disposal or placement activities to avoid spawning or migration seasons and other biologically critical time periods; and*

(G) *avoiding the destruction of remnant natural sites within areas already affected by development.*

Compliance: Discharges within CNRAs are intended to restore eroded and storm-damaged areas. Placement actions include restoration of eroded shorelines, PA levee improvement and fill, repair of storm-damaged shorelines, and potential beach nourishment through direct placement and nearshore berms. These actions target BU and were preferred over offshore disposal or other alternatives with less contribution to CNRA function and value. Compliance with State and Federal regulations and use of BMPs would avoid and minimize impacts.

(7) *Adverse effects on human use potential from dredging and dredged material disposal or placement can be minimized by:*

(A) *selecting sites and following procedures to prevent or minimize any potential damage to the aesthetically pleasing features of the site, particularly with respect to water quality;*

(B) *selecting sites which are not valuable as natural aquatic areas;*

(C) *timing dredging and dredged material disposal or placement activities to avoid the seasons or periods when human recreational activity associated with the site is most important; and*

(D) *selecting sites that will not increase incompatible human activity or require frequent dredge or fill maintenance activity in remote fish and wildlife areas.*

Compliance: Discharges within CNRAs are intended to restore eroded and storm-damaged areas. Placement actions include restoration of eroded shorelines, PA levee improvement and fill, repair of storm-damaged shorelines, and potential beach nourishment through direct placement and nearshore berms. These actions target BU and were preferred over offshore disposal or other alternatives with less contribution to CNRA function and value. Compliance with State and Federal regulations and use of BMPs would avoid and minimize impacts.

(8) Adverse effects from new channels and basins can be minimized by locating them at sites:

(A) that ensure adequate flushing and avoid stagnant pockets; or

(B) that will create the fewest practicable adverse effects on coastal natural resource areas (CNRAs) from additional infrastructure such as roads, bridges, causeways, piers, docks, wharves, transmission line crossings, and ancillary channels reasonably likely to be constructed as a result of the project; or

(C) with the least practicable risk that increased vessel traffic could result in navigation hazards, spills, or other forms of contamination which could adversely affect CNRAs;

(D) provided that, for any dredging of new channels or basins subject to the requirements of §501.15 of this title (relating to Policy for Major Actions), data and information on minimization of secondary adverse effects need not be produced or evaluated to comply with this paragraph if such data and information is produced and evaluated in compliance with §501.15(b)(1) of this title.

Compliance: Circulation modeling indicated no impacts of the Applicant's Proposed Action Alternative, and the channel deepening would occur within the extents of the existing channel. Vessel traffic may be reduced, and proper navigation safety requirements would be in place. Discharges within CNRAs are intended to restore eroded and storm-damaged areas. Placement actions include restoration of eroded shorelines, PA levee improvement and fill, repair of storm-damaged shorelines, and potential beach nourishment through direct placement and nearshore berms. These actions target BU and were preferred over offshore disposal or other alternatives with less contribution to CNRA function and value. Compliance with State and federal regulations and use of BMPs would avoid and minimize impacts.

(c) Disposal or placement of dredged material in existing contained dredge disposal sites identified and actively used as described in an environmental assessment or environmental impact statement issued prior to the effective date of this chapter shall be presumed to comply with the requirements of subsection (a) of this section unless modified in design, size, use, or function.

<u>Compliance: The Applicant's Proposed Action Alternative includes PA levee repair and fill and the Applicant's Proposed Action Alternative is being evaluated by the EIS.</u>

(d) *Dredged material from dredging projects in commercially navigable waterways is a potentially reusable resource and must be used beneficially in accordance with this policy.*

(1) *If the costs of the beneficial use of dredged material are reasonably comparable to the costs of disposal in a non-beneficial manner, the material shall be used beneficially.*

(2) *If the costs of the beneficial use of dredged material are significantly greater than the costs of disposal in a non-beneficial manner, the material shall be used beneficially unless it is demonstrated that the costs of using the material beneficially are not reasonably proportionate to the costs of the project and benefits that will result. Factors that shall be considered in determining whether the costs of the beneficial use are not reasonably proportionate to the benefits include, but are not limited to:*

(A) *environmental benefits, recreational benefits, flood or storm protection benefits, erosion prevention benefits, and economic development benefits;*

(B) *the proximity of the beneficial use site to the dredge site; and*

(C) *the quantity and quality of the dredged material and its suitability for beneficial use.*

(3) *Examples of the beneficial use of dredged material include, but are not limited to:*

(A) *projects designed to reduce or minimize erosion or provide shoreline protection;*

(B) *projects designed to create or enhance public beaches or recreational areas;*

(C) *projects designed to benefit the sediment budget or littoral system;*

(D) *projects designed to improve or maintain terrestrial or aquatic wildlife habitat;*

(E) *projects designed to create new terrestrial or aquatic wildlife habitat, including the construction of marshlands, coastal wetlands, or other critical areas;*

(F) *projects designed and demonstrated to benefit benthic communities or aquatic vegetation;*

(G) *projects designed to create wildlife management areas, parks, airports, or other public facilities;*

(H) *projects designed to cap landfills or other waste disposal areas;*

(I) *projects designed to fill private property or upgrade agricultural land, if cost-effective public beneficial uses are not available; and*

(J) *projects designed to remediate past adverse impacts on the coastal zone.*

Compliance: Discharges within CNRAs are intended to restore eroded and storm-damaged areas. Placement actions include restoration of eroded shorelines, PA levee improvement and fill, repair of storm-damaged shorelines, and potential beach nourishment through direct placement and nearshore berms. These actions target BU and were preferred over offshore disposal or other alternatives with less contribution to CNRA function and value. Compliance with State and Federal regulations and use of BMPs would avoid and minimize impacts.

(e) If dredged material cannot be used beneficially as provided in subsection (d)(2) of this section to avoid and otherwise minimize adverse effects as required in subsection (a) of this section, preference will be given to the greatest extent practicable to disposal in:

(1) contained upland sites;

(2) other contained sites; and

(3) open water areas of relatively low productivity or low biological value.

Compliance: Discharges within CNRAs are intended to restore eroded and storm-damaged areas. Placement actions include restoration of eroded shorelines, PA levee improvement and fill, repair of storm-damaged shorelines, and potential beach nourishment through direct placement and nearshore berms. These actions target BU and were preferred over offshore disposal or other alternatives with less contribution to CNRA function and value. Compliance with State and Federal regulations and use of BMPs would avoid and minimize impacts.

(f) For new sites, dredged materials shall not be disposed of or placed directly on the boundaries of submerged lands or at such location so as to slump or migrate across the boundaries of submerged lands in the absence of an agreement between the affected public owner and the adjoining private owner or owners that defines the location of the boundary or boundaries affected by the deposition of the dredged material.

Compliance: Containment and other BMPs would be used when possible to prevent sediment movements. Proper engineering design of slopes would also prevent slumping.

3.5 SECTION 501.26 – POLICIES FOR CONSTRUCTION IN THE BEACH/DUNE SYSTEM

a) *Construction in critical dune areas or areas adjacent to or on Gulf beaches shall comply with the following policies:*

(4) *Non-structural erosion response methods such as beach nourishment, sediment bypassing, nearshore sediment berms, and planting of vegetation shall be preferred instead of structural erosion response methods. Subdivisions shall not authorize the construction of a new erosion response structure within the beach/dune system, except as provided by subsection (b) of this section or a retaining wall located more than 200 feet landward of the line of vegetation. Subdivisions shall not authorize the enlargement, improvement, repair or maintenance of existing erosion response structures on the public beach. Subdivisions shall not authorize the repair or maintenance of existing erosion response structures within 200 feet landward of the line of vegetation except as provided in §15.6(d) of this title (relating to Concurrent Dune Protection and Beachfront Construction Standards).*

Compliance: The Applicant's Proposed Action Alternative includes placement activities consisting of beach nourishment that would have positive impacts in terms of maintaining coastal barriers. Dredged material from channel deepening would be used beneficially for nearshore berms for potential beach nourishment along San José and Mustang islands. Actions include direct placement on dunes and beaches and nearshore berms. Some portions of the Applicant's Proposed Action Alternative would be constructed on the Gulf shoreline within 1,000 feet of mean high tide, designated as critical dune area. Dredged material from channel deepening would be used beneficially for dune restoration on San José Island that was damaged during Hurricane Harvey.

3.6 SECTION 501.27 – POLICIES FOR DEVELOPMENT IN COASTAL HAZARD AREAS

b) *Pursuant to the standards and procedures under the Texas Natural Resources Code, Chapter 33, Subchapter H, the GLO shall adopt or issue rules, recommendations, standards, and guidelines for erosion avoidance and remediation and for prioritizing critical erosion areas.*

Compliance: Discharges within CNRAs are intended to restore eroded and storm-damaged areas. Placement actions include restoration of eroded shorelines, PA levee improvement and fill, repair of storm-damaged shorelines, and potential beach nourishment through direct placement and nearshore berms. These actions target BU and were preferred over offshore disposal or other alternatives with less contribution to CNRA function and value. Compliance with State and Federal regulations and use of BMPs would avoid and minimize impacts.

3.7 SECTION 501.28 – POLICIES FOR DEVELOPMENT WITHIN COASTAL BARRIER RESOURCE SYSTEM UNITS AND OTHERWISE PROTECTED AREAS ON COASTAL BARRIERS

a) Development of new infrastructure or major repair of existing infrastructure within or supporting development within Coastal Barrier Resource System Units and Otherwise Protected Areas designated on maps dated October 24, 1990, as those maps may be modified, revised, or corrected, under the Coastal Barrier Resources Act, 16 United States Code Annotated, §3503(a), shall comply with the policies in this section.

(4) Where practicable, infrastructure shall be located in existing rights-of-way or previously disturbed areas to avoid or minimize adverse effects within Coastal Barrier Resource System Units or Otherwise Protected Areas.

(5) Development of infrastructure shall occur at sites and times selected to have the least adverse effects practicable within Coastal Barrier Resource System Units or Otherwise Protected Areas on critical areas, critical dunes, Gulf beaches, and washover areas and on spawning or nesting areas or seasonal migrations of commercial, recreational, threatened, or endangered terrestrial or aquatic wildlife.

Compliance: The Applicant's Proposed Action Alternative includes placement actions that would be constructed within Coastal Barrier Resources Act Units on San José Island (Unit: T08), in the form of beach and dune restoration. placement actions are intended have long-term benefits to the overall ecology of the coast. The Applicant's Proposed Action Alternative includes placement activities consisting of beach nourishment that would have positive impacts in terms of maintaining coastal barriers. Dredged material from channel deepening would be used beneficially for nearshore berms for potential beach nourishment along San José and Mustang islands. Actions include direct placement on dunes and beaches and nearshore berms. Dredged material from channel deepening would be used beneficially for dune restoration on San José Island that was damaged during Hurricane Harvey.

b) TCEQ rules and approvals for the creation of special districts and for infrastructure projects funded by issuance of bonds by water, sanitary sewer, and wastewater drainage districts under Texas Water Code, Chapters 49, 50, and 59; water control and improvement districts under Texas Water Code, Chapter 50; municipal utility districts under Texas Water Code, Chapter 54; regional plan implementation agencies under Texas Water Code, Chapter 54; special utility districts under Texas Water Code, Chapter 65; stormwater control districts under Texas Water Code, Chapter 66; and all other general and special law districts subject to and within the jurisdiction of the TCEQ, shall comply with the policies in this section. TxDOT rules and approvals under Texas Transportation Code Chapter 201, et seq., governing planning, design, *construction, and maintenance of transportation projects, shall comply with the policies in this section.*

Compliance: The Applicant's Proposed Action Alternative would comply with all applicable State and Federal regulations and requirements.

3.8 SECTION 501.32 – POLICIES FOR EMISSION OF AIR POLLUTANTS

a) TCEQ rules under Texas Health and Safety Code, Chapter 382, governing emissions of air pollutants, shall comply with regulations at Code of Federal Regulations, Title 40, adopted pursuant to the Clean Air Act, 42 United States Code Annotated, §§7401, et seq, to protect and enhance air quality in the coastal area so as to protect CNRAs and promote the public health, safety, and welfare.

Compliance: The Applicant's Proposed Action Alternative would comply with all applicable State and Federal regulations and requirements.

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4.0 REFERENCES

Texas General Land Office (GLO). 2021. Coastal Resources Mapping Viewer. https://cgis.glo.texas.gov/rmc/index.html. Accessed June 24, 2021.

Triton Environmental Solutions, LLC. 2021. Aquatic Survey Report Port of Corpus Christi Authority Channel Deepening Project, Nueces and Aransas Counties, Texas, SWG-2019-00067. Prepared for the Port of Corpus Christi Authority. October 29, 2021.

______ 2022. Draft Aquatic Survey Report San José Island Beneficial Use Site, Port of Corpus Christi Authority Channel Deepening Project, Aransas County, Texas, SWG-2019-00067. Prepared for the Port of Corpus Christi Authority. January 18, 2022.

W.F. Baird and Associates, Ltd. 2022. Draft Environmental Impact Assessment for Channel Deepening, Port of Corpus Christi – Hydrodynamic and Salinity Modeling Study. Prepared for Freese and Nichols, Inc. March 17, 2022.

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Appendix P

Distribution List

The following is a list of agencies, organizations, and persons to whom copies of the Notice of Availability for the DEIS was sent. The document will be available for review on the USACE, Galveston District website (www.swg.usace.army.mil/).

Federal, State and Local Government Representatives	
Congressman Michael Cloud	Representative J.M. Lozano
Senator John Cornyn	Representative Geanie W. Morrison
Senator Ted Cruz	Congressman Filemon Vela
Representative Abel Herrero	Representative Judith Zaffirrinni
Representative Juan 'Chuy' Hinojosa	Neuces River Authority
Representative Todd A. Hunter	NOAA (National Marine Sanctuaries)
Aransas County	Nueces County
Aransas Pass	Port of Corpus Christi Authority
Aransas County	Portland
Aransas Pass Chamber of Commerce	Portland Chamber of Commerce
Beeville Chamber of Commerce	San Patricio County
City of Corpus Christi	Texas Commission on Environmental Quality
City of Ingleside	Texas Department of Transportation
City of Port Aransas	Texas General Land Office
City of Port Aransas	Texas Historical Commission
Corpus Christi Chamber of Commerce	Texas Parks and Wildlife Department
Ingleside Chamber of Commerce	U.S. Environmental Protection Agency
Ingleside Chamber of Commerce	U.S. Fish and Wildlife Service
National Marine Fisheries Service	U.S. Coast Guard
Representative Lois W. Kolkhorst	

Organizations	
Bickerstaff Health Delgado Acosta LLP	OXY Ingleside Energy Center, LLC
BNSF Railway	Rabalais I&Econstructors
Buckeye Global Marine Terminals	Shintech
Cheniere	Sierra Club, Coastal Bend Group
Coastal Conservation Association	Surfrider Foundation
Coastal Conservation Association Aransas Bay	TEDA TPCO American Corporation
Corpus Christi Polymers	Tenaris Freeport
Frederick, Perales, Allmon & Rockwell, P.C.	Texas Ducks Unlimited Conservation Field Office
Friends of Lydia Ann Channel	The Nature Conservancy
Houston Audubon	Union Pacific Railroad Northern and Eastern Texas
Houston Audubon- Corpus Christi	VencoreX
International Crane Foundation	Voestalpine Texas LLC Management

Individuals		
–, Kayle	Gorn, Jaime	Niece, Jan
–, Nicholas	Govella, Arnold	Nobbie, Naomi
–, Ruth	Graf, DeWayne	Noelke, Ben
–, Traci	Graf, Rosemarie	Noonan, Nick
Abdallah, Geri	Grappe, Shelly	Norman, Cortney
Abdallah, Ryah	Grappe, Steve	Norman, Joey
Abel, Cindy	Graves, Robert	North, Lynda
Abel, Mary	Green, Frances	Novey, Kathryn
Abelman, Fred	Green, Marshall	Novitt, John
Abelman, Nancy	Green, Pam	Nyberg, Ann

Abernethy, Gayle
Ables, Cheryl
Aceves, Jose
Achilles, Chnstie
Adamo, James
Adams, Cathy
Adams, James
Adams, Jerry
Adams, Nanci
Aguirre, Adam
Aguirre, Joann
Ahern, David
Ahern, Marrilee
Alexander, Allan
Allison, Donna
Amos, Michael
Amundsen, Lisa
Andersen, Barbara
Anderson, Sharon
Andrews, Jana
Andrews, Steve
Appling, Anne-Marie
Appling, Dan
Arnold, Cynthia
Arnold, Tommie Sue
Arreaga, Eva
Arredondo, Derek
Arrow, Judith
Arrow, Lloyd
Arue, Jared
Ashmun, Anne
Atkins, Pam and Richard
Averbach, Dorothy
Averbach, William
Avery, Phyllis
Avery, Richard
Baccus, Bryon
Baertich, Darren
Bailey, Sonya
Bain, Dana
Baird, Fred
Baker, Angela
Baker, Angie
Baker, Brett
Baker, Carrie
Baker, Joann
Baker, Paula
Baker, Ron
Balcom, Patsy
Balcom, Paul
Gregory, Jeffery
Griffin, Leslie
Grizzle, Raleigh
Grosse, Mark
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Gruenwaldt, Shelia
Guajardo, Anna
Guenther, Jack
Guerra, Gloria
Guess, Reginald
Gullacher, Robert
Gunckel, Forrest
Gustafson, Greta
Guthrey, Criag
Gutierrez, Andrew
Gutierrez, Melanie
Hada, Nancy
Haddock, Hgata
Hager, Cecilia
Haghann, Blair
Hain, Jeffrey
Halioua, Linda
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Halley, G.
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Hamilton, Jacqueline
Hamilton, Laura
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Hamilton, Stephen
Hamilton, Steve
Hamilton, Sue Ellen
Hamm, Matthew
Hampton, Vernon
Hancock, Kathy
Hancock, Matthew
Hancock, Samuel
Handley, Libby
Hanks, Connie
Hanna, Bruce
Hanna, Jay
Hans, Tom
Hans , Janet
Hansen, Eric
Hansen, John
Harder, Andrea
Harding, Gerald
Harding, Jackie
Hargis, Hal
Nye, Patrick
Oakes, Roger
Oates, Norman
Ochsker, Dorothea
Ochsner, Abby
Ocker, Gail
Oconnor, James
O'Connor, Brendan
O'Connor, Cecile
O'Dell, Colton
O'Dell, Jeffery
Odle, Linda
Ogle, Tesha
Ogline, Christine
Ohmstede, William
Olle, Gary
Olmstead, Kevin
Ordos, Dan
Orear, Mary
Oroian, Colleen
Oroian, Moses
Ortiz, Ava
Ortiz, Johnny Joe
Ortiz, Jose
Ortiz, Laura
Ortiz, Mary Lou
Oryic, Johnny
Osborne, David
Oshman, Sandra Lee
Owen, Patricia
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Owens, Kelly
Owens, Kelly and Beth
Owens, Lisa
Owens, Robert
Pacino, Al
Padilla, Audrey
Padilla, John
Palitza, Jessica
Palmer, Camilla
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Parker, Clayton
Parker, Judy
Parker, Lance
Parks, Karen
Parr, Denise
Parr, Suzanne
Parrish, Maxey
Parsons, Dale
Pasquale, Marueen

Bandli, Douglas
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Barnes, Tim
Barnett, Brenda
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Barnett, Rocky
Barrera, Alfonso
Barrera, Miguel
Barrett, April
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Basche, Carolyn
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Bass, John and Ellen
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Beard, Donald
Bearns, Julia
Beauchamp, Kari
Beaver, William
Becerra, William
Bechtol, Bill
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Behrens, William
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Bender, Jennifer
Benedum, Michael
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Benson, Karen
Bentley, Karen
Bepko, Ashley
Bepko, Ashley
Bepko, Austin
Bepko, Brandon
Bepko, Brandy
Bergner, Christy
Bergner, Joe
Berhow, Dan
Berhow, Jackie
Berk, Palmer
Berlekamp, Randall
Berry, Cynthia
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Berry, Kenneth
Harlan, Robert
Harley, Veleda
Harper, Judy
Harris, Chester
Harris, Deborah
Harris, Elizabeth
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Harris, Marty
Harris, Mina
Harris, Patricia
Hart, Debbie
Hart, Jeffery
Harte, Sarah
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Hartnett, Matthew
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Harvey, Rick
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Hause, Dan
Hausser, Albert
Hausser, Meta
Havers, Ronnie
Hawkins, Michael
Hays, Kevin
Head, Vicki
Hearn, Bill
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Helley, G.
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Henke, Peggy
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Hernandez, Kris
Hernandez, Marissa
Herndon, Joan
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Herrmann, Karen and Ronald
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Hester, Roger
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Hewitt, Elizabeth
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Payne, Richard
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Pearson, Charles
Pearson, Reta
Peba, Dana
Peckenpaugh, Damian
Perkins, Jason
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Poole, Bobby
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Porterfield, Brian
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Pratt, Cameron
Prezqs, Slyvia
Price, Callan
Price, Marcia
Proll, Mandy
Prukop, James
Puentez, Carmen
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Boening, Jackie
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Bond, Michelle
Bond, Shane
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Booth, Suzanne
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Boultinghouse, –
Bowers, Ann
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Box, Sally
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Brandt, Gary
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Brannon, Jon Marc
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Hill, Greg
Hillin, Lila
Hillin, Steven
Hintz, John
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Jansen, Erick
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Reves, Mickey
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Ruhlin, David
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Cante, Noe
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Cants, Carmen
Cantu, Caitlan
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Johnson, Henry
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Johnson, Kay
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Johnson, Rae
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Judson, Mary
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Katara, Gail
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Kennedy, Russel
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Samberson, Randall
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Sanchez, Erika
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Sanders, Lahesha
Sather, Dennis
Sather, Victoria
Savoy, Jennifer
Sayles, Richard
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Scalan, Richard
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Schade, Jeanette
Schafer, Lee
Schlabach, Cliff
Schmalz, Della
Schmalz, Guy
Scholl, Jack
Schram, Margaret
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Schramm, Dorothy
Schroeder, Cody
Schumncher, Warren
Schutte, Wendy
Schwarz, Donald
Schwarz, Stacie
Schwenk, Annette
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Scott, Jerry
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Shannon, J.J.
Shannon, Mike
Shannon, William
Shaw, Kimberly
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Sheets, Dana

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Cardinal, Guy
Cardinal, Jacqueline
Carlson, Jeffrey
Carlson, John
Carlson, Kat
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Carroll, Lauren
Carroll, Marci
Carter, Buford
Carter, Kaye
Casey, Christopher
Castaldo, Deborah
Caza, William
Cerda, Michael
Chandler, EA
Chandler, Jeffrey
Chandler, Julia
Chandler, Justin
Chandler, Melony
Chandler, Pamela
Chandler, Stephanie
Chaney, Gretchen
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Chaney, Taylor
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Charles, Larry
Charpiot, Arnold
Chase, Gaylord
Cherry, Bruce
Cheshire, Daniel
Chessher, Chris
Chesuut, Henry
Ciotta, Jan
Ciotta, Vince
Clampitt, Sean
Clark, Adrian
Clark, Christie
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Clark, Rick
Clark, Sandra
Clark, Warren
Clay, Randy
Clements, Charles
Clopper, C. Robert
Clower, George
Coeckelenbergh, Katie
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Coffey, Diane
Coggins, Carol
King, Ashley
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King, Dalton
King, James
King, Jeff
King, Tammy
Kinkaid, David
Kinkaid, Jennifer
Kirk, Chad
Kirkman, Susan
Klee, Joan
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Klein, James
Klein, Teresa
Kling, Patricia
Kniss, Kevin
Koepp, Annette
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Kollaja, Tom
Kollman, Janet
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Krarik, Deborah
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Krepel, Thomas
Krikman, Susan
Krone, Jane
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Kuecker, Gary
Kuhn, Craig
Kumpula, Carlo
Kurtz, Sharon
Kuzman, Wayne
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Laas, Judith
Laas, Walter
Lacasse, Leona
Lace, Dystanie
Lacombe, Sid
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Lancaster, Aaron
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Lang, Jo
Lanning, Bobbie
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Shepard, Mary
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Shepherd, Shawn
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Sierra, Steve
Simanek, Ashleigh
Simanek, Michelle
Simpson, Josh
Simpson, Susan
Singleton, Chantele
Sites, Tracy
Sjolsetz, Brent
Skildum, Tom
Slagle, Jimmy
Slagle, Juanita
Slevin, Mark
Small, Lisa
Small, Maria
Smallwood, Marie
Smallwood, Tim
Smith, Barney
Smith, Dede
Smith, Elizabeth
Smith, Jay
Smith, Jill
Smith, Joahalys
Smith, Karen
Smith, Kimberly
Smith, Leslie
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Smith, Lou Ann
Smith, Marshall
Smith, Noel
Smith, Rick
Smith, Steve
Smith, Steven
Smith, Thayen
Smith, William
Snow, Ames
Snow, Gerda
Sochz, Mike
Sohl, Walter
Solimine, Anthony

Cole, Ami
Cole, Chandler
Colliet, Boyd
Collins, Chris
Collins, Grace
Collins, Lisa
Collins, Shannon
Collins, Spencer
Colombo, John
Compton, Karen
Compton, Robert
Conrad, Bill
Conrad, Michelle
Contreras, Agustin
Cook, Andy
Cook, Colby
Cook, Kati
Cooksey, Sonny
Coons, Cassidy
Coons, Colten
Coons, Keith
Coons, Michael
Copeland, Carmen
Cornwell, Randy
Cortez, Kathleen
Cortinas, Juanita
Cothrell, Donna
Cou, Chendh
Covault, Wayne
Cowart, Randy
Cox, JD
Cox, Randy and Andrea
Cozart, Linda
Cozart, Steve
Craig, Tiffanie
Craine, Dan
Cramer, Yonie
Crawford, Betty
Crawford, Charles
Crawford, Kelly
Crawford, Margarete
Crawford, Tim
Crawford, Veanna
Creighton, Brian
Crespo-Qunones, Johanna
Crider, Carolee
Crider, Phillip
Crisp, Cody
Crofts, Thomas
Culder, Carolee
Lanoux, Steven
Laosa, Caryn
Laosa, Michael
Larsen, Marg
Larson, Deborah
Laskowski, Lisa
Laskowski, Michael
Lauer, Mike
Lavigne, Robert
Lawson, Monica
Lawson, Robert
Lawson, Susan
Lawson, Woodie
Leavell, Alyssa
Leavell, Cherie
Ledesma, Israel
Lee, Robert
Lee, Sandra
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Leman, Henry
Leman, Terri
Lerma, Thomas
Levens, CD
Lewis, Betty
Lewis, Carol
Lhose, David
Libby, Glidden
Libby, Ruth
Light, Malcolm
Lilly, Logan
Linder, Dorothy
Linder, Heather
Linder, Patrick
Linder, Patrick
Linder, Richard
Lindner, Patrick
Lindsey, Anita
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Link, Charlene
Littleton, Les
Litwin, Mike
Lockely, Charlie
Lockett, Aileen
Lockett, William
Logan, Alicia
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Long, John
Long, Londa
Longue-Ville, Julie
Lopez, Analisa
Spitzer, Brandica
St. Clair, Michael
St. Clair, Susan
Stachz, Candido
Stair, Tracy
Stair, Tracy
Stanley, Carlton
Stanley, Larry
Stanush, Belinda
Stasus, Rachael
Stcutlz, Candido
Stech, James
Stegenga, Corinne
Stegenyg, Brace
Stehn, Thomas
Steinberg, Tyler
Stellges, Brandon
Stellges, Sara
Stenford, Douglas
Stephens, Allyson
Stessman, Neil
Steubing, Darrell
Stevener, Misti
Stevens, George
Stevens, Lisa
Stewart, Jana
Still, Frank
Stockton, Rick
Stokes, Dorothy
Story, Cynthia
Story, Pamela
Stott, Linda
Stott, Norman
Stovall, Charles
Stovall, Liz
Strain, Cliff
Straley, Robert and Alicia
Stratten, Paul
Stroman, Kay
Stroman, Martha
Strong, Sonja
Strong, WR
Strubbe, Tom
Suarez, Joel
Svoboda, James
Swallow, Chuck
Swenson, Johnie
T., Scott
Tacoma, Kris
Taipale, Marilyn

Culpepper, Kay
Cunningham, Sarah
Curlee, Carolyn
Cusack, George
Dahle, Anneliese
Dahle, Hans
Dahlin, Sherry
Dahms-Nelson, Debra
Dailey, Lucia
Dailey, William
Dale, James
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Daley, Tom
Dalton, Leo
Daniels, Christian
Daniels, Kathaleen
Dare, Kathleen
David, Danielle
David, Neil
Davies, Caroline
Davis, Carol
Davis, William
Davison, Nancy
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Del La Pena, Dwayne
Del Moral, Mary
del Moral, Raphael
Del Moral, Ray
DeLeon, Michael
DeLudos, Donna
Denney, Cara
Dennis, Derryl
Depew, Laurie
DeWinne, Ronnie
DeYoung, Roberta
Dibrell, Chris
Dickerman, Ken
Dickey, Rebecca
Dickmann, Walter
Dietz, Wade
Dignazio, Mark
Dillahunty, Raymond
Dinn, James
Dinn, Paige
Dolden, Tab
Dombrosky, Edward
Donalson, Alyson
Donalson, Drew
Donovan, John
Doolittle, J.L.

Lopez, Robin
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Loring, Lynn
Loring, Porter
Love, Charles
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Luedemann, W.F.
Lunday, Dalton
Lunday, Jack
Lunday, Julianne
Lunday, Ruth
Lundborg, John
Lundborg, Mary
Lupton, Eric
Lyerly, Diane
Lyons, Regina
Lyons, Terry
Machac, Terry
Machac, TJ
Mack, Be
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Maddock, John
Magee, Dewey
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Manuel, Nolan
Marco, Sally
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Mariscal, Allen
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Marks, Margie
Marks, Robert
Marksmad, Edward
Marksman, Charlene
Marshall, Joey
Marshall, Rick
Martin, Bart
Martin, Curtis
Martin, Glenn
Martin, Tara
Martin, Wendy
Martinez, Andrew
Martinez, Danny
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Masten, Kathryn

Talbot, Don
Talbot, Don
Talbot, Marilyn
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Talbott, Julia
Tamayo, Elvia
Tatum, Lawrence
Taylor, Arthor
Taylor, Arthur
Taylor, Cathy
Taylor, Monica
Teagin, Troy
Teague, Kenneth
Teague, Marina
Teller, Georgia
Teltschick, Vernon
Terry, Tod
Teshera, Stephanie
Theresa , James
Thetford, Todd
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Thomas, Ronald
Thomasson, Jennifer
Thompson, Brian
Thompson, Dan
Thompson, John
Thompson, Lee
Thompson, Lisa
Thomson, Craig
Thomson, Natalie
Thrasher, Barbara
Tibbetts, Michael
Tillman-Ruiz, Teresa
Timmerman, Casey
Tisset, Florence
Tissot, Florence
Todd, Susan
Tollett, Joyce
Torres, Jose
Treme, Tabetha
Tressa, Nancy
Trippet, Nancy
Trittet, Nancy
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Trumpy, Debra
Truyter, Jean
Tucker, Judy
Tuggle, Morgan
Tunner, Jan

Doolittle, Linda
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Doss, David
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Draeger, Ronald
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Dufelmeier, John
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Dutton, Thomas
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Easinsky, Susan
Eberley, Russell
Echols, Connie
Elias, Marian
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Elliott, Carol
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Ervin, Janae
Ervin, Janita Sue
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Escanilla, Casey
Esposito, Judy
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Estrada, Jose
Evans, Dexter
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Evans, Kent
Evans, Maggie
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F., Bay
False, Joseph
Farley, Barney
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Fate, Marnie
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Matsunami, Shelly
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Maxwell, Holly
Maxwell, R. Earl
May, Lou Adele
May, Margaret
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McAllister, Reagin
McAllister, Taddy
McCarthy, Dan and Lee
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McChesney, Michael
McCune, Emily
McCune, Scott
McDaniel, Katy
McDaniel, Samual
McDavid, Margie
McDonald, Kimberly
McDonald, Susan
McDonough, Gary
McDonough, John
McDonough, Pat
McHenry, Sharon
McIlhany, Bryan
McIlhany, Laurie
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McKeen, Daniel
Mckennon, Jordan
McLaughlin, Matt
McNeely, Jesse
McPherson, Kevin
McRae, Dakota
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Mellon, Stevie
Mellon, William
Menard, Patrick
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Mertz, Trina
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Midgy, James
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Turk, Cathy
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Turner, Kendal
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Tyler, Patricia Ann
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Vanecet, Cassie
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Vela, Marissa
Venker, Ted
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Wadham, Thomas
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Walker, Jennifer
Walker, Willie
Wall, Vinaya
Wallace, Brad
Walls, Robert
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Walpole, Refugia
Walsh, Susan
Wand, Linda
Ward, Tristan
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Warren, Kathy
Washko, William
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Waters, Stormy
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Watson, Retha
Weatherall, Tracy
Weaver, Raymond
Weber, Mary

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Ferry, Emily
Figol, Dawna
Finch, Howell
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Findley, Kate
Fischer, Sonia
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Fish, Ada
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Forsythe, Patty
Foster, Justin
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Franger, Wayne
Franke, Aaron
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Freeman, Chet
Frezna, Faye
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Frishman, Mary Ann
Fuller, David
Fulton, Cathy
Fulton, Erin
Furman, Paul
Furmon, Taylor
G., Ann
G., Mary
Gabel, Scott
Miller, Clay
Miller, David
Miller, Josephine
Miller, Katherine
Miller, Paula
Miller, Randy
Miller, Travis and Carol
Milligan, Christine
Milloy, Ross
Milner, Dana
Milsaps, Paul
Ming, Amber
Minkina, Ron
Minkina, Tina
Mireles, Cissy
Mitchell, Patricia
Mitchell, Patrick
Mitschke, Kimberly
Molder, James
Montez, Alfoso
Montgomery, William
Moomey, Thomas
Moore, Carl
Moore, Charles
Moore, Ethel
Moore, Jane
Moore, Janis
Moore, Myfe
Moore, Paul
Moore, Paul
Moore, Wanda
Mora, Susan
Moral, Raphael
Morales, Paula
Morgan, Kathy
Morris, Art
Morris, John
Morrone, Gary
Morton, Cheryl
Morton, Cheryl
Morton, Richard
Mosher, Erynn
Mosley, Dianne
Mosley, Jeyla
Mosley, Tatiana
Mosty, Jeff
Mott, Charle
Mott, Tina
Moure, Charles
Moyer, Christopher
Wedelich, Terry
Weeks, John
Wehmeyer, Jamie
Weise, C.F.
Weise, Charles
Weise, Laney
Weise, Roye
Weiss, Raymond
Weisz, Mike
Welch, Jennifer
Welder, Allison
Welder, Donna
Wells, Stewart
Wernl, Jin
Wernl, Rox
Wernli, Darren
Wernli, Gary
Wernli, Lynn
West, LaWanda
Wheatley, Lee
Wheeler, William
White, Glery
White, James
White, Lara
White, Lara
White, LeeAnne
White, Maria
White, Randy
White, Tina
White, Tina
Whiteley, Benjamin
Whiteley, Elert
Whitsitt, Lynn
Whittington, Debbie
Whittington, Mike
Whitworth, Cheryl
Whitworth, Sylvia
Wiatrek, Jake
Wicktor, Laurel
Wicktor, Phil
Wilcot, Christian
Wildfang, Phil
Wilhite, Christine
Willhite, Paul
Williams, Carole and Gary
Williams, David
Williams, Jeff
Williams, Miranede
Williams, Temple
Willis, Briane

Gallegos, Andrea
Gallegos, Audrea
Gallegos, Sal
Garlougl, Michael
Garrett, Steven
Garrison, Peggy
Gasca, Pat
Gaspard, Carrol
Gaspard, Eric
Gaspard, Jean
Gates, Jimmie
Gates, Tessa
Gatewood, Daryl
Gernert, Annn
Gibbons, Chet
Gibson, James
Gifford, Tim
Gilmore, Jim
Gist-Barra, Michele
Goldberg, Moses
Golden, Libby and Steve
Golden, Steve and Libby
Goldley, Patty
Goldsmith, Mary
Goldston, Frank
Goldston, Kristi
Goldway, Patty
Golob, Amanda
Gonzales, Refugio
Gonzales, Richard
Gonzalez, Pedro
Goodman, Cullen
Gordon, Mel
Moyer, Maria
Murguia, Marcus
Murphy, Bill
Murphy, Mary
Murphy, Stephen
Muschalek, James
Myers, Barbara
Myers, William
Myska, Monica
Naaldn, Nathan
Naay, Diane
Naeh, Lisa
Nagy, Diane
Nance, Chris
Nance, Sybil
Nangle, Dolores
Naoy, Diane
Narmour, Ronnie
Neagle, Joshua
Neans, Adam
Neblett, Duncan and Georgia
Nelson, Greg
Nelson, Mary
Nettleton, Kimberly
New, Cassidy
Newby, Gwen
Newlin, Leasa
Nicholes, Ellen
Nicholes, Ellyn
Nichols, Donna
Nichols, Karl
Nichols, Suzanne
Nicks, Robert
Willison, Gary
Wilson, Clinton
Wineinger, James
Wineinger, Thomas
Winkler, Sherry
Wise, Sarah Jane
Wise, William
Wisham, Linda
Witagle, Yvette
Witter, Jordan
Woltersdorf, Kay
Woo, Sean
Woodward, Sam
Woolard, Terry
Wright, Jennifer
Wright-Balcom, Patsy
Wysocki, Mark
Yackee, Judy
Yoesel, Harold
Yokum, Shellie
Yorek, Stacey
Yorek, Stacy
Yovich, Monica
Zabrod, Cheri
Zadra, Jeffrey
Zamora, Mary
Zottanelli, James
Zserdin, Joel
Zubrod, Larry
Zufall, Cindy
Zufall, John
Zuniga, Mark
Zupance, Frank