U.S. Army Corps of Engineers

Galveston District
Southwestern Division

Houston Ship Channel Expansion Channel Improvement Project, Harris, Chambers, and Galveston Counties, Texas

Final Integrated Feasibility Report–Environmental Impact Statement

APPENDIX L

ESSENTIAL FISH HABITAT ASSESSMENT

NOVEMBER 2019

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List of Acronyms and Abbreviations

BCC	Barbours Cut Channel
BSC	Bayport Ship Channel
BSCCT	Bayport Ship Channel Container Terminal
BU	Beneficial Use
DMP	Dredged Material Placement
EEZ	Exclusive Economic Zone
EFH	Essential Fish Habitat
FEIS	Final Environmental Impact Statement
FMP	Fishery Management Plan
ft	feet
GBEP	Galveston Bay Estuary Program
GIWW	Gulf Intracoastal Waterway
GMFMC	Gulf of Mexico Fisheries Management Council
GOM	Gulf of Mexico
HAPC	Habitat Areas of Particular Concern
HSC	Houston Ship Channel
km	kilometer
LPP	Locally Preferred Plan
m	meter
MCY	Million Cubic Yards
MITAGS	Maritime Institute of Technology and Graduate Studies
MLT	Mean Low Tide
MSFCMA	Magnuson Stevens Fishery Conservation and Management Act
NED	National Economic Development
NEPA	National Environmental Policy Act

NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NWI	National Wetlands Inventory
PA	Placement Area
PHA	Port of Houston Authority
ppt	parts per thousand
SAFMC	South Atlantic Fishery Management Council
SAV	Submerged Aquatic Vegetation
SF	Square Feet
SFA	Sustainable Fisheries Act
TB	Turning Basin
TEU	Twenty-Foot Equivalent Unit
TPWD	Texas Parks and Wildlife Department
USACE	United States Army Corps of Engineers
U.S.	United States of America
USD	United States Dollar

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1.0 INTRODUCTION

Implementation of the National Economic Development Plan (NED) or the Locally Preferred Plan (LPP) for the Houston Ship Channel (HSC) Expansion Channel Improvement Project (ECIP) would permanently impact the oyster reef within the footprint of the proposed channel modifications. These plans would consist of channel modification measures to widen the HSC, Bayport Ship Channel (BSC), and Barbours Cut Channel (BCC), ease channel bends, expand existing turning basins and constructing new ones, and a possible anti-shoaling feature. These measures are geographically spread along the entire length of the HSC navigation system from Bolivar Roads near the entrance into Galveston Bay, to the Main Turning Basin in the Buffalo Bayou reach of the HSC near the center of Houston. Currently, the HSC-ECIP has completed the Feasibility-Level Analysis milestone phase of the U.S. Army Corps of Engineers (USACE) Specific, Measurable, Attainable, Risk Informed, Timely (SMART) Civil Works planning process. The LPP includes features of the NED Plan, additional widening of the HSC from Barbours Cut to south of Red Fish Island and the proposed shoaling attenuation feature.

As required by the Magnuson Stevens Fishery Conservation and Management Act of 1976, as amended through the Sustainable Fisheries Act (SFA) of 1996 (Magnuson-Stevens Act, Public Law 104-267) an Essential Fish Habitat (EFH) consultation must be conducted for any activity that may adversely affect important habitats of federally managed marine and anadromous fish species. This EFH Assessment has been prepared to analyze and document the potential impacts of the proposed project.

1.1 PROJECT DESCRIPTION

The proposed project is the NED Plan, which is located within the HSC navigation system that traverses Galveston Bay to the tidal portions of the San Jacinto River and Buffalo Bayou in Galveston, Chambers, and Harris Counties, Texas. The HSC is currently maintained by the USACE to depths of -37.5 feet to -46.5 feet mean lower low water (MLLW) [-36 to -40 feet mean low tide (MLT)] plus between one to two feet of advanced maintenance and two feet of allowable overdepth. Currently, the majority of the HSC is 530 feet wide through its length in the Bay, with some relatively short discontinuous sections of 600 feet and 700 feet-wide channel between Morgans Point and the Battleship Texas, and a narrowing down above that from 530 feet to 400 feet, down to 300 feet wide. The side channels to the HSC, the Bayport Ship Channel (BSC) and Barbours Cut Channel (BCC) have been recently deepened to match the -46.5 ft MLLW depth of the HSC, and widened to address navigation deficiencies and inefficiencies associated with the current vessel fleet and berths, with the BSC widened to between 350 and 400 feet wide, and the 300 foot-wide BCC shifted 75 feet northward. The NED Plan proposes a variety of measures to modify the HSC, BSC and BCC, summarized in **Table 2.1** and as follows:

- Widen the lower section of the HSC channel and ease bends of the HSC in Galveston Bay to provide a wider channel of approximately 700 feet wide.
- Widen one segment (CW4 BB-GB) in the HSC above Morgans Point to address places where the channel narrows down from its existing widths.
- Deepen the HSC above Boggy Bayou by between 4 and 5 feet
- Expand the Bradys Island turning basin.
- Widen the BSC to approximately 455 feet, expand the existing flare at its confluence with the HSC, and provide a turning basin at the entrance to the landcut.

- Provide a shoaling attenuation feature (e.g. dike-like groin) for the Bayport Flare, to be planned in the next phases when a hydrodynamic and sediment transport model is ready.
- Widen the BCC to approximately 455 feet, and expand the existing flare in combination with providing a turning basin, at its confluence with the HSC.
- Create two bird islands east of HSC with approximately 18 acres of oyster mitigation.
- Create three bird islands associated with beneficial marsh with approximately 14 acres of oyster mitigation east of HSC and east of MidBay Placement Area (PA).
- Create approximately 67 acres of oyster reef mitigation southeast of Eagle Point

The LPP proposes the following additional measures:

- Widen the HSC channel in Galveston Bay to provide a wider channel of approximately 700 feet wide. Widening would remove two of the NED ease bends associated with the Bayport Channel.
- Create approximately 321 acres of Oyster reef Mitigation north and southeast of Eagle Point.
- Create two new beneficial use (BU) marshes.
- Create a proposed sediment attenuation feature

Figure 1 shows a conceptual map that illustrated the measures that make up the NED Plan and the LPP. As discussed at the beginning of this BA, the study is at a point where the NED Plan and the LPP would be refined in the next planning phase and may change the size or inclusion of some measures that make up the NED Plan and LPP. Specific design details would be developed in later planning phases, and the Preconstruction Engineering Design (PED) phase once the final NED or LPP are approved. Therefore, construction techniques and details can only be discussed generally at this point.

The channel modifications of the NED Plan and LPP would be constructed by dredging to widen and deepen channels, and expand the Brady Island turning basin. The depths of widened features would be in the range of -41.5 feet to -46.5 feet MLLW. **Table 1-2** provides the proposed methods for dredging new work material by general dredging segments and measures involved. **Figure 1** shows the dividing points or limits of these segments as Point A and Point B. The NED Plan and the LPP would be constructed primarily using hydraulic dredging to remove new work material and hydraulically pump it via pipelines to placement sites to be selected in detail in the next planning phase. It is anticipated that some new work dredging using clamshell (aka mechanical) dredges would also be used to remove softer new work materials more suitable for that type of dredge within a segment between Point B near Moses Lake and the Point A. This dredged material would be transported via scow (essentially a barge with bottom doors) to the existing approved ODMDS No. 1, located at the Entrance Channel (reference **Figure 2**).

Table 1-1 – Proposed New Work Dredging Methods by Segment and Measure

Dredging Segment	Extent Description	NED Measures	LPP Measures	New Work Dredging and Placement Method
Lowest segments	Entrance Channel to Point B	BE1_128+731 BE1_138+369 CW1_BR-Redfish (lower)		Hydraulic cutterhead and pipeline
Station 57+00	Point B to Point A	CW1_BR-Redfish (upper)	CW1_Redfish-BSC	Clamshell bucket and

Dredging Segment	Extent Description	NED Measures	LPP Measures	New Work Dredging and Placement Method
to 100+00		BE1_78+844	(lower)	scow
Upper segments	Point A to Main Turning Basin	BE1_28+605 BE2_BSCFlare CW2_BSC CW3 BCC BETB3 BCCFlare CW4 BB-GB CD4 Whole CD5 Whole CD6 Whole TB6_Brady_Island	CW1_Redfish-BSC (upper) BE1_28+605 and BE2_BSCFlare are incorporated in channel widening and not needed as separate measures	Hydraulic cutterhead and pipeline

For long-term maintenance dredging, hydraulic cutterhead, clamshell, and suction hopper dredging would be used to maintain the channels long term, with material deposited at the selected placement sites. Both hydraulic cutterhead and Trailing suction hopper have been used to maintain the existing HSC. Other types of work expected would be installing sheet piling and mooring dolphins. Sheet piling would be limited to a few areas where existing shoreline and bank would be supported where channel slopes are intended to be dredged steeper to minimize land impacts. Currently these areas are limited to the land cut north shore along the BSC [**Figure 1**, bottom inset], the north shoreline along the BCC [**Figure 1**, middle inset], along a short stretch of the HSC at Morgans Point [**Figure 1**, middle inset], and at the expansion of the existing Brady Island Turning Basin [**Figure 1**, top inset]. The construction for the channel modifications would be accessed by water via a dredge. Construction for sheet piling has not been determined, but could be either by the adjacent shore or by water. The project would not be constructed until the study and NED and or the LPP are approved, and Congress appropriates funding for this project. Construction is expected to last several years. Further details of construction would be determined at a later planning phase of the study.

The NED would at maximum impact approximately 94 acres of oyster reef and the LPP would impact approximately 421 (NED 72 + LPP 349 additional) acres of oyster reef. The oyster reefs are located extensively along the HSC and BSC, and would require mitigation. A mitigation plan was provided in Appendix Q of the DIFR-EIS, detailing the reef impacts, mitigation proposed, and candidate mitigation locations. The reef mitigation would require construction of between approximately 90 acres for the NED and additional approximately 315 acres for the LPP of restored reef based on habitat modeling, by beneficially using dredged new work material to build a 1 foot or greater relief off of the bay bottom and capping it with a veneer of suitable cultch material to naturally recruit reef. The candidate sites are shown in **Figure 1** of the Mitigation Plan and proposed oyster reef sites are shown in **Figure 2**, and specific site(s) would be selected from among these or others that emerge from public and agency input during the public and agency review period for this Draft IFR-EIS. Final mitigation amounts would be determined following refinements to the NED and habitat modeling to account for those changes.

1.2 PURPOSE

The purpose of HSC ECIP study is to evaluate Federal interest in alternative plans (including the No-Action Plan) for reducing transportation costs while providing for safe, reliable navigation on the HSC system. Economic conditions have changed significantly since the last HSC study for both the container and bulk industry. An increase in throughput tonnage and a significant shift in average fleet size render current channel dimensions incapable of accommodating the forecasted commodity and fleet growth without significant and system-wide inefficiencies. The study evaluates and recommends measures that address current and expected inefficiencies.

1.3 NEED

The needs for this project are to address problems and opportunities identified during the study including the following problems:

- Inefficient deep and shallow-draft vessel utilization of the HSC system resulting from existing channel depth, width, and configuration;
- Navigation safety concerns for deep and shallow-draft vessel traffic; and
- A lack of environmentally acceptable dredged material placement (PA/BU) with capacity to service the system

The following opportunities were identified:

- Reduce transportation cost of forecasted commodity volume at HSC;
- Eliminate or reduce navigation inefficiencies at HSC for existing and forecasted fleet (i.e., reduce delay times, interport movements, and transit times);
- Eliminate or reduce beam, length, and draft restrictions at HSC for forecasted fleet;
- Optimize channel configuration/design in a cost effective and environmentally acceptable manner that improves safety;
- Establish environmentally suitable PAs/BU sites for new work dredged material, as well as maintenance-dredged material;
- Reduce the environmental impacts from a new project, or protect or improve environmentally sensitive areas in the vicinity of the Federal project through BU of dredge materials; and
- Study the configuration of barge lanes and further optimize them.

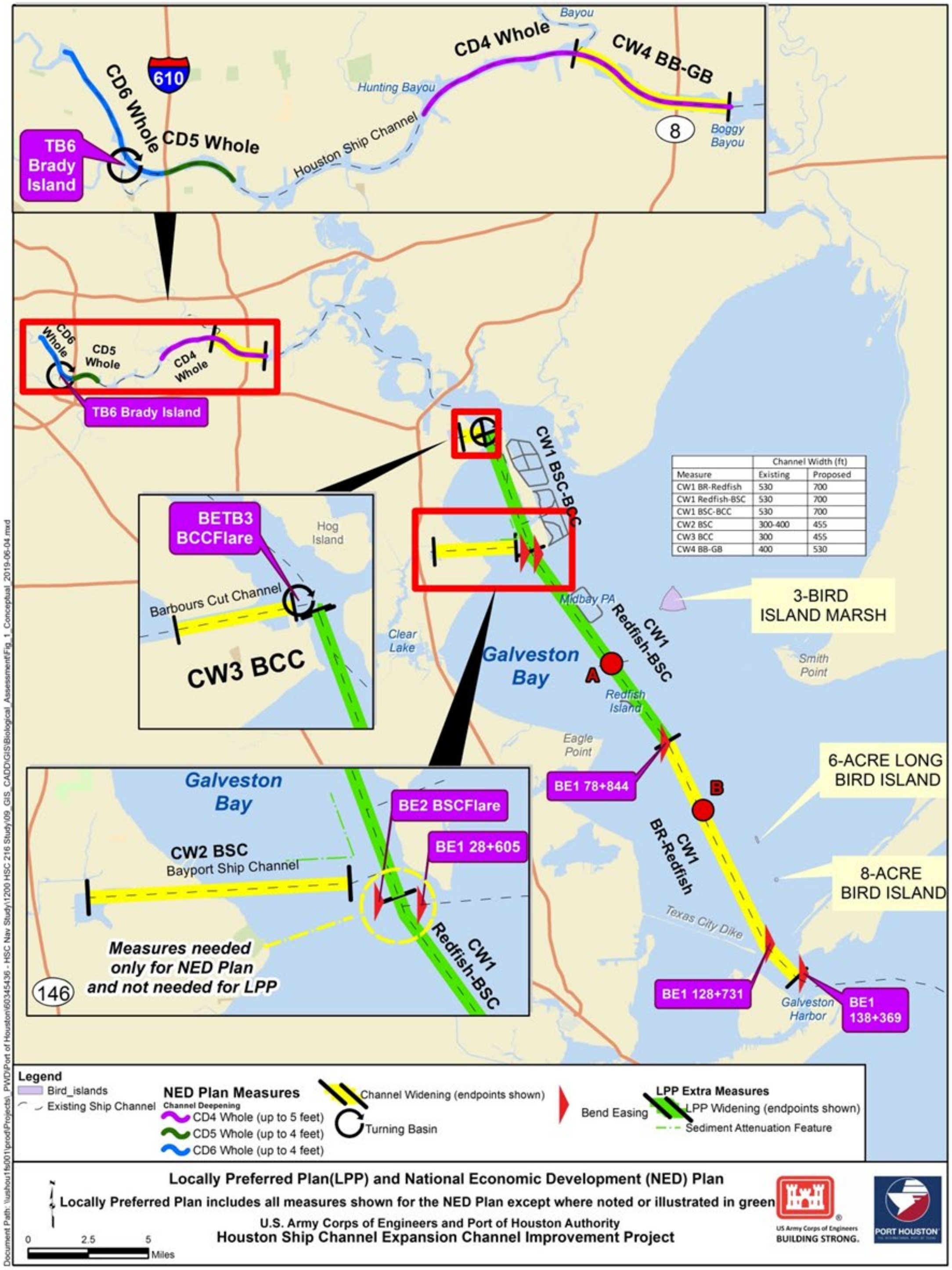

Figure 1 Conceptual Map of the Locally Preferred and National Economic Development Plans

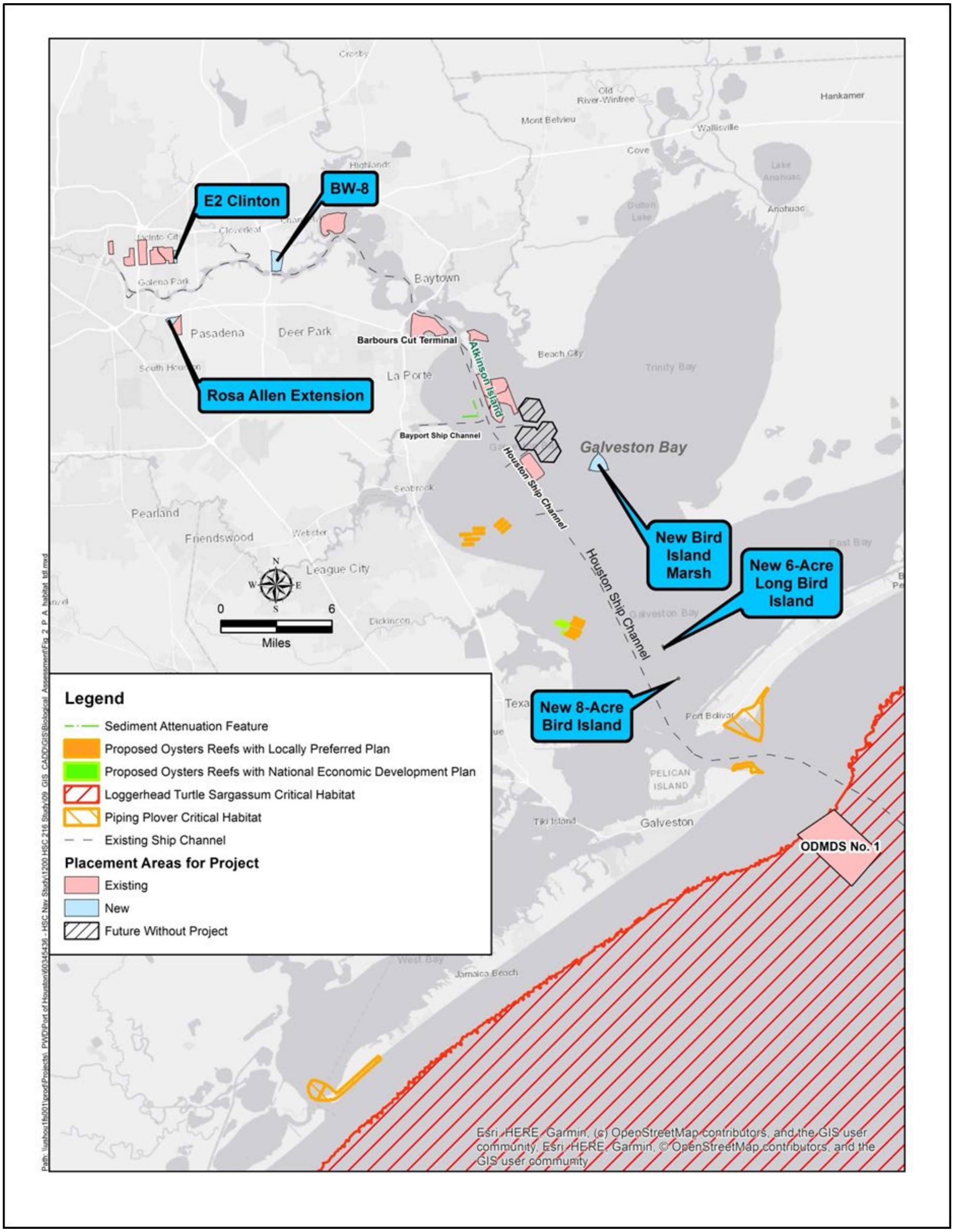

Figure 2 NED Plan and LPP, Placement Areas, and Critical Habitat

1.4 ALTERNATIVES ANALYSIS

The formulation, evaluation, and selection of alternatives followed the USACE's required planning process for a Civil Works feasibility study. This is described in detail in the Main Report, Chapter 5 Formulation and Evaluation of Alternative Plans. This section provides a synopsis of the alternative identification and analysis process that resulted in the final set of alternatives from which the proposed action was selected. A full description and discussion are provided in Chapter 5 of the Main Report.

The planning process started with the identification of identifying the problems and opportunities listed in Section 1.3 related to the navigation study purpose and the study area. Then goals and objectives related to the study and solving those problems and opportunities were identified. These related to addressing the navigation inefficiencies, associated transportation delays and costs, and need for environmentally suitable dredged material placement, among other objectives. Numerous measures focusing on the HSC channel system were conceived to address the problem and opportunities including widening, deepening, vessel moorings, turning basins and other potential improvements on the channel. These were evaluated and screened by assessing the economic, environmental, and engineering performance and aspects of each measure. A key performance requirement for Civil Works studies requires that proposed projects produce more benefits than costs. Measures that did not have the potential to provide more benefit than cost, or provided little net benefit were screened out. Remaining measures were formulated into alternatives that addressed the navigation problems and opportunities and evaluated using economic modeling, environment impact assessment including mapped reef impacted, initial ship simulation, and estimated of construction costs. Alternative plans were evaluated in more detailed in the subsequent planning phase to identify the highest performing alternative plans to analyze in detail. This resulted in a set of the following three remaining alternatives discussed further below:

- Alternative 1 – No Action. No channel improvements and maintaining the channel at its existing width and depth.
- Alternative 2 – National Economic Development (NED) Plan
- Alternative 3 – Locally Preferred Plan (LPP)

The Project is broken down into six (6) segments. The differences between Alternatives 2 and 3 within each segment are discussed below.

Segment 1 – Bolivar Roads to Boggy Bayou

NED Plan and LPP

- Widen HSC from Bolivar Roads to Redfish Reef from 530 ft to 700 feet with barge lane relocation
- 4 Bend Easings along the HSC from Bolivar Roads to BCC [Station's 078+844, 028+605, 138+369, and 128+731]

LPP

- Widen HSC from Redfish Reef to BSC from 530 ft to 700 feet with barge lane relocation
- Widen HSC from BSC to BCC from 530 ft to 700 feet with barge lane relocation

Segment 2 – Bayport Ship Channel

NED and LPP

- Widen BSC from 350 ft/400 ft to 455 feet

NED Only

- BSC Flare Expansion – widen BSC Flare from current radius to 5,300 ft radius

LPP Only

- Sediment attenuation feature – dike/groin structure to reduce shoaling around the BSC Flare to be studied in detail in PED, currently conceptualized as 9,400 ft long berm armored with rip-rap that would cover approximately 24-acres of open bay bottom. The top of the feature would be approximately 10 feet above mean sea level.

Segment 3 – Barbours Cut Channel

NED and LPP

- Widen BCC from 400 ft to 455 feet
- BCC Combined Flare and Turning Basin

Segment 4 – Boggy Bayou to Sims Bayou

NED and LPP

- Deepen HSC from Boggy Bayou to Hunting Turning Basin to 46.5 feet
- Widen HSC from Boggy Bayou to Greens Bayou from 300-400 ft to 530 feet

Segment 5 – Sims Bayou to I-610 Bridge

NED and LPP

- Deepen HSC from Sims Bayou to I-610 Bridge up to 41.5 feet

Segment 6 – I-610 Bridge to Main Turning Basin

NED and LPP

- Deepen HSC from I-610 Bridge to the Main Turning Basin up to 41.5 feet
- Brady Island Turning Basin expansion – expand and shift the turning basin to 900' diameter clear of City Dock #27

These alternatives were evaluated making use of cost estimates, the ship simulation study results, and project-specific oyster survey data developed for the evaluation. Based on the balance of these criteria, the LPP was selected as the preferred channel improvement alternative.

The dredged material placement alternatives analysis was similarly conceived, screened, and evaluated in two stages. Initial planning involved mapping existing constraints in the Bay using existing information existing facilities and PAs, previous oyster reef mapping, pipeline information, and other existing community facilities, as well as practical hydraulic dredging pump distance radii. A 5-mile radius was established as a practical limit of hydraulic dredge placement of new work materials considering previous experience with clays and cost effectiveness from previous PA construction. Capacities of existing PAs within the radius were determined by most recent digital topography data and/or their known fill completion status. Other constraints considered in limiting the available practical placement options included the lack of available undeveloped land around the land cut of sufficient size, the existing residential and industrial development and related infrastructure between the channel and larger undeveloped tracts farther away, the known preservation uses for most of these larger tracts, and the impractical pumping distance for ocean disposal.

The initial planning resulted in a suite of initial placement alternatives consisting of existing and previously planned Bay PAs, existing upland placement sites, and new confined upland Bay PAs with some beneficial use (BU) features. These initial placement alternatives were coordinated with the Beneficial Uses Group (BUG), a multi-agency group that coordinates on PHA projects with a goal of ecologically beneficial use of dredged material. In addition to the Applicant, the BUG includes representatives from the TPWD, U.S. Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), Natural Resource Conservation Service (NRCS), USACE, Environmental Protection Agency (EPA), and Texas General Land Office (TxGLO).

These initial alternatives were screened considering factors of cost, feasibility, environmental impact and desirability, and placement capacity, and in consideration of BUG feedback. General foundation conditions and probing data gathered during this study were also used to inform the decision process on new PA locations. Various alternatives were eliminated due to key reasons related to the aforementioned factors. The preferred version of BU placement alternative was advanced based on BUG feedback. This screening process resulted in placement alternatives that would be evaluated in more detail with the following criteria: 1) Placement of Dredged Material in Most Cost Effective Manner, 2) Optimize BU of Dredged Material Where Practical, 3) Optimize BU of Dredged Material Where Practical, 4) Does Not Create New Environmental Impacts, and 5) Provides Environmental Benefits. The remaining new work alternatives are shown in Table 1.

Table 2. Proposed new work dredged material placement options by alternative.

NAME	STUDY SEGMENT	NED	LPP	TYPE	Status: Existing or New?
8-acre Bird Island	1-Lower Leg	X	X	Eco BU	New
6-acre Long Bird Island	1-Lower Leg	X	X	Eco BU	New
ODMDS No. 1	1-Lower Leg upper part	X	X	Offshore Disposal	Existing
3-Bird Island Marsh	2	X	X	Eco BU	New
M12	3	X	X	Eco BU	New
East-east (E2) Clinton	4	X	X	Upland CDF	New
BW-8	4	X	X	Construction BU	New
Glendale	5, 6	X	X	Upland CDF	Existing
Filterbed	6	X	X	Upland CDF	Existing
ODMDS No. 1	1-Middle Leg lower part		X	Offshore Disposal	Existing
Oyster pad mitigation	1-Middle Leg		X	Eco BU	New
M789 dike rehab	1-Upper Leg		X	Eco BU	Existing
M11	1-Upper Leg		X	Eco BU	Previously Planned
Sediment Atten. Feature	1-Upper Leg		X	Construction BU	New

The approximate size of new work proposed placement areas is as shown in Table 2.

Table 3. Approximate acreage of proposed new work placement areas.

Placement Area	Approximate Acres	Existing Environment
ODMDS No. 1	5,594	Gulf bottom
3-Bird Island Marsh	402	Bay bottom
6-acre Long Bird Island	6	Bay bottom
8-acre Bird Island	8	Bay bottom
BW-8	385	Upland
East-east (E2) Clinton	76	Upland
Filterbed	110	Upland
Glendale	240	Upland
M11	445	Bay bottom
M12	273	Bay bottom
Sediment Attenuation Feature	24	Bay bottom

2.0 ESSENTIAL FISH HABITAT

As required by the Magnuson Stevens Fishery Conservation and Management Act (MSFCMA) of 1976, as amended through the Sustainable Fisheries Act (SFA) of 1996 (Magnuson-Stevens Act, Public Law 104-267) an Essential Fish Habitat (EFH) consultation must be conducted for any activity that may adversely affect important habitats of federally managed marine and anadromous fish species. A provision of the Magnuson-Stevens Act requires that Fishery Management Councils (FMC) identify and protect EFH for every species managed by a Fishery Management Plan (FMP) (U.S.C. 1853(a) (7)). EFH has been defined as (16 U.S.C. § 1801[10]):

> *"those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity."*

The EFH final rule summarizing EFH regulations (50 CFR Part 600.10) outlined additional interpretation of the EFH definition as follows:

> *"Waters include aquatic areas and their associated physical, chemical, and biological properties that are used by fish and may include aquatic areas historically used by fish where appropriate; 'substrate' includes sediment, hard bottom, structures underlying the waters, and associated biological communities; 'necessary' means the habitat required to support a sustainable fishery and the managed species' contribution to a healthy ecosystem; and 'spawning, breeding, feeding, or growth to maturity' covers a species' full life cycle."*

The NOAA Fisheries Gulf of Mexico Fishery Management Council (GMFMC) is responsible for the creation of FMPs in Federal waters off Texas, Louisiana, Mississippi, Alabama, and Florida. GMFMC defines seven FMPs for the Gulf of Mexico (GOM) (for shrimp, red drum, reef fish, coastal migratory pelagics, spiny lobster, aquaculture and corals). There are 52 species managed, excluding the coral complex. EFH consists of areas of higher species density, based on the National Oceanic and Atmospheric Administration (NOAA) Atlas (NOAA, 1985) and functional relationships analysis for the Red Drum, Reef Fish, Coastal Migratory Pelagics, Spiny Lobster and Shrimp FMPs; and on known distributions for the Coral FMP. A map of the composite EFH resulting from the summed EFH of the five Gulf of Mexico FMPs is shown in Figure 2.

In addition, the highly migratory species are managed by the NOAA Fisheries Highly Migratory Species Management Unit, Office of Sustainable Fisheries and two FMPs were developed for these species; one which includes EFH descriptions for sharks, tunas, and swordfish (NOAA 1999a), and another which was prepared for Atlantic billfishes and was amended to include EFH designations for these species (NOAA 1999b). In 2006 these were consolidated into a single document (NMFS 2006) which was amended in 2009 and reviewed in 2015 (NOAA, 2015).

As required, this EFH Assessment includes a description of the proposed action, an analysis of the potential direct impacts and cumulative effects on EFH for the managed fish species and their major food sources, potential indirect impacts created by the proposed action, and proposed mitigation measures selected to minimize expected project effects.

EFH is separated into estuarine and marine components. Estuarine EFH generally is defined as all estuarine waters and substrates including sub-tidal vegetation and adjacent inter-tidal vegetation. Specific habitats in this definition include, but are not limited to, estuarine emergent, scrub/shrub, and forested wetlands; submerged aquatic vegetation; reefs and shell banks; intertidal flats; aquatic beds; soft- and hard-bottom habitats, and the estuarine water column. Marine EFH is defined as all marine waters and substrates (mud, sand, shell, rock hard-bottom, and associated biological communities) from the shoreline to the seaward limit of the Exclusive Economic Zone). The proposed project is located entirely within the Galveston Bay estuary, and the following section describes the existing estuarine habitats within the proposed project area. For anticipated impacts to EFH from the proposed project, please refer to Section 3.0. A summary of all impacts to EFH can be found in Sections 3.1 and 3.2.

2.1 EXISTING ESTUARINE HABITAT TYPES

The proposed project area is located within ecoregion 4 as identified by the GMFMC. The categories of EFH in the project area include estuarine emergent marsh, estuarine shell substrate/oyster reefs, estuarine soft (mud) substrate and estuarine water column. In addition to being designated as EFH, these habitats provide nursery, foraging, and refuge habitats that support various economically important marine fishery species, such as spotted seatrout (*Cynoscion nebulosus*), flounder (*Paralichthys spp.*), Atlantic croaker (*Micropogonias undulatus*), black drum (*Pogonias cromis*), gulf menhaden (*Brevoortia patronus*), striped mullet (*Mugil cephalus*), and blue crab (*Callinectes sapidus*). Such estuarine-dependent organisms serve as prey for other fisheries managed under the MSFCMA by the GMFMC (e.g., red drum, mackerels, snappers, and groupers) and highly migratory species managed by the National Marine Fisheries Service (NMFS) (e.g., billfishes and sharks). These habitats also provide other essential estuarine support functions, including: (1) providing a physically recognizable structure and substrate for refuge and attachment above and below the sediment surface; (2) binding sediments; (3) preventing erosion; (4) collecting organic and inorganic material by slowing currents; and (5) providing nutrients and detrital matter to the Galveston Bay estuary.

2.1.1 Estuarine Water Column

Zooplankton and phytoplankton are the dominant organisms in this habitat and serve as the foundation of the estuarine and marine food webs. Phytoplanktons are major contributors to primary production, which is directly linked to production of biomass of species managed under the MSFCMA. In addition to supplying food for animals, phytoplankton plays a central role in nutrient cycling in Galveston Bay. Due to the bay's shallow bathymetry and resulting high light attenuation throughout the water column, production rates of carbon in Galveston Bay are the highest of all major Texas estuaries (Armstrong, 1987). The phytoplankton communities in Galveston Bay follow repeatable and predictable temporal successional patterns comprised of an estimated 132 species of phytoplankton including the dominant diatoms (54), green algae (45), and blue green algae (14) (Lester, 2002). Information on the temporal and spatial trends in zooplankton abundance and diversity is comparatively less robust than for phytoplankton, and data indicates that the bay may have lower zooplankton densities than other Texas estuaries. In Galveston Bay, it has been observed that zooplankton abundance is closely linked to water temperatures and inversely related to salinity levels (Armstrong, 1987). The increased zooplankton populations observed in the warmer summer months have the capacity to severely limit phytoplankton abundance through intensive grazing and leave the less palatable cyanobacteria (blue green algae) as the dominant phytoplankton group (Ornolfsdottir *et al*., 2003).

2.1.2 Estuarine Mud Substrate

The open-bay bottoms in the project area include flat areas consisting of mixtures of mud and mud/shell hash. Benthic epifauna and infauna are the primary organisms that utilize this habitat by adhering to the surface or burrowing into the sediment. Silty clay (or muddy) sediments tend to support a polychaete dominated community, while the benthic community in more sandy (or coarse) sediments is primarily composed of crustaceans (GBEP, 2002). These organisms feed by filter feeding particles from the water column or by ingesting sediments and extracting nutrients. Many of the epifauna and infauna feed on plankton, and are then directly fed upon by some of the species managed under the MSFCMA, such as shrimp.

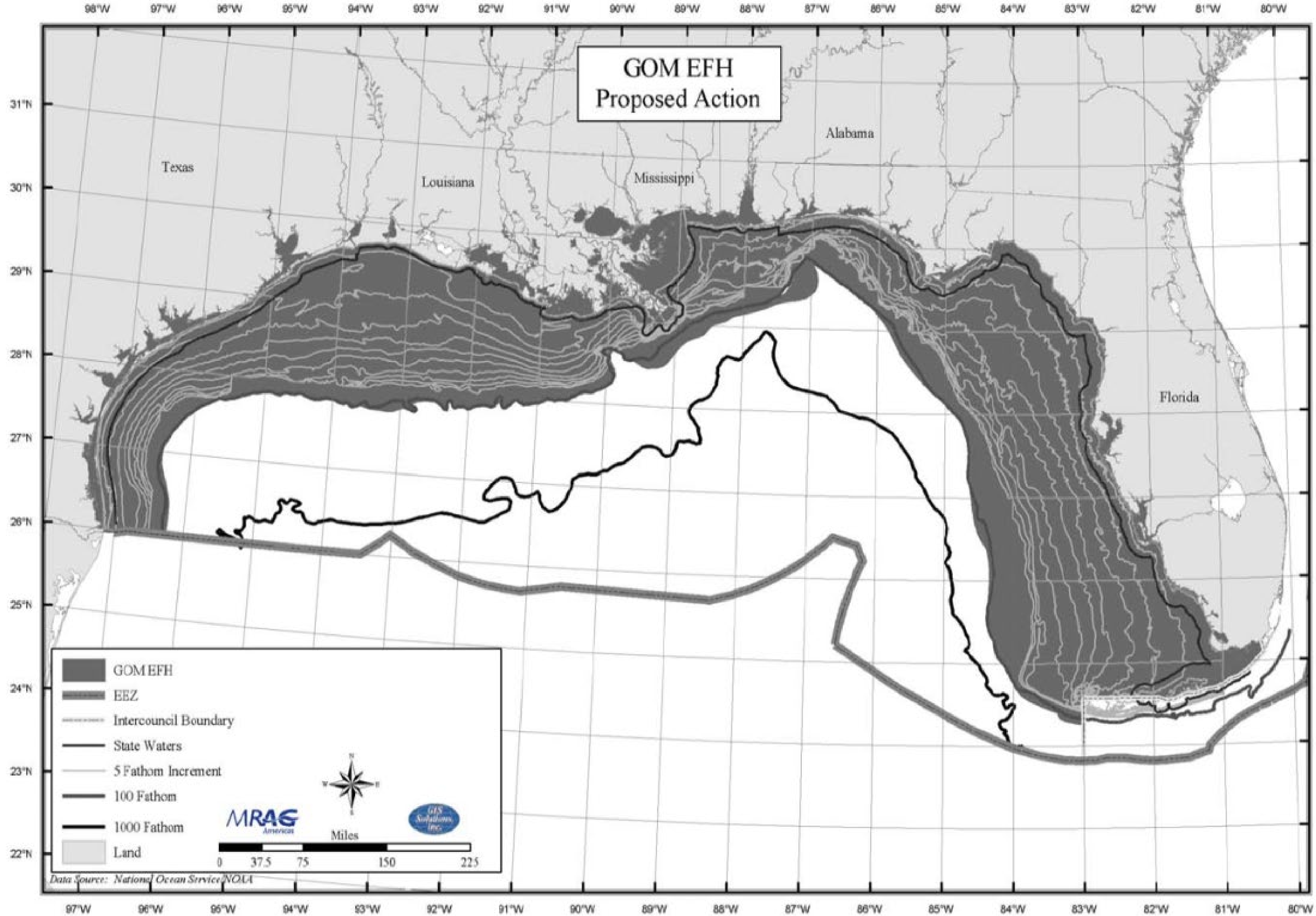

Figure 3 Map of Composite EFH within the Gulf of Mexico for each of the FMPs

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Benthic invertebrate abundance generally increases in a north to south direction from the Trinity Bay-Upper Bay region to the Lower Galveston-West Bay region. A seasonal trend also occurs, with peak benthos abundance in the spring, between February and May, and lower abundances in October and November. Macrofaunal diversity within Galveston Bay is considered to be low or moderate relative to similar estuaries in the GOM, with the highest faunal diversity in areas with stable salinity regimes (e.g., near inlets such as Bolivar Roads and Rollover Pass). The Houston Ship Channel area, which would include the majority of the proposed project area, generally has a lower species diversity compared to the more open Bay stations (GBEP, 2002).

Results from studies conducted within the open habitat of Upper Galveston and Trinity Bays indicate macrofaunal abundance is highly variable and ranges from 2-4,000 individuals per square meter (m^2). Two polychaete species, *Mediomastus ambiseta* and *Streblospio benedicti*, have been commonly noted as being the dominant macrofaunal species present. The population of these species can be so large in areas that it significantly influences abundance trends for the entire assemblage. Other species are reported as being temporally dominant and include *Vioscalba louisianae* (Gastropod), *Peloscolex gabriellae* (Oligochaetea), and *Mulinia lateralis* (Mussel) (GBEP, 1992).

M. ambiseta is a small, opportunistic capitellid polychaete. It occurs within surficial muds and is a deposit-feeder which actively manipulates sediment and deposits copious fecal pellets at the sediment surface (Hughes, 1996). This species lives primarily within the top 2 centimeters of sediment in thin-walled, semi-permanent tubes that protrude several millimeters above the sediment surface. *M. ambiseta* is considered an opportunistic species that responds to disturbance and has the potential for rapid population increase (Starczak et al., 1992).

S. benedicti is a small, segmented, tube-dwelling Spionidae polychaete. This species lives in the top few centimeters of silty clay sediments and is a deposit and suspension feeder at the sediment-water interface. It exhibits two different reproductive strategies (sometimes within the same population) in which either a relatively large number of small eggs develop into small planktotrophic larvae or lecithotrophic brood development occurs in which fewer, larger offspring spend only a short time in the water column and subsist on yolk reserves (Smithsonian, 2009). Similar to *M. ambiseta*, *S. benedicti* is an opportunistic species and it colonizes stressed or organically enriched sediments (Levin, 1984). Sears and Mueller (1989) reported peak densities of more than 5,000 *S. benedicti* individuals per square meter on Galveston Bay tidal flats.

2.1.3 Estuarine Shell Substrate/Oyster Reefs

Oyster reefs**,** composed of Eastern oysters (*Crassostrea virginica*), provide structural complexity and bottom relief in what would otherwise be categorized as a soft sediment, featureless habitat. The heterogeneous habitat provided by oyster reef structure increases the available surface area and creates complex interstitial spaces utilized by other marine organisms. Oyster reefs serve as fish habitat by providing structure, protection and trophic support to juveniles and adults (SAFMC, 1998). In the northern Gulf of Mexico (north of Galveston Bay, Texas, to northwestern Florida) some managed species such as red drum, as well as others such as spotted seatrout, appear to favor oysters reefs as foraging areas in much the same way they use seagrass meadows in areas where seagrasses are abundant. Oyster reefs stabilize the bay bottom and break wave energy, preventing shoreline erosion; act as natural filtration systems removing silt and contaminants from the water thereby improving local water quality and clarity (Galveston Bay Foundation, 2011); and provide habitat to a diverse community of organisms such as other bivalve mollusks, gastropods, barnacles, crabs, amphipods, isopods, and polychaete worms (GBEP 2011).

Oyster reefs of various sizes are present in all Texas estuaries, but are best developed between Galveston Bay and Corpus Christi Bay (Diener, 1975). The majority of oyster reefs in Texas (~7,095 ha; 88. 3 percent) are public (GMFMC, 2004). North of the Brazos River, eastern oysters are typically found in the intertidal zone while along the central and southern coast, they are most often subtidal (Britton and Morton, 1989).

Oyster reef habitat is sporadically found within the general area of the project and is typically associated and concentrated within close proximity of anthropogenic activity such as navigational channels. The majority of the oyster fishery as well as the oyster reefs in Texas are located within the Galveston Bay area (80-90 percent), with some additional areas in the Corpus Christi-Aransas Bay area (Kilgen and Dugas, 1989). Oyster reef habitat is found in the general area of the project as mapped by the Texas Parks and Wildlife Department and confirmed by diver ground-truthing performed during March 7-11, 2011.

2.1.4 Estuarine Emergent Marsh

Typical vegetation types within the estuarine emergent marsh include: glasswort (*Salicornia* spp), smooth cordgrass (*Spartina alterniflora*), salt marsh bulrush (*Scirpusmaritimus*), seashore saltgrass (*Distichlis spicata*), and sea-oxeye (*Borrichia frutescens*). The channel modifications of the LPP consist only of open water areas with the exception short segments where widening approaches the shorelines at the BSC landcut and BCC landcut at Spilmans island, HSC through Morgans Point, and the Brady Island Turning Basin expansion. These areas are steeped sloped and rip-rapped. Previous field visits to the BSC and BCC for the Non-federal Sponsor 204(f) project for widening those channels to the current dimensions confirmed this. The proposed new work PAs in the Bay listed in Table 3 are in areas currently consisting of open water with unvegetated bay bottom. The new ones listed currently in upland environment have isolated terrestrial wetlands comprised predominantly of forested wetland. No extensive estuarine existing emergent marsh would be impacted. The proposed new PAs for new work would foster creation of approximately 1,120 acres of tidal marsh.

2.2 PRIORITY HABITATS

2.2.1 Habitat Areas of Particular Concern (HAPC)

Habitat Areas of Particular Concern (HAPC) are a subset of the EFH information. They are areas that provide extremely important ecological functions or are especially vulnerable to degradation. The EFH regulations require that designation of specific HAPC's be based on one or more of the following considerations:

- The importance of the ecological function provided by the habitat;
- The extent to which the habitat is sensitive to human-induced environmental degradation;
- Whether and to what extent development activities are or will be stressing the habitat; and
- The rarity of the habitat type.

The GMFMC designated HAPC's in the GOM Generic EFH Amendment (GMFMC, 1998). In the Final Generic Amendment Number 3 for Addressing HAPC (GMFMC 2005), the Council identified several HAPC's to benefit all FMP-managed species under Council jurisdiction. The list was reviewed during the 5-year reviews in 2010 (GMFMC, 2010) and 2016 (GMFMC, 2016) but still only covers areas of coral. Figure 4 shows the locations of the areas designated or recommended as HAPC within Region B under the 2016 5-year review. The Project is not in or near any of these areas identified as HAPC. These areas are all well offshore and not close to Galveston Bay.

Figure 4 Areas designated or proposed by the 2016 5-Year Review as HAPC (NOAA 2016)

2.2.2 Submerged Aquatic Vegetation (SAV)

Seagrass areas provide nursery grounds for many species of fish, support a tremendously complex ecosystem and are extremely productive. Seagrass areas are considered EFH for many species of fish. Seagrasses are known not to be present in the majority of Galveston Bay and the HSC, and are limited to small areas in the Christmas, West Bay and upper Trinity Bay portions of the Galveston Bay system well outside of the areas where the channel modifications and placement are proposed. Observation during oyster reef surveys conducted in November 2018, confirmed that there is no seagrass present within or adjacent to the proposed channel project area. Therefore, no direct or indirect impact to seagrass habitat is expected.

2.3 MANAGED FISH AND INVERTEBRATE SPECIES

Because the project falls within EFH and has the potential to adversely affect it, this report has been prepared to discuss the managed species and the habitats in which various life stages of managed species occur. Of the 52 species currently managed by the GMFMC, 39 species (does not include the highly migratory pelagic species) had EFH defined in the 2016 5-Year review (GMFMC 2016) and are included in the mapping and data that can be found on the gulf council data portal (GMFMC 2019). The Stone crab FMP was repealed October 24, 2011, and therefore the Stone crab no longer has defined EFH within the Gulf of Mexico. Of these 52 managed species, only 6 are considered to have EFH within the proposed project for at least one life-history stage (Table 3). Table 4 lists the reef fish species managed through the reef fish FMP. Table 5 lists the billfish and highly migratory species that are managed through the highly migratory species FMP. Of this list of potentially impacted highly migratory species, only four were identified to have EFH within the proposed project area. The following subsections provide detailed discussions for each managed species. The seasonal and year round locations of designated EFH for the managed fisheries were derived from life histories (GMFMC 2004, GMFMC 2008; Pattillo et al. 1997) and habitat association tables (GMFMC 2004, GMFMC 2008, GMFMC 2019), as well as abundance and distribution maps (NOAA 2008). Other documents, such as the Gulf of Mexico Fisheries Management Plans and various websites available through the NOAA/NMFS links also were utilized to estimate potential impacts associated with the proposed project. Table 6 summarizes the life history information for the 10 federally managed species which exhibit EFH within the proposed project area for all or part of their life cycles.

Table 4 Species for which EFH was defined in the 2016 5-year review and status in proposed project area

Management Plan	Common Name	Scientific Name	Life Stage				
			Adult	**Spawning**	**Juveniles**	**Larvae**	**Eggs**
Shrimp FMP	Brown Shrimp	*Penaeus aztecus*	—	—	X	X	—
	Pink Shrimp	*Penaeus duorarum*	—	—	—	—	—
	White Shrimp	*Penaeus setiferus*	X	X	X	X	X
	Royal Red Shrimp	*Pleiticus robustus*	—	—	—	—	—
Red Drum FMP	Red Drum	*Sciaenops ocellatus*	X	—	X	X	—
Reef Fish FMP (species with EFH in Project area)	Gray Snapper	*Lutjanus griseus*	X	X	—	—	—
	Lane Snapper	*Lutjanus synagris*	—	—	X	X	—
Coral and Coral Reefs	Coral and coral reefs	All corals	—	—	—	—	—
Spiny Lobster	Spiny Lobster	*Panulirus argus*	—	—	—	—	—
	Slipper Lobster	*Scyllarides nodifer*	—	—	—	—	—
Coastal Migratory Pelagics	King Mackerel	*Scomberomorus cavalla*	—	—	—	—	—
	Spanish Mackerel	*Scomberomorus maculatus*	—	—	—	—	—
	Cobia	*Rachycentron canadum*	—	—	—	X	X
Highly Migratory Pelagics (with EFH in Project area)	Spinner Shark	*Carcharhinus brevipinna*	—	—	—	X	—
	Blacktip Shark	*Carcharodon limbatus*	—	—	—	X	—
	Bonnethead Shark	*Sphyrna tiburo*	—	—	—	X	—
	Bull Shark	*Carcharodon leucas*	X	—	X	X	—

Source: GMFMC, 2004;
Key:
X Species uses area as EFH during this life stage
— Rare or Not Present (i.e., no EFH)
* Neonates for shark species is checked as "Larvae"

Shrimp FMP EFH: all estuaries; the US/Mexico border to Fort Walton Beach, Florida, from estuarine waters out to depths of 100 fathoms; Grand Isle, Louisiana, to Pensacola Bay, Florida, between depths of 100 and 325 fathoms; Pensacola Bay, Florida, to the boundary between the areas covered by the GMFMC and the SAFMC out to depths of 35 fathoms, with the exception of waters extending from Crystal River, Florida, to Naples, Florida, between depths of 10 and 25 fathoms and in Florida Bay between depths of 5 and 10 fathoms (GMFMC, 2005).

The Shrimp FMP covers brown shrimp - *Farfantepenaeus aztecus,* pink shrimp - *F. duorarum,* royal red shrimp - *Pleoticus robustus*, and white shrimp - *Litopenaeus setiferus.*

The area of Galveston Bay where the proposed project is planned is determined to be EFH for larvae, pre-settlement postlarvae, late postlarvae, juveniles to subadult life stages for brown shrimp and all life stages of white shrimp(GMFMC, 2016).

Brown Shrimp Life History: Brown shrimp eggs are demersal and occur offshore. Larval and pre-settlement postlarval brown shrimp are found in estuarine, nearshore, and offshore waters with depths of 0-82 m in the water column, year-round with peak abundances occurring in the spring (GMFMC, 2016).Late postlarvae and juvenile brown shrimp are found during the spring through fall in estuarine waters in depths less than one meter, temperatures of 7-35°C, salinities of 2-40 ppt, and experience mortality at dissolved oxygen (DO) concentrations less than one parts per million (ppm). They occupy nearly all estuarine environments, including submerged aquatic vegetation, emergent marsh, oyster reef, soft bottom, and sand/shell habitats (GMFMC, 2016). Postlarval shrimp migrate through passes on flood tides at night mainly from February - April with a minor peak in the fall. 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 plant-water interfaces. Sub-adults migrate from estuaries at night on ebb tide on new and full moon. Abundance offshore correlates positively with turbidity and negatively with hypoxia. 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. Spawning occurs at depths of 18-110 m during the fall and spring and year-round at depths greater than 64 m (GMFMC, 2016). Brown shrimp are highly commercially valued nationwide; population estimates in shallow water habitats of Galveston Bay, Texas are approximately 1.3 billion (GMFMC, 2016).

White Shrimp Life History: White shrimp are offshore and estuarine dwellers and are pelagic or demersal, depending on life stage. White shrimp eggs are found in estuarine, nearshore, and offshore waters from spring through fall, occupying water depths of 9-34m (GMFMC, 2016). The eggs are demersal and larval stages are planktonic; both occur in estuarine and nearshore marine waters of the project area. White shrimp larvae are also found in estuarine, nearshore, and offshore waters spring through fall. Postlarval shrimp migrate through passes mainly from May-November with peaks in June and September. Migration is in the upper two meters of the water column at night and at mid depths during the day. 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 or abundant marsh, and develop into juveniles. Juveniles are common to highly abundant in all Gulf estuaries from Texas to about the Suwannee River in Florida. Postlarvae and juveniles inhabit mostly mud or peat bottoms with large quantities of decaying organic matter or vegetative cover. Densities are usually highest in marsh edge and submerged aquatic vegetation, followed by marsh ponds and channels, inner marsh, and oyster reefs. Juveniles prefer lower salinity waters (less than 10 ppt), and frequently are found in tidal rivers and tributaries throughout their range. As juvenile white shrimp approach adulthood, they move from the estuaries to coastal areas where they mature and spawn. Migration from estuaries occurs in late August and September and appears to be related to size and environmental conditions (e.g. , sharp temperature drops in fall and winter). Adult white shrimp are demersal and inhabit estuarine, nearshore, and offshore Gulf waters to depths less than 30 meters on bottoms of soft mud or silt. Spawning occurs in estuarine, nearshore, and offshore waters from spring through late fall, peaking from June to July at depths of 9-34 m and salinities greater than or equal to 27 ppt (GMFMC, 2016). See Nelson (1992) and Pattillo *et al*. (1997) for more detailed information on habitat associations of white shrimp.

Red Drum FMP EFH: All estuaries; Vermilion Bay, Louisiana, to the eastern edge of Mobile Bay, Alabama, out to depths of 25 fathoms; Crystal River, Florida, to Naples, Florida, between depths of 5 and 10 fathoms; and Cape Sable, Florida, to the boundary between the areas covered by the GMFMC and the South Atlantic Fishery

Management Council (SAFMC) between depths of 5 and 10 fathoms (GMFMC, 2005). This FMP covers only the red drum - *Sciaenops ocellatus.*

The area of Galveston Bay where the proposed project is planned is considered to be EFH for larval to adult stages of the Red Drum (GMFMC, 2016).

Red Drum Life History*:* In the GOM, red drum occur in a variety of habitats, ranging from depths of about 40 meters offshore to very shallow estuarine waters. They commonly occur in virtually all of the Gulf's estuaries where they are found over a variety of substrates including sand, mud, and oyster reefs. Red drum can tolerate salinities ranging from freshwater to highly saline, but optimum salinities for juveniles and adults are between 20-40 ppt. Types of habitat occupied depend upon the life stage of the fish. 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). The eggs hatch mainly in the Gulf, and larvae are transported into the estuary where the fish mature before moving back to the Gulf (Perret *et al*. 1980; Pattillo *et al*. , 1997). Adult red drum use estuaries but tend to spend more time offshore as they age. Schools of large red drum are common in deep Gulf waters. Estuarine wetlands are especially important to larval, juvenile, and subadult red drum. Yokel (1966) concluded that abundance of red drum varied directly with the estuarine area (habitat). He also reported that, in general, landings within a state varied with the amount of that state's suitable habitat. 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).

Reef Fish FMPs EFH: all estuaries; the US/Mexico border to the boundary between the areas covered by the GMFMC and the (SAFMC) from estuarine waters out to depths of 100 fathoms (GMFMC, 2005). The Reef Fish FMP covers all the species listed in Table 4.

The area of Galveston Bay where the proposed project is planned is considered to be EFH only for adults and spawning adults of the gray snapper and larvae to late juvenile life stages of the lane snapper (GMFMC, 2016).

Gray Snapper Life History: The gray snapper occurs on the shelf waters of the Gulf and is particularly abundant off south and southwest Florida. Gray snapper occur in almost all of the Gulf's estuaries but are most common in Florida. Considered to be one of the more abundant snappers inshore, the gray snapper inhabits waters to depths of about 180 meters. Adults are demersal and mid-water dwellers, occurring in marine, estuarine, and riverine habitats. They occur up to 32 km offshore and inshore as far as coastal plain freshwater creeks and rivers. They are found among mangroves, sandy grassbeds, and coral reefs and over sandy, muddy, and rocky bottoms. Spawning occurs offshore around reefs and shoals from June to August. Eggs are pelagic and are present June through September after the summer spawn, occurring in offshore shelf waters and near coral reefs. Larvae are planktonic, occurring in peak abundance June through August in offshore shelf waters and near coral reefs from Florida through Texas. Postlarvae move into estuarine habitat and are found especially over dense grass beds of *Halodule* sp. and *Syringodium* sp. Juveniles also are marine, estuarine, and riverine dwellers, often found in estuaries, channels, bayous, ponds, grassbeds, marshes, mangrove swamps, and freshwater creeks within eco-regions 1 and 2. They appear to prefer *Thalassia* sp. grass flats, marl bottoms, seagrass meadows, and mangrove roots.

Lane Snapper Life History: The lane snapper occurs throughout the Gulf, and also in the western Atlantic from North Carolina to southeastern Brazil. Juveniles and adults are found across most habitat types including submerged aquatic vegetation, sand/shell, reefs, soft bottom, banks/shoals, and mangroves, while adults mostly occupy nearshore and offshore waters (GMFMC, 2016). Lane snapper eggs are found throughout offshore waters of the Gulf within the water column, in depths from 4-132m from March through September, with peaks July-August. Lane snapper larvae are found throughout the Gulf at depths of 0-50 m mostly from June to August. Juvenile lane snapper are most prevalent from late summer to early fall at depths of 0-24 throughout the Gulf in habitats including submerged aquatic vegetation, sand/shell, reefs, soft bottom, banks/shoals, and mangroves (GMFMC, 2016). Adults are also found throughout the Gulf in nearshore and offshore waters of depths ranging from 4-132 m in habitats of sand/shell, hard bottom, reef, and bank/shoal.

Table 5 Species Managed Through the Reef Fish FMP (GMFMC 2005)

almaco jack – *Seriola rivoliana*	mutton snapper – *L. analis*
anchor tilefish - *Caulolatilus intermedius*	Nassau grouper – *E. striatus*
banded rudderfish – *S. zonata*	queen snapper - *Etelis oculatus*
blackfin snapper - *Lutjanus buccanella*	red hind - *Epinephelus guttatus*
blackline tilefish - *Caulolatilus cyanops*	red grouper – *E. morio*
black grouper- *Mycteroperca bonaci*	red snapper - *L. campechanus*
blueline tilefish – *C. microps*	rock hind – *E. adscensionis*
cubera snapper – *L. cyanopterus*	sand perch - *Diplectrum formosum*
dog snapper – *L. jocu*	scamp grouper - *M. phenax*
dwarf sand perch - *Diplectrum bivittatum*	schoolmaster – *L. apodus*
gag grouper - *M. microlepis*	silk snapper – *L. vivanus*
goldface tilefish – *C. chrysops*	snowy grouper – *E. niveatus*
goliath grouper - *Epinephelus itajara*	speckled hind - *E. drummondhayi*
gray snapper – *L. griseus*	tilefish - *Lopholatilus chamaeleonticeps*
gray triggerfish - *Balistes capriscus*	vermilion snapper - *Rhomboplites aurorubens*
greater amberjack – *S. dumerili*	Warsaw grouper – *E. nigritus*
hogfish - *Lachnolaimus maximus*	wenchman - *Pristipomoides aquilonaris*
lane snapper - *Lutjanus synagris*	yellowedge grouper *E . lavolimbatus*
lesser amberjack - *S. fasciata*	yellowfin grouper – *M. venenosa*
mahogany snapper – *L. mahogoni*	yellowmouth grouper – *M. interstitialis*
marbled grouper – *E. inermis*	yellowtail snapper - *Ocyurus chrysurus*
misty grouper – *E. mystacinus*	

Coastal Migratory Pelagics FMPs EFH: all estuaries; the US/Mexico border to the boundary between the areas covered by the GMFMC and the (SAFMC) from estuarine waters out to depths of 100 fathoms (GMFMC, 2005). The Coastal Migratory Pelagics FMP covers Spanish mackerel - *Scomberomorus maculatus,* king mackerel – *S. cavalla,* and Cobia – *Rachycentron canadum.*

The area of Galveston Bay where the proposed project is planned is considered to be EFH for only egg and larvae stages of the Cobia (GMFMC, 2016); no other coastal migratory pelagics have EFH within the proposed project area.

Cobia EFH: Cobia are found in coastal and offshore waters (from bays and inlets to the continental shelf) from depths of 1-70 m. Adults feed on fishes and crustaceans, including crabs. Spawning occurs in coastal waters from April through September at temperatures ranging from 23-28° C. Cobia migrate seasonally, similar to other coastal pelagic species in the same family. Eggs are found in the top meter of the water column, drifting with the currents. Larvae are found in surface waters of the northern Gulf, where they likely feed on zooplankton. Juveniles occur in coastal and offshore waters feeding on small fishes, squid, and shrimp (GMFMC, 2016).

Cobia Life History: Cobia eggs in estuarine and nearshore waters in the water column within the upper meter during the summer, and have been collected at temperatures of 28.1-29.7°C and salinities of 30.5-34.1 ppt (GMFMC, 2016). Larvae are found in estuarine, nearshore, and offshore waters, near the surface above waters with depths of 3-300 m from May through September. Larvae are water column associated, and have been collected at temperatures of 24.2-32.0°C and salinities of 18.9-37.7 ppt (GMFMC, 2016). Juvenile cobia are found in nearshore and offshore waters and are water column associated. Early juveniles have been collected from April through July at temperatures of 16.8-25.2°C and salinities of 30.0-36.4 ppt (in the U.S. South Atlantic), and occupy surface waters above depths of 5 to 300 m (GMFMC, 2016). Adult cobia are found throughout the Gulf in nearshore and offshore waters in the water column and can be found on banks/shoals (hard bottom) at depths of 1-70 m, temperatures of 23.0-28.0°C, and salinities of 24.6-30.0 ppt. Adults seasonally migrate (March through October in the northern Gulf and November through March in the southern Gulf and south Florida), with spawning occurring from April through September (GMFMC, 2016).

Spiny Lobster FMP EFH: from Tarpon Springs, Florida, to Naples, Florida, between depths of 5 and 10 fathoms; and Cape Sable, Florida, to the boundary between the areas covered by the GMFMC and the SAFMC out to depths of 15 fathoms (GMFMC, 2005). The Spiny Lobster FMP covers the Spiny Lobster – *Panulirus argus*, and the Slipper Lobster – *Scyllarides nodife*.

The area of Galveston Bay where the proposed project is planned is not considered to be EFH for any life stage of Spiny Lobster (GMFMC, 2016).

Coral FMP EFH: the total distribution of coral species and life stages throughout the Gulf of Mexico including: coral reefs in the North and South Tortugas Ecological Reserves, East and West Flower Garden Banks, McGrail Bank, and the southern portion of Pulley Ridge; hard bottom areas scattered along the pinnacles and banks from Texas to Mississippi, at the shelf edge and at the Florida Middle Grounds, the southwest tip of the Florida reef tract, and predominant patchy hard bottom offshore of Florida from approximately Crystal River south to the Florida Keys (GMFMC, 2005). The Coral FMP covers varied coral species and coral reef communities comprised of several hundred species. They are not listed here because no coral communities exist within Galveston Bay.

The area of Galveston Bay where the proposed project is planned is not considered to be EFH for any life stage of coral (GMFMC, 2016).

Highly Migratory Species FMP: The highly migratory species are managed by the NOAA Fisheries Highly Migratory Species Management Unit, Office of Sustainable Fisheries through a single FMP (NMFS 2006) which was amended in 2009 and reviewed in 2015 (NOAA, 2015). EFH has been mapped for 49 of the species managed by this FMP, and are listed in Table 5.

Of the 49 highly migratory species for which EFH has been mapped, only the following have EFH within the area in Galveston Bay where the proposed project is planned: Blacktip Shark (*Carcharhinus limbatus*) neonates, Bonnethead Shark (*Sphyrna tiburo*) neonates, Bull Shark (*Carcharhinus leucas*) neonates, juveniles and adults, and Spinner Shark (*Carcharhinus brevipinna)* neonates only.

Table 6 Billfish and Highly Migratory Species FMP and Managed Species

Billfish blue marlin - *Makaira nigricans* longbill spearfish - *Tetrapturus pfluegeri* white marlin - *T. albidus* sailfish - *Istiophorus platypterus* **Swordfish** swordfish - *Xiphias gladius* **Tuna** albacore - *Thunnus alalunga* Atlantic bigeye - *T. obesus* Atlantic yellowfin - *T. albacares* skipjack - *Katsuwonus pelamis* western Atlantic bluefin - *T. thynnus* **Sharks** Atlantic angel shark - *Squatina dumerili* Atlantic sharpnose shark – *Rhizoprionodon terraenovae* A basking shark - *Cetorhinus maximus* bigeye sand tiger - *Odontaspis noronhai* bigeye sixgill shark - *Hexanchus vitulus* bigeye thresher shark - *Alopias superciliosus* bignose shark - *Carcharhinus altimus* blacknose shark - *C. acronotus* blacktip shark - *C. limbatus* blue shark - *Prionace glauca* bonnethead - *Sphyrna tiburo* bull shark - *C. leucas* Caribbean reef shark - *C. perezi*	**Sharks (continued)** Caribbean sharpnose shark - *R. porosus* common thresher shark - *A. vulpinus* dusky shark - *C. obscurus* finetooth shark - *C. isodon* Galapagos shark - *C. galapagensis* great hammerhead - *S. mokarran* lemon shark - *Negaprion brevirostris* longfin mako shark - *Isurus paucus* narrowtooth shark - *C. brachyurus* night shark - *C. signatus* nurse shark - *Ginglymostoma cirratum* oceanic whitetip shark - *C. longimanus* porbeagle shark - *Lamna nasus* sandbar shark - *C. plumbeus* sand tiger shark - *O. taurus* scalloped hammerhead - *S. lewini* sharpnose sevengill shark – *Heptranchias perlo* shortfin mako shark - *I. oxyrinchus* silky shark - *C. falciformis* sixgill shark - *H. griseus* smalltail shark - *C. porosus* smooth hammerhead - *S. zygaena* spinner shark - *C. brevipinna* Tiger shark - *Galeocerdo cuvieri* whale shark - *Rhinocodon typus* white shark - *Carcharodon carcharias*

Blacktip Shark (*Carcharhinus limbatus*) Life History: The blacktip shark is circumtropical in shallow coastal waters and offshore surface waters of the continental shelves. In the southeastern United States it ranges from Virginia to Florida and the GOM. The young are born at 55 to 60 cm total length in late May and early June in Bay systems in the GOM (Carlson, 2002; Parsons, 2002) and the Texas coast (Jones and Grace, 2002). EFH includes all major bay systems along the Gulf coast of Texas from Sabine Lake to Lower Laguna Madre.

Bonnethead Shark (*Sphyrna tiburo*) Life History: All life stages of the bonnethead shark are found in the northern GOM. The bonnethead is a small hammerhead that inhabits shallow coastal waters where it frequents sandy or muddy bottoms. The juveniles of this species prefer inlets, estuaries, and coastal waters less than 25 m. Adults have a distribution from Mobile Bay, Alabama, to South Padre Island, Texas. These life stages of bonnethead shark are highly mobile and predatory.

Bull Shark (*Carcharhinus leucas*) Life History: The bull shark is a large, shallow water shark that is cosmopolitan in warm seas and estuaries. This species can be found primarily in shallow coastal waters and is common in lagoons, bays, and river mouths. Bull sharks can also be found in fresh water that connects with salt water and have been caught in the Mississippi River as far upstream as Illinois. The bull shark prefers to live in shallow coastal waters less than 100 ft deep (30 m), but ranges from 3-450 ft deep (1-150 m) (FLMNH 2011a). It commonly enters estuaries, bays, harbors, lagoons, and river mouths and is the only shark species that readily occurs in freshwater (FLMNH 2011a). Juvenile bull sharks enter low salinity estuaries and lagoons as readily as adults do, and use these shallow areas as nursery grounds (FLMNH 2011a). They can also tolerate hypersaline water as high as 53 ppt (FLMNH 2011a). In the United States the nursery areas are in low salinity coastal estuaries of the GOM. In the western north Atlantic off Florida and the Gulf of Mexico, and off South Africa, the young are born in late spring or early summer (MBCS 2011).

Spinner Shark (*Carcharhinus brevipinna*) Life History: The spinner shark is a coastal-pelagic, warm-temperate, and tropical shark of the continental and insular shelves (Compagno, 1984). It inhabits inshore waters less than 30 m deep, but ranges offshore to at least 150 m deep (Aubrey and Snelson 2007). The spinner shark often swims in schools, leaping out of the water while spinning. It is a migratory species, but its patterns are poorly known. Off the eastern United States the species ranges from Virginia to Florida and in the Gulf of Mexico. Juveniles tend to stay inshore of the 20m bathymetric line, whereas adults are found inshore and in offshore habitats to the 90m bathymetric line. Adults are generally not found in inland bays or bayous.

EFH for neonate spinner sharks in the Gulf of Mexico includes coastal areas surrounding the Florida Keys and from the Big Bend Region to southern Texas and consists of sandy bottom areas where sea surface temperatures range from 24.5 to 30.5 °C and mean salinity is around 36 ppt. EFH for juvenile and adults includes coastal areas from Apalachicola, Florida to southern Texas. In all locations, juveniles EFH extends from shore to depths to 20m, whereas adult EFH extends from shore to 90m in depth.

Table 7 Summary of life history information for Federally-Managed Fisheries Species that exhibit EFH within Project area for all or part of their Life Cycle (GMFMC 2016 and NOAA 2008).

Species	Life Stage	Geographic Area	Temp. (°C)	Salinity (ppt)	Depth (m)	Seasonal Occurrence	Habitat Description	Notes
Brown shrimp (*Penaeus aztecus*)	Larvae, pre-settlement postlarvae	Estuarine, nearshore, offshore	28-30 (optimal)	24-36	0-82	Year-round; Peak recruitment of postlarvae into estuaries in spring	Water column associated	Prey: phytoplankton and zooplankton Predators: fish and some zooplankton.
	Post-Larvae, juveniles	Estuaries	7 - 35	2-40	<1	Spring – fall	Nearly all estuarine environments: submerged aquatic vegetation (SAV), emergent marsh, oyster reef, soft bottom, and sand/shell habitats	Experience mortality at DO concentrations less than one ppm, predation, mass kills due to cold temperatures in shallow water, and habitat loss (marsh edge)
	Sub-adult	Estuarine, nearshore	18-28	0.9-30.8	1-18	Spring-Fall	soft bottom, sand/shell	Mortality stems from predation (fish), cold fronts and hypoxia
White shrimp (*Penaeus setiferus*)	Eggs	Estuarine, nearshore, offshore			9-34	Spring-Fall		Demersal eggs hatch 10-12 hrs after spawning

Table 7 Summary of life history information for Federally-Managed Fisheries Species that exhibit EFH within Project area for all or part of their Life Cycle (GMFMC 2016 and NOAA 2008).

Species	Life Stage	Geographic Area	Temp. (°C)	Salinity (ppt)	Depth (m)	Seasonal Occurrence	Habitat Description	Notes
	Larvae, pre-settlement postlarvae	Estuarine, nearshore, offshore	17 – 28. 5		0-82	Spring-Fall		Egg/larval stage lasts 16 days. Migrate at night in shallow water and during the day at mid-depth from May to November
	Post-Larvae / Juveniles	Estuarine, nearshore	Postlarvae 13-31; juveniles 9-33	0.4 - 37	<1	Late Spring – Fall	Emergent marsh, SAV, oyster reefs, soft bottom, mangroves	DO > 1.0 ppm, research suggests greater abundances with increases in temperature, salinity, and turbidity
	Sub-adult	Estuarine, nearshore, offshore	>6	1-21	1-30	Summer - Fall	Soft-bottom, sand and shell	Omnivorous, DO concentrations > 2.0 ppm; Migrates from estuary late Aug/Sept
	Adult	Estuarine, nearshore, offshore	7-38	2-35	<27	Late Summer/ Fall	Soft-bottom w/high org. matter content	Omnivorous, DO concentrations > 2.0 ppm

Table 7 Summary of life history information for Federally-Managed Fisheries Species that exhibit EFH within Project area for all or part of their Life Cycle (GMFMC 2016 and NOAA 2008).

Species	Life Stage	Geographic Area	Temp. (°C)	Salinity (ppt)	Depth (m)	Seasonal Occurrence	Habitat Description	Notes
	Spawning Adults	Estuarine, nearshore, offshore		>27	9-34, but mostly <27	Spring - Late Fall, peak June-July		stage duration is about 237 days; 0.4-1.0 mm/day
Gray snapper (*Lutjanus griseus*)	Adult	Estuarine, nearshore, offshore	13. 4 – 32.5	0-47.7	0-180		Hard bottom, soft bottom, reef, sand/shell, banks/shoals, emergent marsh	
	Spawning Adults	Estuarine, nearshore, offshore			0-180	Summer	Reef, hard bottom	Maturation at 185 mm TL for males and 200 mm TL for females
Lane Snapper (*Lutjanus synagris*)	Larvae	Estuarine, nearshore, offshore	28.4-30.4		0-50	Summer; June through August	WCA, SAV	
	Juveniles	Estuarine, nearshore, offshore	28-29.5	30-35.5, though can be found at lower salinities < 15 ppt	0-24	late summer-early fall	SAV, reefs, sand/shell, soft bottom, banks/shoals, mangrove	DO = 4.4-5.7 mg/L
Red drum (*Sciaenops ocellatus*)	Larvae	Estuarine	18.3-31, 25 opt.	8-36.4		Late summer, fall; Mid-Aug. - Late Nov.	SAV, soft bottom, WCA	Prey: copepods, Predators: larger piscivorous fishes

Table 7 Summary of life history information for Federally-Managed Fisheries Species that exhibit EFH within Project area for all or part of their Life Cycle (GMFMC 2016 and NOAA 2008).

Species	Life Stage	Geographic Area	Temp. (°C)	Salinity (ppt)	Depth (m)	Seasonal Occurrence	Habitat Description	Notes
	Postlarvae	Estuarine	18.3-31.0	8-36.4		Late summer, fall	SAV, emergent marsh, soft bottom, sand/shell	Prey: copepods, Predators: larger piscivorous fishespredators
	Early Juvenile	Estuarine, nearshore	> 5-32.2	0-45, optimal 20-40	0-3	September to December	SAV, soft bottom, emergent marsh	
	Late Juvenile	Estuarine, nearshore	> 5-30	0-45, optimal 20-40	0-5	Fall; Sept. - Early Oct. (peak)	SAV, soft bottom, hard bottom, sand/shell	
	Adult	Estuarine, nearshore, offshore	2-33	0-45, optimal 20-40	1-70		SAV, emergent marsh, soft bottom, hard bottom, sand/shell, WCA	
Cobia (*Rachycentron canadum*)	Eggs	Estuarine, nearshore	28.1-29.7	30.5-34.1	top meter of water column	Summer	WCA	
	Larvae	Estuarine, nearshore, offshore	24.2-32	18.9-37.7	3-300, in surface waters	Spring to fall; May to September	WCA	
	Neonate and young of year (YOY)	Coastal areas, including estuaries, out to the 30 m depth contour in the Gulf of Mexico from the Florida Keys to southern Texas.	20.8 to 32.2	22.4 to 36.4	0.9 to 7.6	Summer (May – Sept.)	Silt, sand, mud, and seagrass habitats.	DO ranging from 4.32 to 7.7

Table 7 Summary of life history information for Federally-Managed Fisheries Species that exhibit EFH within Project area for all or part of their Life Cycle (GMFMC 2016 and NOAA 2008).

Species	Life Stage	Geographic Area	Temp. (°C)	Salinity (ppt)	Depth (m)	Seasonal Occurrence	Habitat Description	Notes
Blacktip shark (*Carcharinus limbatus*)	Neonate							
Bull shark (*Carcharhinus leucas*)	Neonate	Estuarine	28.8-21	16.9- 0.9	<9		Estuaries and river mouths, silt	DO levels around 4.5 mg/L
	Juvenile	From just east of Galveston Bay, TX to the U. S. /Mexico border	24.2 - 30.9	10.6 - 30.8	1.4 -5.8		In shallow coastal waters, inlets and estuaries, sand, mud, and seagrass	
	Adult	In US the nursery areas are in low salinity coastal estuaries of the GOM	15 - 37		1-150, prefers <30		shallow coastal waters; common in lagoons, bays, and river mouths	
Bonnethead shark (*Sphyrna tiburo*)	Neonate	From the Mississippi River westward to the Rio Grande River (TX/Mexico border)	18-33.5	17.2-26.2	<25		Shallow coastal waters, inlets and estuaries	
Spinner shark (*Carcharhinus brevipinna*)	Neonate	Coastal areas surrounding the Florida Keys and from the Big Bend Region to southern Texas	24.5 - 30.5	36	<30	Summer	Shallow coastal areas including bays and estuaries	

2.4 RECREATIONAL AND COMMERCIAL FISHERIES

The finfish and shellfish resources in Galveston Bay support the most lucrative commercial and recreational fisheries of all the major bays in Texas and annually constitute approximately 33 percent of the total commercial revenue and 50 percent of the total recreational revenue for the entire State (Lester, 2002). While the majority of recreational revenue is generated through the collection of finfish, the commercial catch is predominantly comprised of shellfish (shrimp).

In 2015, total landings in the Bay were 16.4 million pounds worth approximately $42 million (all figures given are in U. S. dollars (USD)) (Texas Almanac, 2019). From 1997 to 2001, landings of white shrimp (*Penaeus setiferus*) from Galveston Bay comprised 62 percent of the landings from Texas bay systems and were valued at $5.7 million in 1999, while brown (*Penaeus aztecus*) and pink (*Penaeus duorarum*) shrimp comprised the majority of landings (36 percent) for these species in Texas bays, with Galveston Bay landings worth an estimated $2.5 million in 1999 (Culbertson et. al., 2004). In addition, Galveston Bay supports a robust live and dead bait shrimp fishery and is responsible for over 50 percent of coastal Texas landings worth $1.6 million in 2001 (Culbertson et. al. , 2004).

Although trawl based shrimp landings account for nearly half of the bay's commercial harvest, other shellfish landed relatively frequently from the Bay include blue crab (*Callinectes sapidus*), accounting for 28 percent of coastal Texas landings from 1997-2001 and worth $1.6 million in 1998, and eastern oyster (*Crassostrea virginica*), which accounts for 91 percent of Texas landings from 1997-2001 worth an estimated $13.2 million in 1999). Galveston Bay commercial finfish landings ($234,000 in 1999) pale in comparison to shellfish landings and typically only account for about 7 percent of annual coastal Texas finfish landings (Robinson et. al. 1998). Commercial finfish landings in the bay are primarily comprised of mullet (*Mugil cephalus*) at 26 percent, southern flounder (*Paralichthys lethostigma*) at 13 percent, black drum (*Pogonias cromis*) at 11 percent, and sheepshead (*Archosargus probatocephalus)* at 10 percent, in order of decreasing pounds landed from 1991 to 2001.

Recreational fishing in the Galveston Bay system accounts for almost 40 percent of the total coastal fishing revenue and 35 percent of the landings. Over 262,000 fishing licenses are issued and most fish are caught by anglers using primarily hook and line equipment (TPWD, 2000). The primary species targeted and landed by recreational fisherman largely include members of the drum family (*Sciaenidae* sp.), Atlantic croaker (*Micropogonias undulatus*), star drum (*Stellifer lanceolatus*), spot (*Leiostomus xanthurus*), sea trout (*Cynoscion arenarius*), hardhead catfish (*Arius felis*) and bay anchovy (*Anchoa mitchilli*) (TAMUG, 2019).

Although commercial and recreational fishing is important in the Galveston Bay area, much of the Bay is subject to fishing restrictions and consumption advisories. The Texas Department of State Health Services (DSHS) Seafood and Aquatic Life Group (SALG) conducted a study to investigate blue crab and fish tissue contaminant concentrations in the HSC (Texas DSHS, 2015). The outcomes of the study influenced revisions to fishing advisories for the HSC and Galveston Bay.

The entire area of the Bay where the proposed project is planned is currently within an area restricted for shellfishing. This designation means the area is closed to the harvesting of shellfish for direct marketing.

The HSC and all contiguous waters north of the Fred Hartman Bridge, State Highway 146 including the San Jacinto River below the Lake Houston Dam is within an advisory area for all species of fish and blue crab and it is recommended that adults and children do not eat fish and blue crab from this area (Texas DSHS, 2019). Upper Galveston Bay and all contiguous waters north of a line from Red Bluff Point to Five-Mile Cut marker to Houston

Point is with an advisory area for all species of catfish, spotted seatrout, and blue crab and it is recommended that adults limit consumption to no more than one-eight ounce meal per month; and that women of child bearing age and children under twelve years old should not consume these species from this area. Galveston Bay and all contiguous waters are within an advisory area for all species of catfish and it is recommended that women of child bearing age and children less than 12 years old should not consume any catfish from this area and women past child bearing age and men limit consumption to one-eight ounce meal per month.

2.4.1 Life History Characteristics

A brief description of life history characteristics, habitat preferences, and distribution of commercially and recreationally important species, except for those previously described in Section 2.3 is provided in the following sections.

Pink Shrimp (*Penaeus duorarum*) Life History: Pink shrimp occupy a variety of habitats, depending on their life stage. Eggs are demersal and occur in offshore marine waters, at depths from 9 m to 48 m. Larvae and pre-settlement postlarvae occur in estuarine, nearshore, and offshore waters at depths of 1-50 m. They are water column associated and can be found year-round at temperatures of 15-35°C and salinities of 0-43. They recruit to nearshore environments through passes or open shorelines, primarily on flood tides at night. Postlarvae and juveniles of pink shrimp occur in estuarine and nearshore waters of wide-ranging salinity (0 to >30 ppt) at depths less than 3 m. Juveniles inhabit a wide variety of habitats, such as submerged aquatic vegetation, soft bottom, sand/shell and mangroves. Sub-adults occur offshore, nearshore and in estuarine waters at depths ranging from 1 to 65 m. They too have a wide habitat range, including submerged aquatic vegetation, soft bottom, sand/shell, oyster reefs, and mangroves. They are present in Texas from fall through spring. Adults inhabit nearshore and offshore waters with sand/shell habitats. They are found spring through fall off of Texas at depths of 9-48 m. Pink shrimp densities are highest in or near seagrasses, low in mangroves, and near zero or absent in marshes (GMFMC 2019).

Blue crab (*Callinectes sapidus*) Life History: Blue crabs are recreationally and commercially fished all across the coastal waters of the GOM. Blue crabs can be found in estuaries as well as marine environments depending on life stage. Early larval stages are found in the lower estuary and adjacent marine waters; later stage zoeae exist mainly in the open Gulf, entering the estuary as megalopae when they adopt a benthic existence (Perry and McIlwain 1986). Spawning of blue crabs in northern GOM waters occurs in coastal and estuarine waters in the spring, summer and fall (Perry 1975 cited Perry and McIlwain 1986). Juvenile blue crabs are found on soft, mud sediments with faunal food available (Evink 1976 cited Perry and McIlwain 1986). Adult males tend to remain in low salinity waters while mature females prefer the higher salinities of the lower estuary and adjacent marine waters (Perry and McIlwain 1986). Blue crabs are opportunistic benthic omnivores and feed on crustaceans, mollusks, fish, detritus, as well as on other blue crabs (Perry and McIlwain 1986). Blue crabs are prey to many birds, gars, catfish, sciaenids, lutjanids, and serranids.

Eastern Oyster (*Crassostrea virginica*): Eastern oysters are found in a variety of estuarine and nearshore habitats with a depth range of 0 to 4 m. Oyster larvae are free-swimming; the first larval stage (trochophore) is formed 4 to 6 hours following fertilization and lasts approximately one to two days, the trochophore larva does not feed. The next stage, veliger, are planktotrophic, and feed on small plants and animals an last about 2 months. As adults, oysters are sessile and often occur in beds or reefs. Oyster growth is dependent on temperature, salinity and food availability, so maximum growth normally occurs in the summer and fall. Oysters are capable of growth throughout the year in the Gulf region but optimum temperatures range from 20 to 30º C. Oysters can tolerate salinities from 0 to 42 psu, but the optimum range is 14 to 28 psu. Oysters are filter feeders, feeding primarily on phytoplankton and suspended detritus. In the Gulf of Mexico, eastern oysters have been found to live 25-30 years and reach sizes to 30 cm. Large individuals are usually associated with undisturbed bottoms where commercial fishing is prohibited.

Mullet (*Mugil cephalus*) Life History: Mullet are a coastal species that often enters estuarine and freshwater habitats. They are catadromous, meaning they spawn in marine waters but spend most of their lives in freshwater. Adults form large schools near the surface over sandy or muddy bottoms and dense vegetation, and migrate offshore to spawn in large aggregations (FLMNH 2011b). Ditty and Shaw (1996) found larvae most abundant in the western GOM during November and December. They found the majority of spawning occurs at stations over or beyond the outer continental shelf when surface temperatures drop below 25°C. The larvae move inshore to extremely shallow water for feeding and refuge, spending their first year in coastal waters, salt marshes, and estuaries (FLMNH 2011b). Mullet are ecologically important in estuaries because they work the top layer of sediments removing detritus and microalgae (FLMNH 2011b). Predators include fish (the spotted seatrout), birds, and marine mammals.

Southern Flounder (*Paralichthys lethostigma*) Life History: Adult southern flounder leave bays during the fall to spawn in depths of 50 to 100 ft. Young fish enter the bays during late winter and early spring, and seek shallow grassy areas near passes. As they grow some move farther into the bays while others enter coastal rivers and bayous, feeding mainly on crustaceans. After spawning the adults return to the bays in the spring (TPWD 2011). Glass *et al*. (2008) found the density of southern flounder were significantly greater in East Bay (2.75 per 100 m^2) than in Galveston Bay (0.91 per 100 m^2) or in West Bay (0.45 per 100 m^2).

Black Drum (*Pogonias cromis*) Life History: Adult black drum are common in shallow estuaries throughout the GOM (Silverman 1979 cited Sutter *et al*. 1986). They spawn mostly in February and March in or near passes and in open bays and estuaries (Sutter *et al* 1986). Larvae are transported into estuaries by tidal currents (Sutter *et al* 1986). Juveniles prefer shallow, nutrient rich and relatively muddy waters (Pearson 1929 cited Sutter *et al.* 1986). Juveniles eat polychaetes, crustaceans, and small fish, while black drum longer than 20 cm primarily eat the bivalve *Mulinia transversa corbuloides* (found in muddy sediments) (Sutter *et al*. 1986). Adults have been known to destroy large numbers of oysters (Benson 1982 cited Sutter *et al* 1986).

Sheepshead (*Archosargus probatocephalus)* Life History: Young juvenile sheepshead commonly live in grass flats over mud bottoms; adults and older juveniles usually live on the bottom or along the shore near rocks, pilings, breakwaters, jetties, and piers (Jennings 1985). They congregate in nearshore waters of the Gulf in March, April, and May, and migrate to offshore waters to spawn in spring and return later to nearshore waters and estuaries (Jennings 1985). Sheepshead eggs hatch in offshore waters and the larvae or postlarvae move inshore along beaches and into estuaries (Jennings 1985). Juveniles are found on grass flats and near structures (Jennings 1985). Sheepshead are omnivorous feeding on small crustaceans, oysters, clams, and even smaller finfish (Jennings 1985).

Atlantic Croaker (Micropogonias undulatus) Life History: Atlantic Croaker eggs and larvae are offshore pelagic, normally occurring during the late fall to early winter. By spring, the larvae/juvenile move more nearshore and begin to migrate to estuaries. Estuarine habitats include seagrass meadows, salt marshes, tidal creeks and rivulets, and areas with both mud and sand substrates. As adults, migrate out of estuaries to nearshore and offshore waters of greater salinity to spawn in the early fall and continues through the winter, with peaks from October to November. Fish older than one year are less abundant in estuaries; when present, are usually found around oyster reefs or structures such as bridges or piers in deeper waters. Adult croaker are found offshore and inhabit muddy or sandy bottoms. Atlantic croaker can tolerate a wide range of salinities from 0-70‰. Adult croaker tolerate higher salinities than do juveniles and are most often associated with salinities ranging from 6-20‰. Optimal temperatures for growth in adults have been reported to be between 27 and 31°C.

Star Drum (*Stellifer lanceolatus*) Life History: Star drums are small sciaenids which are considered to be "lesser sciaenids". Lesser sciaenids normally have a short life span, small maximum size, young age of maturity, short spawning season, high spawning frequency and high relative fecundity. A star drum is considered mature at one year of age and about a size of 80 mm – 100 mm. Spawning occurs in the spring through summer, April to June (Waggy et Al., 2006). Star drums inhabit hard sandy mud bottoms in coastal waters to about 20 m depth. They are also common in river estuaries. They mainly feed on small crustaceans. The star drum is not marketed for human consumption and is normally caught as bycatch (Fishbase.org (a) 2019).

Spot (*Leiostomus xanthurus*) Life History: Spot are normally found in Gulf of Mexico estuarine and coastal waters to depths of up to 205 m. Adult spot migrate seasonally between estuarine and coastal waters. They enter bays and sounds during spring. They remain in these areas until late summer or fall before moving offshore to spawn or escape low water temperature. Spot larvae have been collected from within estuaries to the edge of the continental shelf (Hildebrand and Cable 1930; Berrien et al. 1978; Lewis and Judy 1983;Warlen and Chester1985) from October through May. Larvae were smaller and more numerous offshore (34–128 m) than inshore (17–26 m).

Sea Trout (*Cynoscion arenarius*) Life History: Seatrout inhabit shelf and estuarine waters of the Gulf of Mexico. Sea Trout exhibit an annual migratory pattern where they move offshore during the fall and winter then return to bays and estuaries for the spring and summer. Spawning occurs primarily from March through September with distinct peaks in both March-April and August-September. Spawning initially takes place in midshelf to offshore waters and moves shoreward as the season progresses, with most occurring in the lower estuary and shallow waters of 7-15 m. Larvae inhabit water depths greater than 25 m. Larvae migrate into shallow areas of the estuary where they remain until they reach at least 50-60 mm in size then move to deeper water. Juvenile and adult sea trout have been found in waters ranging from 5-37°C, with optimum temperatures ranging from 20-35°C (Ditty and Bourgeois 2001).

Hardhead Catfish (*Arius felis*) Life History: Hardhead catfish inhabit shallow, turbid coastal and estuarine waters with sand or muddy bottoms. Spawning occurs in and near bays and inlets in the summer. Eggs are brooded in the mouth of the male, then larvae remain 2 to 4 weeks after hatching. They are opportunistic bottom feeders, preying mostly on worms and small crustaceans (Natureserve.org 2019). Hardhead catfish are commonly caught while fishing from catwalks, bridges and piers, particularly in passes and inland waterways. They are edible, but generally not consumed (Fishbase.org (b) 2019).

Bay Anchovy (*Anchoa mitchilli*) Life History: Bay anchovy are the most abundant species of fish in the estuarine waters of northen Gulf of Mexico (Robinette 1983). Abundance is seasonal, and in the Gulf of Mexico varies from spring through early winter (Robinette 1983; Ross et al. 1987; Modde and Ross 1983). In East Galveston Bay, peak abundance occurs fromApri1 to June (Arnold et al. 1960) with Galveston Bay showing an abundance of adults and juveniles from May to November (Monaco et al. 1989). The bay anchovy travels in schools and is a key species in many food webs and is a major food source for predators (Griffith and Bechler 1995).

3.0 ASSESSMENT OF EFH IMPACTS

The proposed channel improvement dredging project has been sited and designed to minimize impacts to managed species and their associated EFH as much as possible while achieving the project goal. EFH has been described over broad spatial scales throughout the coastal Gulf of Mexico region; therefore it is difficult to propose any large scale project without impacting EFH for some species.

3.1 POTENTIAL IMPACTS OF THE ALTERNATIVES

No Action Alternative

No new impacts to EFH would occur under the No Action Alternative. The current periodic temporary impacts by existing vessel traffic and channel maintenance dredging, and the continued development of currently used placement areas, which would affect the estuarine mud, shell and sand substrate, and water column within the connection area would occur as previously planned.

Alternative 1 – NED Plan and Alternative 2 - LPP

Dredging Impacts on Species, Estuarine Bottom, and Water Column

The majority of impacts to managed species and their associated EFH would be limited to the estuarine benthic environment where the actual dredging would take place, as well as temporary impacts to the water column as a result of localized increased turbidity. The majority of the juvenile and adult lives stages present in the project footprint are primarily forage and pelagic species capable of detection and avoidance behavior when exposed to unfavorable conditions. It is expected that construction of the proposed project would not have any direct impacts to juvenile and adult fish other than a temporary displacement and minor/temporary loss of prey items for benthic foragers. Individuals would be expected to return to temporarily affected areas upon dredging completion and the benthic habitat is expected to recover within a year or two.

The dredging would occur in the estuary of Galveston Bay, which is a nursery area for some species known to inhabit the GOM. The degradation of estuarine EFH habitats is associated with the following:

- Temporary disturbance and displacement of fish species;
- Increased sediment loads and turbidity in the water column;
- Temporary loss of benthic food items to fisheries;
- Limited disruption or destruction of oyster/reef habitats; and
- Limited sediment transport and redeposition.

For the purposes of this project, most of the above effects are temporary and likely either offset by environmental protection guidelines, or are negligible considering the localized effect of the actions compared to the proportional area of the Gulf that would be unaffected. In this sense, the coastal and marine environmental degradation from the proposed action would have minor effects on designated EFH or commercial fisheries.

Sediment displacement will result from the dredging process. The LPP described for the Project would extract approximately 29.9 MCY of new work sediment and 1.3 MCY of maintenance sediment annually over a 50 year period, for a total estimated at 62.5 MCY over the 50 year period. The NED Plan would extract approximately 18.1 MCY of new work sediment and 0.9 MCY of maintenance sediment annually for a period of 50 years, for a total estimated at 46.6 MCY over the 50 year period. The life stages of federally managed species anticipated to be most impacted are the eggs and larval stages, with those utilizing benthic habitats within the dredged footprint expected to have 100 percent mortality. However, most of the species with EFH in the Project area for these life stages are either not demersal, or prefer SAV (shrimp, gray snapper and red drum). In addition, the removed sediment would no longer be available to managed species for foraging. Only the surface sediments would provide habitat for demersal eggs, or would be home to the macrobenthic species used as food by the managed species. A total of 774 acres for the NED plan or 1,717 acres for the LPP of surficial sediments would be removed through the dredging process in Galveston Bay. Approximately 416 acres of tidal riverine bottom in the HSC above Galveston Bay would be impacted. The large majority of this is currently deepened navigation channel. The opportunistic benthic species which currently occupy most of the affected surface sediments would be expected to colonize the new surfaces within a short timeframe after the dredging process is completed and would continue to provide food sources to the managed species currently using the area for foraging.

Increased turbidity and sedimentation caused by a number of project-related activities, including the anchoring for the construction barges and support vessels could result in direct and indirect impacts on the habitat of demersal and pelagic fish including spawning and nursery areas. Of the 10 species with EFH within the project area only white shrimp and gray snapper are described as spawning in the Project area. White shrimp eggs are demersal while gray snapper eggs are pelagic.

Turbidity generated by the project could affect the foraging behavior of visual predators and the efficiency of filter feeders. The turbidity plume would be expected to migrate only a short distance over a small area relative to the total pelagic habitat area available to managed species, and dissipate quickly due to prevailing water circulation. Numerous studies indicate that dredge-induced turbidity plumes are, more often than not, localized, spreading less than a thousand meters from their sources and dissipating to ambient water quality within several hours after dredging is completed (Higgins et al, 2004). A literature review of dredging operation effects on suspended sediments found that in almost all cases, the vast majority of re-suspended sediments resettle close to the dredge within an hour (Anchor Environmental CA L. P., 2003). The anticipated dredging technique for this project will be hydraulic cutterhead dredging, which generally produces small plumes that rapidly decay (U. S. Army ERDC, 2002). Properly operated dredges can confine elevated suspended bottom sediments to several hundred meters from the cutterhead with levels dissipating exponentially towards the surface with little turbidity actually reaching surface waters, and in many cases, at concentrations no greater than those generated by commercial shipping operations or during severe storms (Higgins et al, 2004). Therefore, the effects of dredging turbidity are expected to be localized and of short duration. The impact to the water column EFH would be considered minor and temporary.

Table 8 Acres of Dredging Impacts

			Acres for Indicated Channel Width Option	
Proposed Plan Component	**Current Condition**	**Proposed Plan Dredged Condition**	**700' NED**	**700' LPP**
HSC Bay Widening	Deep main channel side slopes	Deepened main channel	246.0	500.2
	Upper main channel side slopes and shallow draft barge lanes	Deepened main channel	246.0	680.4
	Shallow undredged bottom	Main Channel Side Slope and Barge Lanes	67.3	385.5

		Total	**559**	**1,566**
Other Bay Measures	Existing channel side slope and shallow undredged bottom	New toe and side slope	214.7	151.4
Upper HSC Measures	Primarily existing channel side slope or deepened berth area, some undredged bottom	Side slope and new Toe	84.0	84.0
	Deepened channel bottom within existing toes	Further deepening	331.8	331.8
		Total in Galveston Bay	**774**	**1,717**
		Total Buffalo/San Jacinto River	**415.8**	**415.8**
		TOTAL DREDGE FOOTPRINT	**1,190**	**2,133**

Oyster Reef Impacts

The LPP includes the majority of the features of the NED Plan, and is the bigger plan of the two. The NED Plan would impact approximately 88.2 acres of oyster reef with a total of approximately 73 average annual habitat units (AAHUs). The increment of the LPP in addition to the features of the NED Plan, would impact approximately 321 acres of oyster reef with a total of approximately 260 AAHUs (Table 8). In total, the LPP would require mitigation for 409 acres, and 333 AAHUs. Explanation of the Oyster Habitat Suitability Index Model (OHSIM) and calculations for this estimate can be found in Appendix P-1 (ECIP Oyster Mitigation Plan) of the Final Integrated Feasibility Report and Environmental Impact Statement (FIFR-EIS). It is anticipated that all oyster habitats within the widening and deepening footprint will be permanently lost by deepening and widening of the channel and is considered a significant, adverse impact. The proposed mitigation method is to beneficially use dredged material to build relief above the surrounding bay bottom and cap it with a veneer of suitable cultch, which would provide the hard substrate for natural recruitment and settlement of oysters during the spat set season. The height of the relief was determined through literature review of papers discussing the relief height of 0.3m or higher as the criteria for success (Lenihan 1999, Luckenbach (2000, Schulte et al. 2009, Lipcius et al. 2015, Powers et al. 2009, Blomberg 2015, Byers et al. 2015, Colden et al. 2017 and Malmquist 2017). However, for the NED there is not enough of appropriate dredged material within an acceptable distance to raise the bottom of the bay. Therefore the NED Plan would use rock or other hard substrate to build the reef. With the LPP, there is enough appropriate dredged material to raise the bottom of the bay.

To mitigate for the NED Plan approximately 88.2 acres of reef impacts, approximately 85 acres of oyster reef would be created in three locations: 4 acres (3.6 AAHUs) as part of the 6-acre Long Bird Island, 14.1 acres (9.9 AAHUs) for part of the 3-Bird Island and 67 acres (59.8 AAHUs) offshore of Dollar Bay with three 20-acre pads approximately 300 feet by 2,171 feet and one 12.1-acre pad approximately 300 feet by 1,757 feet of rock. The rock would be a layer approximately 1- to 2-feet thick. However, the final design of the NED pads would be determined in the preconstruction engineering design (PED) phase, which would conduct geotechnical review of the pad locations and review other pad design that could reduce the amount of rock required. This would reduce the costs of creation of these pads and would have a beneficial use if dredged material could be used. Other options such as placing a ring of rock and filling the inside with material that would settle to become dense enough to support the 4- to 6-inch layer of rock may be considered in the PED phase.

Since the LPP has enough appropriate material within acceptable distance to create all the required mitigation pads, the beneficial use of dredged material to raise the bottom with a veneer of suitable cultch. Again, the PED would conduct geotechnical review of the pad locations and review other pad designs. The current beneficial plan is to place the appropriate material from the dredging to raise the bottom elevation approximately 1 to 2 feet with a 4- to 6-inch layer of rock on top. This beneficial use design has been used by others and by using submerged diffusers has increased the precision in placement, reduced resuspension and spread of the dredged material with reduction of water column turbidity (Appendix P-1 Mitigation Plan for Oyster Reef Habitat).

Table 9 Direct Impacts to Oyster Reef of NED Plan and LPP Measures

NATIONAL ECONOMIC DEVELOPMENT MITIGATION		
National Economic Development Measure	**Acres Impacted**	**AAHUs Impacted**
CW1_BR-Redfish_700 (lower leg w/ standalone bend transition)	52.8	-48.0
BSC Widening to 455' wide channel	5.0	-3.5
Bayport Flare Easing	13.5	-9.4
BE_28+604 for ex. 530' channel	13.7	-9.6
BETB3_BCCFlare_1800NS	3.3	-2.7
Total National Economic Development mitigation needed	**88.2**	**-73.2**
Mitigation Chosen	**Acres**	**AAHUs Provided**
6 ac Long bird island oyster mitigation acreage	4.0	3.6
3-Bird Island oyster mitigation acreage	14.1	9.9
Dollar Mitigation Site	67.0	59.8
Total Replacement Oyster Reef Provided	**85.1**	**73.2**
LOCALLY PREFERRED PLAN INCREMENT MITIGATION		
Locally Preferred Plan Measure	Acres Impacted	AAHUs Impacted
Transition (overlap) of National Economic Development into the lower section of the middle leg of Locally Preferred Plan		
National Economic Development lower leg	52.8	48.0
CW1_BR-Redfish_700 (lower leg) of Locally Preferred Plan	35.0	31.8
Transition of National Economic Development into Locally Preferred Plan to be subtracted from Locally Preferred Plan middle leg	17.8	16.2
CW1_Redfish-BSC_700 (middle leg, MIDG regime) minus National Economic Development overlap	97.5	-88.7
CW1_Redfish-BSC_700 (middle leg, RED regime)	107.7	-75.8
Total CW1_Redfish-BSC_700 with 28+604 Bend	**205.2**	**-164.2**
CW1_BSC-BCC_700 (upper leg)	143.3	-114.4
Total CW11_BSC-BCC_700 with 28+604 Bend	**143.3**	**-114.4**
Minus Bayport Flare Easing	13.5	-9.4
Minus BE_28+605 Acreage in the National Economic Development	13.7	-9.6
Total Locally Preferred Plan incremental mitigation needed	**321.3**	**-259.6**
Mitigation Chosen	**Acres**	**AAHUs Provided**
San Leon and Dollar Mitigation Sites	**291.0**	**259.6**

The use of submerged diffusers for the placement of dredged materials is the recommended methodology for the construction of LPP oyster pads because it can control turbidity and suspended solids to near background within 500 feet of the discharge point, and often much closer. This would limit turbidity to the bottom of the water column where discharge is taking place and any indirect turbidity impacts to adjacent existing reef. The proposed mitigation is discussed in more detail in Section 3.4 and in Appendix P.

Deposition of suspended sediments could partially or entirely bury shellfish and other sessile organisms. Oyster reefs near the project area may be indirectly affected by the temporary increased turbidity during the dredging operations, but long term adverse effects to nearby oyster reefs are not expected from the proposed project. Suedel et al. (2015) found eastern oysters had relatively high tolerance levels to elevated concentrations (up to 500 mg/L) of suspended sediments. They reported that there were no significant differences in weight change or condition index for exposed oysters meaning growth was unaffected. Accretion of oyster reefs in areas adjacent to the HSC modifications is probable considering the high occurrence of this habitat within close proximity of other anthropogenic activity in Galveston Bay.

Dredged Material Placement Impacts on Bay and Gulf Bottom

Construction of the NED Plan or LPP would involve placement of new work dredged materials in a variety of upland and bay PAs, some of which are BU sites. Table 2 and Table 3 listed the PAs, their use in the NED Plan or LPP, and the existing environment impacted. The PAs that involve impacts to existing EFH are those that impact bay bottom or Gulf of Mexico bottom, and are listed in Table 10. Construction of the marsh cells M-11 and M-12, and 3-Bird Island marsh would convert unvegetated homogenous bay bottom to tidal marsh. The new work would be used to build the containment dike for these marsh features for future placement of maintenance material to provide interior marsh fill. Placement of dredged material in the new marsh area will result in permanent habitat conversion. This conversion from mostly open-bay featureless bottom to marshland and emergent habitat is expected to be a gradual process occurring over extended periods of time as maintenance material is generated. As the bathymetry in this area is slowly reconfigured, it is anticipated that various types of fish communities will utilize the newly created EFH habitats present. Furthermore, it is expected that the noise and light generated during actual material placement will elicit an avoidance response in juvenile and adult finfish and cause them to emigrate to the large expanses of similar open-bay and estuarine habitats located immediately adjacent to the new placement area. Any disruption to foraging behavior of adult and juvenile life stages during placement would be considered minor and of short duration. Unavoidable impacts to benthic EFH would be offset by the eventual creation of marsh within these new BU features, increasing the amount of nursery areas, protective habitat, and food sources within the Galveston Bay estuary. While unvegetated bay bottom habitat would be lost, the creation of marshes would offset the effects of this bay bottom habitat loss since marshes provide essential habitat for federally managed species. The marsh is expected to result in greater productivity than unvegetated bay bottom. One recent study comparing the crustacean population and production between tidal marsh and open water habitat in Galveston Bay, demonstrated a consistent and marked measured decline of shrimp and blue crab density observed as one moves from the peak density in marsh edge vegetation to their low values in open water (Minello et al 2008). The results of the study confirmed that salt marshes in Galveston Bay are important in sustaining fishery production of penaeid shrimps and blue crabs, and are more productive for these species than open water habitat. The NED Plan would create approximately 675 acres of marsh features, and the LPP would create 1,120 acres of marsh.

The bird island sites would convert unvegetated homogenous bay bottom to upland to provide shorebird nesting habitat. The use of the ODMDS No. 1 would involve placement of mechanically-dredged new work material by scow into this existing, dispersive site. This would have temporary effects of burying existing benthos during the one-time placement into this approved offshore placement site. No permanent habitat conversion would occur.

Construction of the proposed sediment attenuation feature would convert 24 acres unvegetated homogenous bay bottom to upland island that has 12 acres of riprap below mean high tide for shore protection. This additional riprap is good habitat for oysters. It is anticipated that various types of fish communities would utilize this newly created EFH habitat. Impacts and mitigation for them were assessed using Habitat Evaluation Procedure (HEP)-based Habitat Suitability Index (HSI) models using USFWS models for Gulf menhaden, Red drum, and White shrimp. The loss of the 24 acres of bay bottom (5.8 AAHUs) would be mitigated by the construction of part of 3-bird island (20.9 acres). Explanation of the model and calculations for this estimate can be found in Appendix P-3 (Mitigation Modeling for Proposed Sediment Attenuation Feature) to the EIS.

Similar to dredging, material placement creates a potential risk to passive egg and larval life stages present in water column and benthic EFH habitats. As such, dredged material placement in the new area will have minimal impacts due to the small proportion of soft bottom, open-bay habitat affected by the placement area relative to similar available habitat elsewhere in upper Galveston Bay. During periods of placement inactivity it is expected that reproductive capability of finfish and shellfish species will not be impacted and that species specific spawning behavior will transition with the changing bathymetry as new maintenance material is generated.

Table 10 New Work PA EFH Conversion Impacts

Placement Area	Approximate Acres	Existing Environment	Habitat Converted To
3-Bird Island Marsh	402	Bay bottom	Tidal Marsh
	6	Bay bottom	Upland – Bird Habitat
6-acre Long Bird Island	6	Bay bottom	Upland – Bird Habitat
8-acre Bird Island	8	Bay bottom	Upland – Bird Habitat
M11	445	Bay bottom	Tidal Marsh
M12	273	Bay bottom	Tidal Marsh
Sediment Attenuation Feature	24	Bay bottom	Upland
ODMDS No. 1	5,594	Gulf bottom	No conversion

As part of the maintenance of the proposed project, PAs constructed as part of the new work placement would provide placement capacity for the maintenance dredging to be performed on the existing HSC and the modifications of the NED Plan or LPP. Due to the capacity constraints, the future without project planning of the USACE for the existing HSC would include the concept of Bay Aquatic Beneficial Use (BABUS) sites. Only a portion of these sites would be required for proposed project maintenance dredging placement of the LPP. The full evaluation for National Environmental Policy Act (NEPA) purposes of the BABUS sites will occur with a revision to the existing HSC DMMP. The concept involves a series of beneficial use cells constructed from dredging in situ bay bottom material to form confining dikes that themselves would host a variety of marsh, oyster reef, and other aquatic habitat types, and the interior of the cell would be filled with HSC maintenance material over a long term to ultimately be converted to beneficial use habitat.

A synopsis of the potential ecological features is as follows. Multiple habitat types would be created on the sides of the CAD cells. The height of the CAD cell crest would be approximately 8’ above MLLW. To estimate the amount of each habitat that would be created, a template was created for where each habitat type would be established. Oyster habitat would be established from approximately -2’ to -10’ MLLW on the outer slope of the cells. This would provide 38 acres of reef on the larger cells and 33 acres on the smaller cells. Emergent marsh habitat could be established from 0 to 3’ on both the inner and outer slops of the cells, providing 33 acres on the larger cells and 20 acres on the smaller cell. This concept is illustrated in Figure 5. After the CAD cell has been filled the interior of the cell can then be utilized to establish another 178 acres of marsh in each of the larger cells and 64 acres in the smaller cell. Upland/bird island habitat could be established from 3' to the top of the crest of the cell, covering both the inner and outer slopes. This habitat would provide 59 acres of habitat on each of the larger cells and 39 acres on the smaller cell. A plan view concept is shown in Figure 6.

USACE performed modeling to assess the impacts and lift provided by this concept using the Habitat Evaluation Procedure (HEP). HEP-based Habitat Suitability Index (HSI) models were used to estimate impacts from the placement of the CAD cells to the bay bottom. Two models were used to estimate the impacts to different species groups. Red drum was selected as the proxy for finfish, while brown shrimp was chosen as the proxy for invertebrates. The AAHUs for each model were averaged to give a representative impact to the community utilizing the bay bottom. When the succession of four CAD cells were included in the model over a 50-year project horizon the average AAHUs are estimated to be 224. The American Oyster HSI model estimated the benefits of the oyster reefs over the project life to be 95 AAHUs. The Brackish Marsh WVA V 2.0 model estimated the benefits of the fringing emergent marshes over the project life to be 255 AAHUs. The Roseate spoonbill HSI model estimated the benefits of the upland/bird island habitat at 149 AAHUs. While the impacts to the bay bottom of over the 50-year project life will total an estimated 224 AAHUs, the benefits returned by the aquatic ecological habitats created would total an estimated 340 AAHUs, for a net benefit of 116 AAHUs.

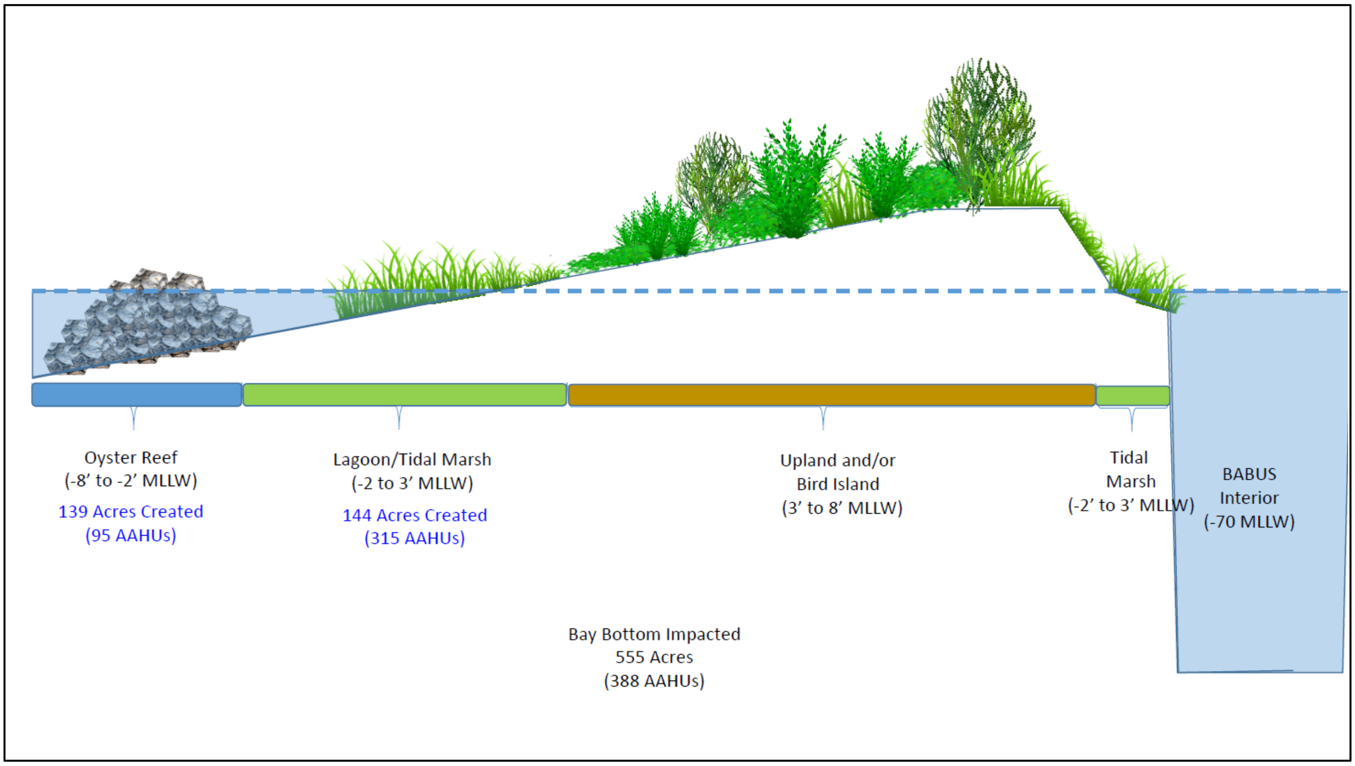

Figure 5 Conceptual Cross Section of a BABUS Containment

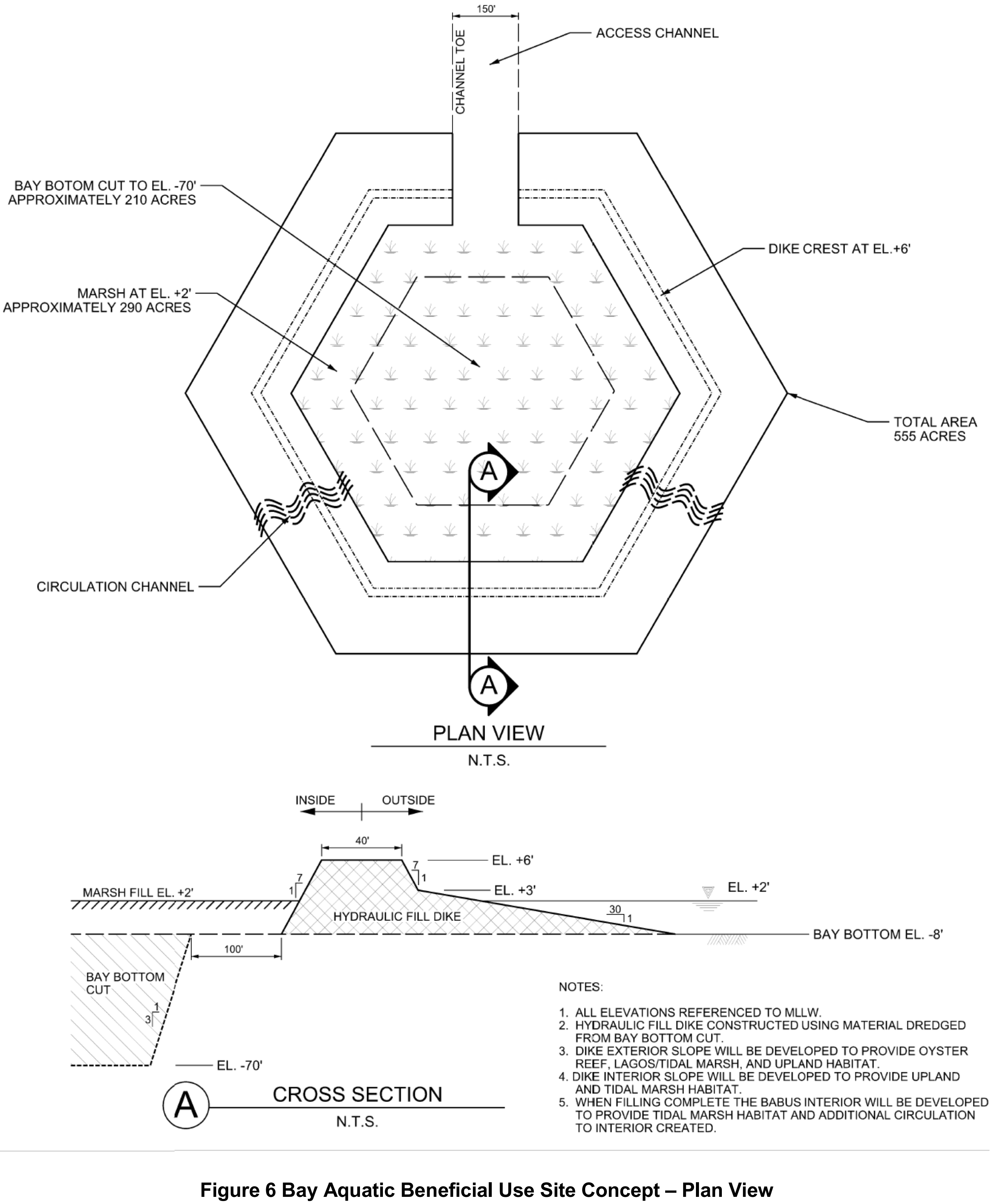

Figure 6 Bay Aquatic Beneficial Use Site Concept – Plan View

Other Effects on the Estuarine Environment

The proposed channel improvements could slightly increase salinity within and near the vicinity of the HSC due to deepening. A deeper channel in an estuary typically allows the density current to be stronger and move higher salinity water farther upstream under certain conditions, increasing the salinity in the system. The effects are expected to be strongest following larger freshwater inflow events, such as from storms, when there is a strong salinity gradient from the upper to the lower bay. Salinity modeling conducted by the USACE Engineer Research and Development Center (ERDC) using a hydrodynamic model of the estuarine system, indicated that the proposed channel modifications result in only a change from without-project conditions of a few tenths of a part per thousand (ppt). This is still within the range of the EFH salinity tolerances for managed and typical species for the estuarine life stages. The details on the hydrodynamic modeling can be found in the Main Report and Appendix G, Section 3.1.4.2. No significant adverse effects were expected with the project-induced changes seen, considering the salinity tolerance ranges involved, and the greater natural variability in salinity. Therefore, it is expected that the proposed action would similarly have small slight increases in salinity with no significant adverse effects.

No aquatic vegetation has been identified in the dredged or adjacent buffer zone areas, therefore no impacts to seagrass or the nursery habitat it provides to juvenile fish will occur from the proposed project. Temporary disturbance to transient, floating *Sargassum* sp. could occur during the dredging and placement operations, but would be considered to be minor and temporary.

Entrainment of fish eggs and larvae into the water intake systems for cooling and ballast water intake during shipping operations will be the most significant direct long-term impact to the EFH of managed species. However, this practice is already utilized by the vessels within the HSC, and the potential slight increased impact to eggs and larvae as a result of the water intakes is not expected to significantly affect fisheries resources. The only managed species with EFH in the project area for eggs is the red drum. Species with larval stage within the Project area that may be affected include the shrimp, red drum, and gray snapper.

The proposed project is not in or near any of the areas identified as HAPC. These areas are all located offshore. Therefore, no impacts to HAPC are anticipated through the completion of the proposed project.

3.2 CUMULATIVE IMPACTS

For the purposes of framing the impacts of the HSC Improvements Project in the context of permanent cumulative impacts on EFH, projects constituting past and present actions were considered. The relevant past and present actions are those that have had or continue to have effects on the resources carried forward in the analysis, and within the geographic scope identified for those effects. These represent the other actions that affect the resources, ecosystems, and human communities of concern. For purposes of these past or present impacts, a timeframe of 50 years from the present to the past was selected, which is the assumed lifespan of USACE navigation/dredging project. This is also a timeframe for which sufficient impact information is reasonably and readily available.

The analysis focused on projects with a more substantial impact to Galveston Bay and bay bottom through dredging or dredged material placement. Channel dredging projects that were for changes to existing channel geometry were selected. Commercial and private docks and berthing areas were considered for past projects. However, with the exception of the Clear Lake Channel and the BSC and BCC side channels to the HSC, private berthing facilities on Galveston Bay are all small piers and docks for recreational or small fishing shallow draft vessels that would only require small-scale dredging to maintain depths near the docks and shoreline to the relatively shallow drafts of Galveston Bay (6 to 8 ft). Upstream of Morgans Point, the commercial berths, where most of the large vessel berthing activity takes place are larger than private berths in the Bay. However, not much information on their past construction and dredging is readily available, and the majority of the larger berths appear to be excavation of uplands converted to deep water. Most of the other berths appear to be deepening in the section of Buffalo Bayou upstream of the San Jacinto Battleground that was widened to create the modern HSC. So most of these past actions above Morgans Point were in a section that expanded the estuarine water column and bottom. The area of small bays downstream of San Jacinto Battleground had a few large areas that were historically emergent land or swamp that subsided and were eventually supplanted by the Lost Lake PA, Lynchburg Reservoir, and the Black Duck Bay placement feature. So the net change in estuarine bottom from these features appears somewhat limited. The largest past changes to natural bay bottom appear to occur in Galveston Bay. Therefore the past and present projects focus on that part of the study area.

The following descriptions summarize the projects constituting the past and present actions. Data from publicly available environmental documents (i.e. EAs, EISs), Federal feasibility studies, and related documents were used. These projects have been constructed, except for the Bayport Ship Channel Container Terminal, which has been partially constructed and will continue to expand as the projected container cargo demand grows. For the most part, these projects would only pose future impacts from maintenance dredging and placement for the effect being analyzed.

- Houston and Galveston Navigation Channels (HGNC) – This project involves deepening and widening the 53-mile long HSC and deepening the 2-mile long Galveston Ship Channel (GSC), which have already been completed as of 2010. Placement of dredged material was planned for 50 years to go to existing and future upland and BU marsh PAs and ocean disposal sites along these channels from the lower reach of the Buffalo Bayou/HSC before it enters Galveston Bay to just outside of Galveston Bay in the Gulf of Mexico (GOM). The project had 118 acres in the main channel and 54 acres in the barge lanes of oyster reef impact which were mitigated.

- Cedar Bayou Federal Navigation Channel – This project involved the deepening of the Federal navigation barge channel in 1975, and is completed. The channel is located approximately 4.5 miles northeast of the BSC starting near Atkinson Island and extending into Cedar Bayou, to approximately Mile 3, near the City of Baytown in Chambers and Harris Counties, Texas. It joins the HSC between the north tip of Atkinson Island and Hog Island.

- Barbours Cut Terminal and Channel – This project involved the deepening of the Barbours Cut turning basin and side channel to the HSC, and constructing a container terminal along the channel in the 1970's. Barbours Cut Terminal and Barbours Cut Channel (BCC) are located near Morgans Point, which is at the mouth of the HSC/Buffalo Bayou leading into Galveston Bay.

- BCC Improvements – This project involved improving the BCC by deepening by 5 feet and shifting northward by 75 feet to allow a wider modern crane span and an increased safety setback required by vessel pilots to pass berthed ships. It was completed in 2016.

- Bayport Ship Channel Container Terminal (BSCCT) – This is an ongoing project to build a container and cruise ship terminals with the first phase completed in 2007 providing three berths. The terminal is located on the south shore of the BSC within the land cut.

- Bayport Ship Channel – This project involved the dredging of the original BSC, dredged in the mid 1960's and deepened in the 1970's.

- BSC Improvements – This project involves the recently completed (2017) modifications to the BSC to deepen it by 5 feet and widen it by 50 feet within the land cut and by 100 feet outside of the land cut. The project provided levee construction material for raising the levees at PA 15 to increase its capacity. The 4.6 acres of oyster reef impacted were mitigated.

- Odfjell Bulk Liquid Terminal – This project involved the construction of 2 large vessel wharves and 3 smaller barge docks to service bulk petrochemical liquid vessels on the BSC TB, west of the BSCCT.

- LBC Bulk Liquid Terminal – This project involved the construction of 3 large vessel wharves and 5 smaller barge slips to service bulk petrochemical liquid vessels on the BSC TB, west of the BSCCT. Some of these facilities were originally built by Celanese and sold to LBC in 2000.

- Enterprise Ethane Terminal – This was a recently completed (2016) project turn an existing wharf (Wharf No. 8) into an ethane export terminal by constructing new docks, mooring structures, pipe racks, gangways, and other structures, and dredging the berth to match the depths of the HSC. Approximately 0.8 acres of oysters were impacted and assumed mitigated.

- Texas City Channel Deepening – This project involves deepening the Federal navigation channel, which was completed in 2011. The Texas City Channel is located in the lower part of Galveston Bay near its outlet to the GOM.

- Clear Lake Channel – An approximate 7-ft deep channel running the length of Clear Lake and emptying to Galveston Bay at a draft of 10 to 12 ft. It receives periodic maintenance to maintain this draft for recreational users.

- Expansion of PAs 14 and 15 – This project involved expanding the existing PAs 14 and 15 by filling the gap between them with an upland PA connection and creating adjacent BU marsh cells M10 and a future cell M11. Mitigation for impacts to the saline marsh and tidal flats in the connection were achieved by construction of 88 acres of marsh at the Bolivar BU Marsh site, which is reflected under the HGNC project. PAs 14 and 15 are just to the east and north of the HSC-BSC confluence.

The foreseeable future projects were focused on those that had effect in the marine or estuarine environment of the study area, defined by the HSC, its side channels, and Galveston Bay. Because any project with substantial actions that could impact the HSC or Bay waters, which are navigable waters, would require a USACE CWA Section 404 and Section 10 permit, information from the Department of the Army (DA) permit system was researched. This ensured projects that were being planned, which would have to obtain a DA permit, were captured in the search for reasonably foreseeable future actions. Issued permits from 2014 to the first quarter of 2017, and the pending permit applications which typically cover permits submitted within the last year that have not been yet issued. The permits were first screened using the project location coordinates and GIS to capture an area consisting of Galveston Bay and a 1-mile buffer around the existing HSC, BSC, and BCC. Duplicate actions representing resubmissions of other selected permits were removed. Project description and application information were then obtained from the USACE Galveston District Regulatory Branch for these permit numbers to help filter out smaller actions with little potential to impact Galveston Bay through dredging. The following filtering process was used:

- Projects consisting solely of constructing or modifying dock structures, piers, mooring piles, and shore protection were not included because their construction requires no dredging, and only minimal bottom disturbance to drive piles, place shore protection etc.

- Similarly, permits to construct small well pads were not included.

- Permits consisting solely of extending routine berth maintenance dredging permits or to modify the conditions of their maintenance that do not require new areas of dredging were not included because these projects represent routine maintenance dredging over an existing deepened berth footprint. These would not further modify the estuarine bottom, but remove new periodically shoaled material.

- Ensure permits did not list dredging in addition to the other actions.

The remaining projects consisted of dredging projects that would have the similar types of impacts carried forward in the analysis. In addition to the regulatory permits, the USACE Galveston District's Civil Works studies in Galveston Bay for which planning was completed or in progress were considered for inclusion in the reasonably foreseeable projects. Finally, some known previously planned and permitted projects in Galveston Bay that had not been constructed were not included, because information indicated that project implementation was not moving forward. These were the Shoal Point Container Terminal in Texas City, and the Cedar Bayou Federal Navigation Channel Extension. Table 8 lists the reasonably foreseeable future actions, based on this process. Where information was available to quantify the size of project impacts, this information was extracted and summarized in the table.

The bay bottom and known oyster reef impacts are summarized in Tables 7 and 8. Data from publicly available environmental documents (i.e. EAs, EISs), Federal feasibility studies, and related documents were mainly used. In a few cases for new impending projects, internal project information or communication was used. In a few cases where acreage information was lacking but channel project dimensions were available, approximate areas were estimated. Except for the HGNC dredged material PAs, no attempt was made to update information or to contact project authorities for changes to dredged material placement plans or other project changes.

The following factors may be considered in evaluating the potential for cumulative impacts:

- whether the resource is especially vulnerable to incremental effects;
- whether the proposed action is one of several similar actions in the same geographic area;
- whether other activities in the area have similar effects on the resource;
- whether these effects have been historically significant for this resource; and
- whether other analyses in the area have identified a cumulative effects concern.

The following sections consider types of impacts that may affect marine resources. The potential for significant cumulative impacts is evaluated by considering the project-specific impacts in combination with those of past, present, and reasonably foreseeable future projects.

Table 11 Cumulative Impacts of Past, Present and Reasonably Foreseeable Projects

Project	**Bay Bottom Impacts (acres)**					
	Excavation (Channels etc.)	**Placement/Fill**			**TOTAL**	**Oyster**
		Upland	**Marsh**	**Total**	**Excavation & Placement**	
Past and Present Actions						
HGNC	480	3,870	3,346	7,216	7,696	118
Cedar Bayou Fed Navigation Channel	83			0	83	
Barbours Cut Terminal and Channel				0	0	
Bayport Ship Channel Container Terminal	74	1. 4		0	74	
Bayport Ship Channel	220			0	220	
Texas City Channel Deepening	15	163	642	805	820	
Expansion of PAs 14 and 15		113	729	842	842	
Bayport Flare Easing	20			0	20	21
Barbours Cut Modernization				0	0	
BSC Improvements	68			0	68	
Subtotal Past & Present	**960**	4,146	4,717	8,863	**9,894**	**139**
% of Galveston Bay area	0.25%	1.08%	1.23%	2.31%	2.58%	0.04%
Reasonably Foreseeable						
Larsen Tankers dredge, dock and bulkhead	9.3			0	9.3	0
Odfjell Terminals Adding of disposal areas	9.06			0	9.06	
Gulfcoast Ammonia	19.02			0	19.02	
Oiltanking North America Dredging	113.17		47.57	47.57	160.74	
Texas International Terminals	18.73			0	18.73	
Subtotal Reasonably Foreseeable	**169.28**	**0**	**47.57**	**47.57**	**216.85**	**0**
% of Galveston Bay area	0.04%	0.00%	0.01%	0.01%	0.06%	0.00%
TOTAL PAST, PRESENT, & REASONABLY	**1,129**	**8,863**	**4,765**	**8,911**	**10,111**	**139**

FORESEEABLE						
% of Galveston Bay area	0.29%	1.08%	1.24%	2.32%	2.63%	0.04%
Total Cumulative Impacts with NED or LPP Improvements Added						
NED Cumulative Impacts	774	20	675	695	1469	88
% of Galveston Bay area	0.20%	0.01%	0.18%	0.18%	0.38%	
LPP Cumulative Impacts	1,717	37	1120	1,157	2,874	410
% of Galveston Bay area	0.45%	0.01%	0.29%	0.30%	0.75%	
Galveston Bay Area:	600	square miles				
	384,000	acres				

3.2.1 Alteration to Seafloor Habitat and Turbidity

The cumulative projects impact the seafloor and EFH in two principle ways: by deepening the shallow bottom when navigation channel, berths, and turning basins are excavated, and by filling in most or all of the water column and converting shallow bay bottom to upland or marsh when dredged material placement areas or other terminal facilities are built. Table 11 summarizes the quantities for each type of impact. In the first type of impact, the water column and bottom are not permanently removed, but are converted to areas of frequent disturbance and impact from vessel traffic, which is summarized in the column labeled "Excavation." In the second type, conversion to upland removes the water column and EFH permanently (summarized under "Upland"), while conversion to marsh (summarized under "Marsh") removes most of the water column and converts the EFH to a type more conducive to juvenile life stages of certain species (shellfish etc.).

Galveston Bay encompasses 600 square miles (384,000 acres). The total amount of impact from past and present actions from excavation is approximately 960 acres (0.25% of the Bay area). Impacts of excavation from reasonably foreseeable actions are approximately 169 acres. The total excavation impacts from past, present and reasonably foreseeable actions are approximately 1,129 acres, or about 0.29% of the Bay area. The total impacts of placement and fill from past and present actions is approximately 8,863 acres (1.08% of the Bay) and 47.6 acres from reasonably foreseeable actions, for a total of 8,911 acres, or 2.3% of the Bay area. Therefore, the total of all past, present, and reasonably foreseeable impacts to bay bottom from excavation and placement are approximately 10,111 acres, constituting 2.63% of the Bay area, a relatively small proportion. It should be noted that impacts to oyster reefs occur during either excavation or placement/fill (or both) in the Bay, and are therefore, not added to the total.

The HSC improvements will result in temporary and permanent impacts on the seafloor; and short-term, localized turbidity. Table 11summarizes the impacts of the HSC Improvements Project on all bottom areas of open water. In total, up to 1,469 acres of bay bottom and 88acres at most of oyster habitat would be impacted by the NED Plan. For the LPP, this would be 2,874 acres of bay bottom and 410 acres of oyster reef. These impacts are minor compared to the unaffected bay bottom of the 600 square mile Galveston Bay habitat and the approximately 28,000 total acres of oyster habitat within the Bay. They are also minor considering that the greatest acreage is associated with marsh restoration. The 410 acres of oyster reef that would be impacted by the LPP channel modifications comprise approximately 1.4 percent of the 28,000 acres of historically mapped reef in Galveston Bay (Powell et al. 1994). TPWD estimated that between 50 and 60 percent of reefs in the Bay were impacted by Hurricane Ike. Conservatively assuming a remaining unaffected portion of 40 percent, the LPP oyster reef impacts would represent up to 3.6 percent of the unaffected reef. Though the amount is a relatively small percentage, it is an impact that will be mitigated. The cumulative impacts of all projects change negligibly when adding HSC Improvement impacts including mitigation, increasing only a few tenths of a percent from 2.76% to 3.64% and 3.27%, respectively, for LPP and NED plan. The cumulative impact of the proposed action can be characterized as a negligible contribution to a small impact on bay bottom.

3.2.2 Impingement and Entrainment (Seawater Intake)

The BSC improvement project will allow larger vessels to access the container terminal within Galveston Bay, which has the potential for impacts to eggs and larval stages of fish and shellfish to impingement and entrainment during ballast and cooling water uptake. However, ballast water exchange is a practice that is currently utilized by the ships already accessing the Bay, and the improved configuration of the channel would allow for fewer vessels to achieve the same volume of transport.

3.3 SUMMARY OF EFH IMPACTS

The EFH impact evaluation process for the Project is summarized below in Table 9. Impacts are listed by type and nature (i.e., significance of effects). Impacts are considered direct, indirect, temporary, short-term, long-term, permanent, and/or cumulative.

Table 12 Summary of Anticipated Impacts to EFH

Type of Impact	Temporary [Recovery within Days to Weeks]	Short Term [Recovery within <3 Years]	Long Term[Recovery in >3 to <20 Years]	Permanent [Recovery in >20 Years]	Cumulative
Turbidity/Sedimentation	I	I	—	—	Temporary
Barge Anchoring	D	—	—	—	Temporary
Disruption of Oyster Habitat	I	—	—	D	Permanent
Disruption of SAV Habitat	—	—	—	—	—
Disruption of Live Bottoms/Hard Substrate	—	—	—	—	—
Seafloor Area Occupied by Channel	—	—	—	D	Permanent
Fish Fauna Disruption - Species	D	I	—	—	Temporary
Fish Fauna Disruption - Habitat	I	I	—	D	Temp for channel, Perm for placement areas
Entrainment/Impingement	D	D	—	D	Permanent
Beneficial Impact Providing Marsh Habitat	—	—	—	D	Permanent

D = Potential Direct Impact
I = Potential Indirect Impact
— = No Impact

Most of the above effects are temporary and will be offset by environmental protection guidelines or are negligible considering the localized effect of the actions compared to the unaffected habitat available in Galveston Bay.

3.4 PROPOSED MITIGATIVE MEASURES AND GUIDELINES FOR EFH PROTECTION

Potential impacts associated with the proposed HSC Improvements Project were avoided and minimized through the project planning process and coordination with State and Federal agencies. The coordination included interagency meetings through the BUG. In addition to the Applicant, the BUG includes representatives from the TPWD, USFWS, NMFS, NRCS, USACE, EPA, and TxGLO. The following describes proposed mitigation for unavoidable impacts to EFH and guidelines for EFH protection that have been or would be considered during project planning and construction.

3.4.1 Oyster Mitigation

The channel improvements of the NED Plan will result in unavoidable, permanent adverse impacts to approximately 88.2 acres of oyster hard bottom habitat an additional 321.3 acres for the LPP. Mitigation for these impacts would replace the oyster habitat that would be removed or buried by the construction of these alternatives by constructing new oyster reef pads. This large-scale oyster restoration would replace the important ecological benefits to Galveston Bay of impacted oyster habitat such as improvement of water quality and clarity as well as re-establishment of essential fish and invertebrate habitat.

In accordance with USACE planning policy, credit for mitigation was determined by using USACE-certified habitat models to determine functional losses from impacts and functional gains (or “lift”) from mitigation. USACE Civil Works policy contained in the CECW-CP policy memo *Policy Guidance on Certification on Ecosystem Output Models*, dated August 13, 2008, requires that only standard models already certified by the USACE Ecosystem Planning Center of Excellence (PCX) be used to determine mitigation, or that models proposed for use undergo the model certification process outlined by the USACE. The Oyster Habitat Suitability Index Model (OHSIM) developed by Swannack *et al.* (Swannack *et al.* 2014) was certified and was selected for use in this mitigation plan (Young. 2018). One key expectation and assumption incorporated into the modeling was that a functional reef would not be present until Year 3, until initial oyster recruits could reach full adult stage and harvestable sizes. This was implemented following resource agency input during the initial oyster subcommittee meeting held on January 19, 2017 that renewed an assumption used in the HGNC oyster mitigation determination. The basis for the HGNC assumption is described in the FWCAR of the 1995 HGNC LRR, which documents the expectation of functional recovery in 3 years and supporting observations from oyster ecology experts from experimental reefs and oil exploration shell drilling pads. This is consistent with modern observations and literature for the American oyster growth in the Gulf of Mexico (TPWD 2010, NOAA undated). Because the OHSIM does not have a live oyster density-based variable, the assumption was implemented by making the restored reef cover type appear in Year 3, to reflect the attainment of functional reef and the maximum relative score for the conditions being modeled.

The proposed mitigation sites total approximately 85.1 acres in three locations (including 18.1 acres of oyster reef shoreline protection features at proposed bird islands) for the NED plan and approximately 290.9 additional acres for the LPP in two locations. Mitigation would require consideration of additional acreage within the vicinity of these sites as needed to accommodate the final mitigation amount. The full mitigation plan is provided as Appendix P-1 of the FIFR-EIS.

Monitoring of the restoration sites would be conducted pre- and post-restoration in order to assess the success of the mitigation. Criteria for restoration success will include one structural and one functional endpoint. The structural endpoint would be the number of hard-bottom acres restored. The functional endpoint would be a measure of the live oyster density or recruitment onto the cultch that would be determined in coordination with TPWD. The specific method and techniques would be adapted to the scale of mitigation required and may follow TPWD monitoring methods suitable for large acreages of restoration. Monitoring would be conducted yearly to ensure the selected success criteria are met following the spat set season. When the success criteria are met, the monitoring would cease and the mitigation project would be determined to be successful.

The first report to the resource agencies would include the findings of the restored reef acreage as determined by side-scan sonar, and would be submitted no later than 90 days after placement of the reef substrate. The results of all monitoring activities would be summarized annually. The subsequent three annual reports over the 3-year monitoring period would include the oyster density findings of the SCUBA divers, including when the post-restoration oyster density success criteria was met.

3.4.2 Guidelines for EFH Protection

GMFMC developed guidelines that, if incorporated into project plans, would minimize impacts to various fishing and non-fishing related activities. Listed below are the guidelines specifically developed for activities associated with navigation channels and placement of dredged material (GMFMC 2005) that were or would be considered during the development of the Project.

- Channel improvements will be aligned along the least environmentally damaging route. **Project Implementation:** Environmentally critical habitats have been avoided as much as possible.

- Pipes used in the hydraulic dredging process will be placed and moved so as not to destroy sensitive habitats (i.e. submerged grasses and shellfish beds). **Project Implementation:** No SAV is present in or near the Project area, and the oyster areas have been delineated and can be avoided as much as possible. Pontoon flotation of hydraulic pipelines is typically used in dredging projects in Galveston Bay and would be used as conditions allow. This flotation avoids pipelines dragging on the bay floor.

- Excavated materials will be beneficially used to the extent practicable. **Project Implementation:** Dredged material placement for initial improvements as well as the fifty years of maintenance following have been accounted for in proposed action. Construction of the new bird islands and marshes will convert unvegetated homogenous bay bottom to marsh. The acreage for all proposed new beneficial use mitigation areas totals 1074 acres for the NED Plan and 1519 acres for the LPP.

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