U.S. Army Corps
of Engineers

Galveston District
Southwestern Division

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

Draft Integrated Feasibility Report–Environmental Impact Statement

APPENDIX P

MITIGATION PLAN FOR OYSTER REEF HABITAT

August 2017

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1.0 BACKGROUND

Implementation of the Tentatively Selected Plan (TSP) for the Houston Ship Channel (HSC) Expansion Channel Improvement Project (ECIP) will permanently impact the oyster reef within the footprint of the proposed channel modifications. The TSP will 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 construct new ones, and provide a multipurpose mooring. 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 TSP milestone phase of the U.S. Army Corps of Engineers (USACE) Specific, Measurable, Attainable, Risk Informed, Timely (SMART) Civil Works planning process, where a plan has been tentatively selected for agency, technical, and public review, and vertical chain of command approval. At this stage of the planning, the major components of the plan have been identified and evaluated at a higher level of analysis, and will be analyzed in greater detail and refined in the next planning phase, following approval during the Agency Decision Milestone (ADM) meeting. Consistent with USACE policy in Planning Bulletin PB 2017-01, there is a certain level of uncertainty expected in the size and make-up of the TSP, and other plans identified from the suite of alternatives analyzed in this initial phase, including the National Economic Development (NED) Plan, or a variant preferred by the Non-Federal Sponsor (the Locally Preferred Plan). As such, the final size of the measures (width, length etc.), and inclusion or exclusion of some of them in the TSP presented in this Draft Mitigation Plan may change in the next planning phase. These changes can affect the reef impacted.

Because of the conservative nature of economic and engineering assumptions used during the initial planning of the TSP, it is anticipated that the sizes of measures will be refined to smaller footprints. The large majority of reef impacts would occur along the margins of the HSC within Galveston Bay, because that is where the most extensive, contiguous reef is mapped. The proposed HSC channel widening through the Bay would result in the majority of TSP impacts, and a range of revised channel widths from 650 feet to 820 feet has been conservatively proposed for further analysis and refinement in the post-ADM planning phase. Sufficient width to realize the economic benefits necessary to justify the plan depends on having enough width for safe two-way traffic meeting of design vessels. This is to be determined by ship simulation under a variety of sailing conditions to be conducted with participation from, and coordination with the Houston Pilots Association (HPA) in the next planning phase. The 650 feet to 820 feet range was determined using preliminary navigation engineering assumptions in consideration of HPA input during several meetings in the initial planning phase. A wider 900-foot width for the Bay widening was eliminated due to economics, cost, impacts, and because it was not anticipated to be required for adequate two-way navigation. The upper limit of 820 feet was assumed considering HPA input and experience, and a width narrower than this could result from the simulations, which would reduce reef impacts. The Bay widening is also divided lengthwise into the 3 straight segments of the existing HSC alignment, and one of those segments may not be justified for widening, or may be justified only to a narrower width than other segments, following refined economic analysis and ship simulation. This would also reduce reef impacts.

The need to replace the existing shallow draft barge lanes directly adjacent to the main channel of the HSC and shift them outward of the revised channel also accounts for a majority of potential reef impact. The Non-Federal Sponsor (NFS), the Port of Houston Authority (PHA) is coordinating with the shallow draft waterways users groups, to investigate whether the full current width is needed in the replacement lanes, or whether the lanes can share part of their footprint with the revised deeper HSC main channel to provide adequate barge navigation alongside the deep draft ship navigation. If they can share footprint, replacement barge lanes would reduce the overall width needed, and reduce reef impacts.

Reef mapping is not available above Morgans Point at the head of the Bay to determine potential reef impacts of measures upstream of Galveston Bay. However, adequate salinity and unmaintained, shallow depth needed to support reef growth is limited in the areas of the measures comprising the TSP above Morgans Point. Most of these measures are in portions of the existing HSC, turning basins, or adjacent to berths where waters are deepened and periodically maintained by dredging. Therefore, the potential for reef acreage is small compared to the potential impacts in the Bay. The limited areas with potential to contain reef have been identified for post-ADM surveillance to determine the presence or potential to contain reef through probings, sidescan sonar, or other exploratory means. Also, only the Powell et al. historical reef mapping (circa 1991) was available to determine impacts below MidBay Placement Area (PA). Newer sidescan sonar data would be acquired either during the post-ADM planning phase or during Preconstruction Engineering Design (PED) to determine the final impact and mitigation amounts. However, the majority of the reef coverage in Powell mapping along the HSC below MidBay PA is already solid where widening is proposed. Therefore, impacts would not be anticipated to increase from that indicated in the historical mapping.

Because of the preliminary nature of the planning to identify the TSP at this initial phase and planning policy requiring detailed analysis post-ADM, the specific dredged material management plan (DMMP) to provide for the placement of dredged material during construction (“new work”) and for long term periodic incremental maintenance of the channel improvements has not yet been developed, but will be accomplished during the post-ADM phase. However, reef mapping and surveillance would be used to site any new PA features needed for the TSP to avoid reef. Every attempt has been made to identify the maximum potential footprint of the TSP and its associated maximum reef impacts. It is anticipated that the aforementioned potential refinement to HSC Bay widening width and length would reduce impacts more than any increase from identification of reef above Morgans Point post-ADM. The proposed mitigation methods presented in this plan are not expected to be affected by these changes in impact acreage.

The USACE Civil Works CECW-PC Memorandum for *Implementation Guidance for Section 2036(a) of the Water Resources Development Act of 2007 (WRDA 07) - Mitigation for Fish and Wildlife and Wetlands Losses,* dated 31 August 2009, reiterates mitigation requirements for any report being submitted to Congress for approval, but also adds the requirement for mitigation plans to comply with the mitigation standards and policies of the USACE Regulatory Program including specific mitigation plan components. The memo is applicable to Civil Works water resources projects that require specific authorization. The content and structure of this Draft Mitigation Plan are being developed to meet the requirements for Regulatory Program compensatory mitigation plans in 33 CFR 332.4(c).

As discussed in Section 3 below, mitigation site planning and selection is at a preliminary stage for the reasons discussed therein. Therefore, the functional habitat modeling for this Draft Mitigation Plan has been conducted to identify the range of potential mitigation amounts associated with the varying habitat quality (driven by the salinity regime) among the sites to aid the mitigation planning process in the next phase. This Draft Mitigation Plan will be updated at the end of the post-ADM planning phase to revise the impact and mitigation amounts with changes driven by the project refinement and more detailed mitigation site planning.

2.0 OBJECTIVES

The primary objective of the mitigation project is to replace the significant net losses of Average Annual Habitat Units (AAHUs) of oyster reef habitat that would be removed during modifications made to the HSC to implement the TSP through restoration of oyster habitat at one or more of the sites identified in Galveston Bay, shown in **Figure 1**. Specifically, the mitigation plan proposes to provide the sufficient area of elevated relief and hard substrate surface for oyster attachment to compensate for the direct impacts associated with dredging the TSP. The restoration would replace the existing oyster habitat in Galveston Bay by providing the needed acres of hard surface area available for natural recruitment of oyster larvae. Restoration would take place at one or more of several sites impacted by Hurricane Ike-induced sedimentation in 2008 that were identified in the initial phase of planning for the TSP. Texas Parks and Wildlife Department (TWPD) has estimated that more than 50% of the reef in Galveston Bay was impacted by hurricane-induced sedimentation, and the Bay's oyster reef is a vital component of the commercial fishery of the State and Gulf Coast region. The restoration would also replace the oyster reef that contributes important ecological benefits to Galveston Bay, including provision of aquatic habitat structure for several fish and invertebrate species, improvement of water quality and clarity, as well as general re-establishment of essential fish and invertebrate habitat. The potential mitigation sites are shown in **Figure 1**.

3.0 SITE SELECTION CRITERIA

At this preliminary phase of planning, potential mitigation sites in Galveston Bay have been identified in consultation with the local resource agencies including Texas Parks and Wildlife Department (TWPD), National Marine Fisheries Service (NMFS), U.S. Fish and Wildlife Service (USFWS), Texas General Land Office (TGLO), Natural Resource Conservation Service (NRCS), U.S. Environmental Protection Agency (EPA), Texas Water Development Board (TWDB) and others. Primary potential site identification has focused on sites targeted by TPWD for reef restoration as part of their ongoing effort to restore areas of previous reef impacted by Hurricane Ike in 2008. The proposed mitigation method discussed in Section xx involves beneficially using project-dredged new work material to construct part of the topographical relief needed to restore reef. As such, more detailed engineering analysis during the post-ADM phase to optimize and phase the new work dredging and placement may factor into specific site selection. Also, more site-specific geotechnical information to assess bottom foundation conditions for placement and reef building may be collected in the next planning phase that could inform site selection. Therefore, more detailed mitigation site planning will take place post-ADM to narrow down the most optimal sites considering salinity, dredging, and foundation factors as well as further resource agency input on the desired part of the Bay to restore.

Some of the candidate sites (Trinity and Fishers Reef, Dollar Reef, and San Leon Reef) were selected based on indication that they were impacted by sedimentation according to post-Hurricane Ike TPWD side-scan sonar data and sub-bottom profiling data collected by Texas A&M University at Galveston. The sub-bottom data indicated these reefs were silted over by 6 or more inches of sediment, and would be conducive to restoration by cultch placement. Another candidate site just north and south of the BSC seeks to expand on the smaller existing local reef complexes there. The candidate site footprints are in waters variously restricted or conditionally approved for shellfish harvesting by the Texas Department of State Health Services (TDSHS). This means the areas are closed to commercial harvesting for direct marketing (restricted) or subject to approval status changes based upon meteorological or hydrological (e.g. salinity) conditions. The majority of reef that would be impacted by the TSP are similarly in restricted or conditionally approved waters.

Following Hurricane Ike, the TPWD side-scan sonar surveys found that as much as 60 percent of the reefs in Galveston Bay were covered by hurricane-induced sedimentation eliminating or substantially reducing their function. This triggered an ongoing restoration effort by TPWD to reverse these losses. Because the candidate sites are in Galveston Bay, the mitigation would occur in the same bay system that the impacts would occur in, and where restoration efforts have been planned and targeted by the resource agency with primary responsibility for oyster reef conservation. Direct on-site mitigation is not applicable in this situation as replacement reef cannot be appropriately located in the deepened navigation channel of the TSP. The restoration relies on natural oyster larvae recruitment and growth, and would be self-sustaining. This method has been successfully used on past similar restoration projects in Galveston Bay and around the nation. Monitoring of a similar restoration at Fisher’s Reef, one of the candidate sites, indicated successful recruitment and sustained growth, even after two years of historically high freshwater inflows into the Bay, and accompanying depressed salinity, in 2015 and 2016.

The sites are located in different salinity regimes that influence their relative quality for restoring reef when assessed by oyster habitat models. **Figure 1** displays the Habitat Suitability Index (HSI) for baseline conditions at each site measured by the habitat model selected for determining functional impacts, which is discussed in Section 6, assuming the same 100% restored cultch density. As shown, the highest relative scores occur lower in the Bay, and are a product of the optimal average, monthly and spawning season salinities. The USACE’s Engineering Research and Development Center (ERDC) is preparing a hydrodynamic model of Galveston Bay that will be used to assess the hydrodynamic impacts of the TSP, including salinity. The results of this modeling will also be considered in site selection during the next planning phases.

Figure 1 – Candidate Oyster Reef Mitigation Sites

4.0 SITE PROTECTION INSTRUMENTS

The candidate sites are located within Galveston Bay, for which, in general, the submerged land is State-owned and managed by the Texas General Land Office (TxGLO). Natural resource use or impact is subject to regulation by various governmental agencies including but not limited to TPWD, USACE, NMFS, and the EPA. In addition, natural oyster reefs are public resources managed by TPWD, and subject to compensation for losses under the Restitution and Restoration Rule, Chapter 69 of Title 31 of the Texas Administrative Code (TAC) to seek restoration of fish, wildlife and habitat loss occurring as a result of human activities, pursuant to enforcement powers in the Parks and Wildlife Code and Water Code. Any activity impacting the resources regulated by those agencies within the proposed mitigation area would be regulated by these governmental agencies. This would include development or fill of the Waters of the U.S., and oyster reefs that would be present or restored there. Additionally, once the appropriate interest is acquired for the selected site(s) for restoration, the restored reef would become part of the Federal Civil Works project, subject to regulation under Section 408 of Title 33 of the U.S. Code for any modifications to a Federal project in navigable waters.

Because the reef being impacted will include publicly available reef that is currently commercially harvestable, the restored reef will have to consider eventual harvesting access to the restored reef to replace the resources lost to commercial harvesting from TSP impacts. This coordination and eventual access will be determined in coordination the resource agencies, the State and Federal agencies charged with managing fishery resources

5.0 BASELINE INFORMATION AND IMPACTS

Galveston Bay is characterized as a relatively large shallow bay with an extensive interconnected system of deeper navigational ship channels. With the exception of ship navigation channels and the Mid Bay constriction caused by Redfish Bar, both natural and anthropogenic oyster reefs constitute the largest physiographic feature in Galveston Bay. Remaining portions are comprised of sand, mud, silt and clay particles, and shell, with little bottom relief. Only very small portions of the Bay contain any sea grasses, limited to the West Bay and Smith's Point area of the Bay, which excludes the area impacted by the TSP and the candidate mitigation sites. The project area in the vicinity of the TSP within the Bay, and the candidate mitigation sites, are typical of Galveston Bay habitat.

5.1 Baseline Benthic Habitat Characterization and Mapping

The baseline condition of the benthic habitat within the TSP footprint that would be impacted was determined primarily by two reef mapping datasets, briefly described below. These mapping datasets relied primarily on sonar which is a robust method for detecting and characterizing the hard and soft nature of bay bottom and distinguishing oyster reef from soft mud bottom, the two prevalent conditions in Galveston Bay. As discussed at the beginning of this section, sea grasses in the Bay are limited to the West Bay and Smith's Point area of the Bay and therefore are not targeted for characterization in this Federal study or mitigation plan. The mapping datasets used were the following:

1. TPWD Post-Hurricane Ike Survey– Mapping provided to USACE Galveston District, produced from post-Ike damage assessment side-scan sonar surveys collected from 2010-2012, with coverage of Galveston Bay west of Atkinson Island, from approximately Morgans Point down to just south of MidBay PA. This covers the TSP footprint from MidBay PA to Morgans Point

2. Powell Historical Mapping (Powell et al. 1997) – Mapping conducted by Texas A&M University (TAMU) for the Galveston Bay National Estuary Program (GBNEP). Produced from sonar surveys collected in 1991, with coverage of central Galveston Bay, West Galveston Bay, portions of Trinity Bay, and most of East Bay. This was used to cover the TSP footprint below MidBay PA to the study limit at Bolivar Roads.

Figures 3 through **6** shows the mapped reef in the study area. The TPWD survey mapping used newer side-scan sonar techniques and data processing, and more accurate positioning than the Powell mapping, and will therefore have higher resolution and detail for the reef extent map. The extent mapped by the TPWD survey north of the BSC and west of the HSC had a high degree of visual agreement with mapping performed for the PHA's BSC Improvements Project (Department of the Army permit SWG-2011-1183) in the same part of the Bay. The PHA permit surveys were conducted in 2011 by side-scan sonar surveys ground truthed by aquatic science divers, with mapping produced by similar raster analysis techniques. This agreement helps validate the accuracy and confidence in the mapping used. The Powell mapping relied on older sonar techniques and earlier, less accurate Global Positioning Systems (GPS), but did have ground truthing where equivocal reef signatures were encountered. Nevertheless, the Powell mapping used for impacts below MidBay PA is conservative and likely accurate. Below MidBay PA, the TSP impacts occur exclusively adjacent to the HSC. Except for a quarter of the length of this part of the channel with reef mapped, the Powell mapping already shows a high percent coverage of the area along the channel margin. Given the similarly high percent coverage exhibited in the newer TPWD mapping along the HSC, the same conditions (salinity, substrate, current etc.) leading to this growth density along the HSC at MidBay PA and above, would be expected to be present along the HSC below, up to the natural terminus of reef in the Bay at southern extent of Redfish Reef.

As discussed in Section 1, reef mapping is not available above Morgans Point to determine potential reef impacts of measures upstream of Galveston Bay. However, conditions needed to support reef growth is limited and efforts to identify the few areas with potential for reef is discussed in the next subsection.

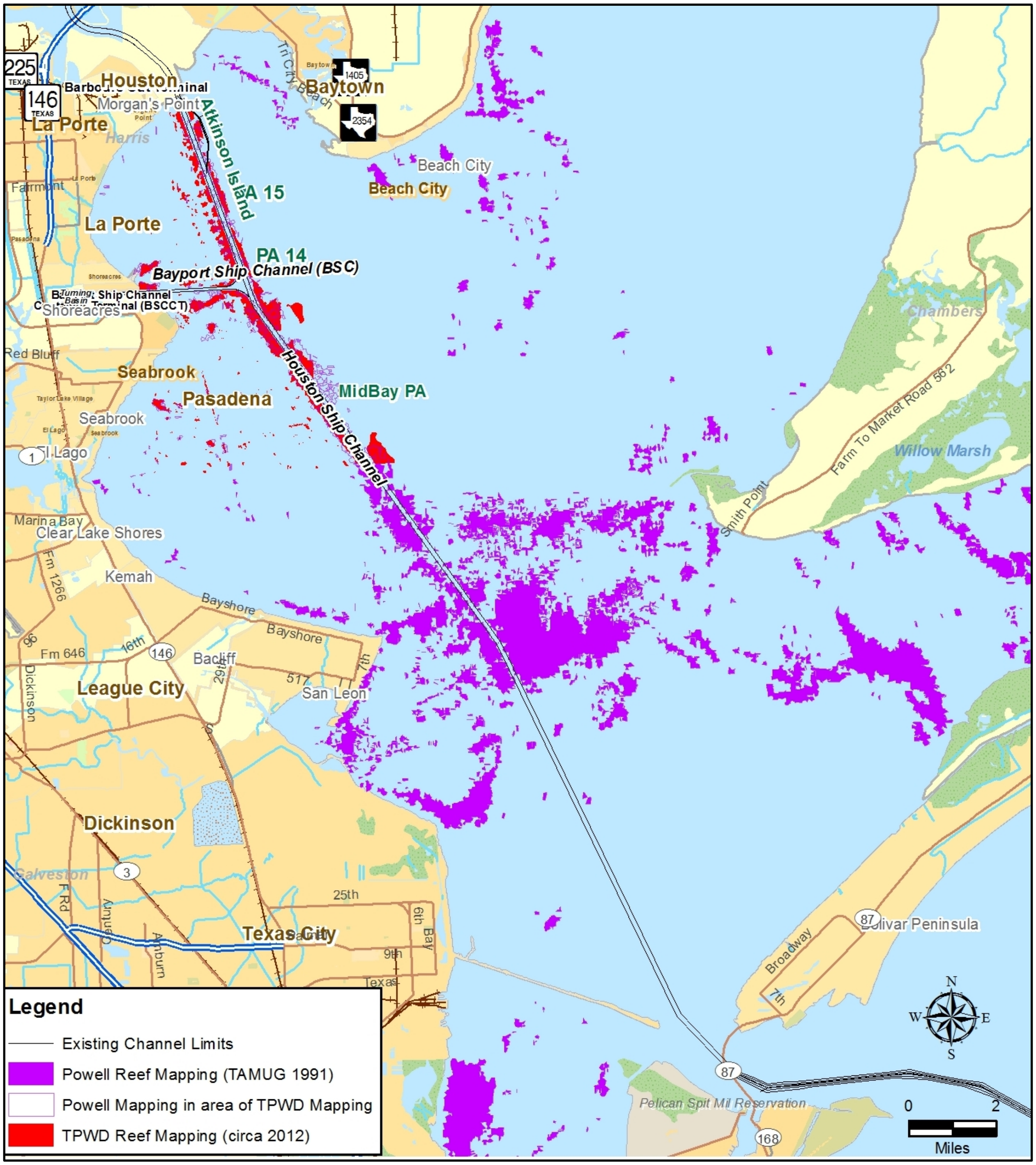

Figure 2 – Mapped Reef in the Study Area

5.2 Reef Potential Above Morgans Point

Because reef mapping is not available above Morgans Point to determine potential reef impacts of measures upstream of Galveston Bay, various information that would indicate conditions conducive (or not) to reef development were reviewed to identify areas in the TSP footprint that would have the potential to support growth.

Salinity

Though oysters can survive in salinities from 5 to 40 parts per thousand [ppt] (Cake, 1983), they grow and spawn most successfully when salinity is between 10 and 30 ppt, and dissolved oxygen is greater than 5 ppm (NRCS, 2011, Volety et al, 2009, Cake, 1983, Butler, 1954). Below prolonged salinities of 5 ppt, oysters will die of osmotic stress (Cake 1983). Data from the Texas Commission (TCEQ) Surface Water Quality Monitoring (SWQM) Program, and from the TWDB's Bays and Estuaries monitoring program were examined. Data from the TCEQ SWQM for stations along the HSC was obtained and analyzed within a database and Geographic Information System (GIS). The TCEQ data contains many years' worth of grab samples that typically reflect monthly sampling at many locations throughout the Bay and upstream along the HSC. The TWDB program operates continuously monitoring data sondes; however, this only covers 10 locations throughout the Bay, and not upstream of Morgans Point. To address concerns that the TCEQ monthly grab sample would not capture the variability of salinity that occurs with tidal cycling, short freshwater inflow events, and other causes, data were compared between TCEQ and TWDB datasets at common stations with similar periods of record. This is shown in Table 1 below. As shown, the difference in average salinity is within 1.5 ppt. Therefore, TCEQ salinity data upstream of Morgans Point was deemed useful for assessing average and prevailing conditions for supporting reef growth for the purposes of prioritizing surveys in the next planning phase.

Table 1: Comparison of TCEQ and TWDB Salinity at Common Locations

	TCEQ			TWDB		
Location	**Station**	**Avg. Salinity (ppt)**	**Year Range of Data**	**Station**	**[1]Avg. Salinity (ppt)**	**Year Range of Data**
Redfish Reef	13364	16.9	1980-2016	MIDG	18.1	2001-2016
Upper Bay near Seabrook	17091	12.8	1996-2003	RED	11.9	1990-1999
Fred Hartmann Bridge	11254	13.2	1999-2015	BAYT	12.5	2001-2016

1. TWDB data was actually provided in practical salinity units (PSU), but the numerical difference between ppt and PSU is negligible and ppt is shown for consistency with the rest of the document

Of 35 stations between Morgans Point and the upstream study limit at the Main Turning Basin, key stations were selected along the HSC to observe the expected downward average salinity trend moving upstream. Only stations with long periods of records and greater than 100 samples were considered. Data were averaged by depth and month to observe seasonal conditions related to the high inflow (i.e. spring) and spawning seasons. Data at numerous stations were reviewed and observed to be reflecting a decreasing average salinity across months moving upstream. It was expected that the lower reaches of the HSC above Morgans Point would have sufficient salinity, as reef growth on the shallow bottom was observed in side-scan sonar data and low tide observations in the shallow bay south of Alexander Island for a recent proposed liquid natural gas terminal project (Judith, personal communication 2016). Therefore stations above there were focused on. Table 2 summarizes the monthly salinities at the key stations, ordered from downstream to upstream, left to right.

Table 2: Average Monthly Salinity at Key Locations Upstream of Morgans Point

	Average Salinity (ppt) at Indicated Station			
	HSC at Battleship	HSC at Greens Bayou	HSC at Vince Bayou	HSC at Main Turning Basin
Month	11264	11271	11299	11292
Jan	11.7	9.8	5.2	6.6
Feb	11.7	9.8	7.1	6.8
Mar	8.5	8.9	7.5	5.2
Apr	8.2	6.4	3.9	4.0
May	8.4	5.9	4.2	3.7
Jun	8.5	5.9	8.9	3.7
Jul	10.2	9.0	5.3	5.2
Aug	12.4	10.2	7.6	6.4
Sep	13.6	11.0	12.1	6.2
Oct	13.7	11.4	8.0	7.6
Nov	13.0	11.1	5.1	6.5
Dec	13.7	12.0	4.3	7.6

Typically in Galveston Bay, there are two major spawning/spat set peak periods in the year: the greatest peak from April to June, and a smaller one approximately around August. As seen, the HSC salinity at the Battleship, while not at the optimal range at 10 ppt and above during both spat set periods, it approaches optimal during the first peak, is in the preferred range during the second August peak, and the average values are well above 5 ppt. For salinity near Greens Bayou, the values are lower during the first peak and approach but are above 5 ppt; however, they are in the optimal range during the second August peak. Once at Vince Bayou however, the HSC average salinity is below the lethal level of 5 ppt for most of the first peak spawning months, and decrease almost to 5 ppt in several later months. This is also true at the upmost station at the Main Turning Basin. With an average below lethal levels for 2 or more months, this salinity would cause mortality, especially during the key spawning period.

Considering this data, HSC salinity above Vince Bayou would be suspected to be too fresh to sustain any appreciable reef growth. No reef is expected above Vince Bayou. Between Greens Bayou and Vince Bayou, the average salinity, although not optimal during peak spawning, it is not lethal. The salinity condition makes the probability of developing reef growth low. Between the Battleship and Greens Bayou, HSC salinity during peak spawning moves away further away from lethal values, and although not optimal, approaches the preferred range of 10 ppt. The salinity condition increases the likelihood of developing some reef growth, and thus is qualitatively assigned a medium probability with respect to salinity. Below the Battleship, salinity would be expected to reach the preferred range above 10 ppt during the first and second peak spawning periods, and therefore the probability for reef development, given all the other needed factors, would be higher. In summary, the HSC salinity condition for reef growth above Morgans Point can be summarized as follows:

- Morgans Point to the Battleship – higher probability for growth
- Battleship to Greens Bayou – medium probability for growth

- Greens Bayou to Vince Bayou – low probability for growth
- Vince Bayou to Main Turning Basin – too fresh; growth not expected

Depth and Disturbance

Besides salinity, depth and disturbance factor into the likelihood for reef development. The American oyster has been documented to occur as deep as anywhere between 40 feet and 100 feet (Cake 1983, SCDNR 2015), but are known to thrive in depths less than 15 feet (SCDNR 2015, NOAA Fisheries Eastern Oyster Biological Review Team 2007). Most reef along the Gulf Coast occurs at 10 feet or less of depth with a preferred depth of approximately 13 feet or less (Kilgen and Dugas 1989, NOAA Fisheries Eastern Oyster Biological Review Team 2007).

However, 2011 side-scan imagery for reef surveillance around the BSC to 3 miles north along the HSC in support of the PHA's BSC Improvements and the HSC Project Deficiency Report (PDR) projects showed signature indicative of continuous reef at locations on the BSC and HSC side slopes. This imagery indicates reef signature on side slopes that would be at depths between 15 and 20 feet, and in the existing HSC barge lane bottom that would be at approximately 12 feet of depth upon reviewing NFS project and Galveston District hydrographic data. In isolated cases, the imagery along the HSC indicated signature in depths between 30-35 feet, but prevailingly reef appears in side slopes at less than 20 feet, and in no cases appears in navigation channel bottoms. This is mainly due to the periodic maintenance dredging of the channels that focuses on the deepest parts of the channel, including the bottom.

Other factors such as local dissolved oxygen (DO) and phytoplankton (oyster's food source) distribution in deeper water could limit growth deeper within the navigation channels. The presence of reef development from the 20-foot depth contour and out towards shallower depths along the HSC is consistent with observations of reef habitat extent along the channel margins contained in the Fish and Wildlife Coordination Act Report (FWCAR) for the 1995 Houston and Galveston Navigation Channels (HGNC) Limited Reevaluation Report [LRR] (Appendix E, USACE 1995). The FWCAR specifically recognized the prime channel-side habitat as occurring from the 20-foot depth and outward of the channel. This clear depth breakpoint is also observed in the recent TPWD reef mapping data discussed in Section 5.1.

Using the 20-foot depth as the practical limit for supporting reef development, the most current National Oceanic and Atmospheric Administration (NOAA) bathymetric charts, 2015-2016 aerial imagery, and geospatial footprints for the TSP measures were used to assess which measures below Vince Bayou were located in sufficiently shallow and undisturbed bathymetry to support growth. Most of the measures are in portions of the existing HSC, turning basins, or adjacent to berths where waters are deepened and periodically maintained by dredging. Besides the 20-foot contour, the presence of existing berths or deepened waters to access them for both deep and shallow draft vessels were also considered as areas of disturbance that would not support growth, due to the periodic disturbance from maintenance dredging. Areas within the TSP measure footprints with less than 20 feet of depth and no sign of active vessel berthing were identified as areas that could potentially support growth. These areas were flagged for post-ADM surveillance to determine the presence or potential to contain reef through probings, sidescan sonar, or other exploratory means. The acreage of these areas was roughly estimated for survey planning purposes and not to infer that all of this area could contain reef or that lower priority areas would not receive some level of survey to verify absence. Table 3 summarizes the measures with sufficient salinity and shallow enough bathymetry. The scope, extent, and methods to further detail all areas to be surveyed will be coordinated with the resource agencies in the next planning phase. Overall, the potential reef acreage that could possibly exist is small compared to the potential impacts in the Bay.

Table 3: TSP Measures above Morgans Point Identified with Higher Potential for Reef

Measure	Significant areas <20' Bathymetry	Existing Docks? Y/N	Acres of potential areas	Higher interest area?	Oyster Salinity Quality*
CW3_BSC	Y	N	3.6	N	Higher
BETB3_BCCFlare	Y	N	8.1	Y	Higher
CW1_820	Y	N	24.5	N	Higher
CW1_HOG	Y	N	17.0	N	Higher
BE1_153+06	Y	N	17.2	N	Higher
BE1_246+54	Y	N	8.3	N	Higher
MM1_520+00	Y	N	40.7	Y	Medium
CW1_SJM_BB	Y	N	17.4	N	Medium
CW4_BB_GB	Y	N	9.1	N	Medium
TB4_775+00	Y	N	30.0	Y	Medium
		Total	175.8		
	Total High Interest Areas	**Salinity Qual.**	**Acres**		
		High	8.1		
		Medium	70.7		

5.3 <u>Direct Impacts</u>

Oyster reef will be directly impacted by new work dredging necessary to construct the TSP, to widen and deepen channels, excavate turning and mooring basins, and ease bends and channel Flares. All of these features will be dredged to 40 or 45-foot depths over the majority of their footprint, with side slopes excavated at depths greater than the existing bay bottom. To estimate direct impacts, georeferenced Computer Aided Design and Drafting (CADD) files of the measures, and GIS versions of them, were used to clip the geospatial mapping data from the TPWD and Powell reef surveys. To account for the full potential extent of the dredging footprint, measure footprints were produced to account for anticipated side sloping beyond the full depth extent of the toe. Measure footprints were extended by taking the outer extent from the toe of the measure design feature, and projecting a 3H:1V side slope from the depth of the toe until it met existing bay bottom, using the available most current bathymetric data for the Bay and channels. For the Bay channel widening, the extent included replacement of the existing adjacent barge lanes to their full current width, outward of the revised main channel toe. As a result of the deep existing bathymetry below Redfish Reef, the actual dredging extent is less than the required replacement barge lane width for part of the length of this reach of the HSC.

The existing barge lanes had permanent mitigation for 54 acres of oyster reef when they were constructed in association with the 1995 HGNC LRR project. The permanent mitigation was performed to allow the USACE to maintain the depth in those barge lanes as necessary. The impacts from the barge lane additions are documented in 2003 *Final Environmental Assessment, Houston - Galveston Navigation Channels, Texas Project, Upper Bay Barge Lanes*. As discussed under the Depth and Disturbance subsection of Section 5.2, regrowth has occurred in the barge lanes. The mapping indicates approximately 208 acres of reef within the existing barge lanes, which exceeds the 54 acres originally mitigated. Likely, much of this represents new reef growth into the barge lane, while some of the extra acreage is also likely due to not having a need to actually dredge during planning and construction of the existing barge lanes due to adequate natural depth. As part of the resource agency coordination for this study, periodic subcommittee meetings focusing on oyster reef impact and mitigation have been conducted. Coordination during the January 19 and March 24, 2017 oyster subcommittee meetings confirmed the need to enumerate and mitigate for acreage in the existing barge lanes in excess of the 54 acres already mitigated. Widening of the main channel will extend into most or all of the existing barge lane footprint, and shifting of the barge lane outwards will impact the remainder of the existing barge lane footprint. The total impacts within the existing barge lane were calculated by subtracting the 54 acres previously mitigated from the total mapped reef acreage.

Currently, two NFS and Federal projects to modify the BSC and the HSC near the BSC are in the stages of completion or already planned and let, that had reef impacts and mitigation that had to be accounted for in enumerating reef impacts of the HSC-ECIP. The PHA's BSC Improvements Project had impacts along the northern margin of the BSC from the 100-foot widening, and the USACE HSR PDR project (now being executed as part of a Deferred Environmental Restoration project) had impacts at the margins of the BSC Flare and in the widener at the Station 28+605 bend. The HSC ECIP measures for further widening the BSC and the Flare will be outward of these projects' features. The GIS features for the outer extent of the BSC Improvements and PDR projects footprints used to determine reef impacts and mitigation for those projects were used as the inner boundaries of ECIP measures for reef impact determination purposes.

Table 4 shows the results of determining the direct impacts by TSP measure. **Figures 3** through **6** displays the reef impact footprint of the TSP. As indicated in the table results, oyster reef within the TSP footprint is found primarily in the Bay channel widening measures ("CW1" measures) accounting for approximately 95% of the impacts of the TSP.

Table 4: Direct Impacts of TSP Measures with Mapped Reef

MEASURE/INCREMENT		Acres	Previous HGNC Barge Lane Mitigation	Net Acres	AAHUS
CW1_BSC-BCC_820 [1]	BSC to BCC HSC Widening 820' wide channel	210	20	190	151.6
CW1_BSC-BCC_650 [1]	BSC to BCC HSC Widening 650' wide channel	171	20	151	121.2
CW1_Redfish-BSC_820 [1,3]	Redfish to BSC HSC Widening 820' wide channel	329	34	295	238.2
CW1_Redfish-BSC_650 [1,2]	Redfish to BSC HSC Widening 650' wide channel	305	34	271	218.2
CW1_BR-Redfish_820 [3]	Bolivar Roads to Redfish HSC Widening 650' wide channel	34	0	34	31.0
CW1_BR-Redfish_650 [2]	Bolivar Roads to Redfish HSC Widening 820' wide channel	28	0	28	25.5
BE1_028+605 [4]	Bend easing near Bayport	16	-	16	11.2
BE1_078+844 [4]	Bend easing near Redfish Reef	24	-	24	22.1
BE2_BSCFlare	Bayport Flare Easing	14	-	14	9.8
CW2_BSC	BSC Widening to 455' wide channel	5	-	5	3.5
TB2_BSC_RORO	Turning basin at Bayport Auto Terminal	0.1	-	0.1	0.1
Total Impact Acres (net) [5]	820' HSC Option			**538.4**	**434.0**
	650' HSC Option			**469.4**	**378.2**

1. Bend easings measures integrated with widening - impacts includes portion of BE1_028+605 impact
2. Bend easings measures integrated with widening - impacts includes portion of BE1_078+844 impact
3. Assumes mitigation at Bayport sites in RED salinity regime (i.e. lowest salinity quality site)
4. Bend easing in isolation (i.e. not paired with widening). Shown only for informational purposes
5. Totals summed not to double count individual bend easings shown for informational purposes

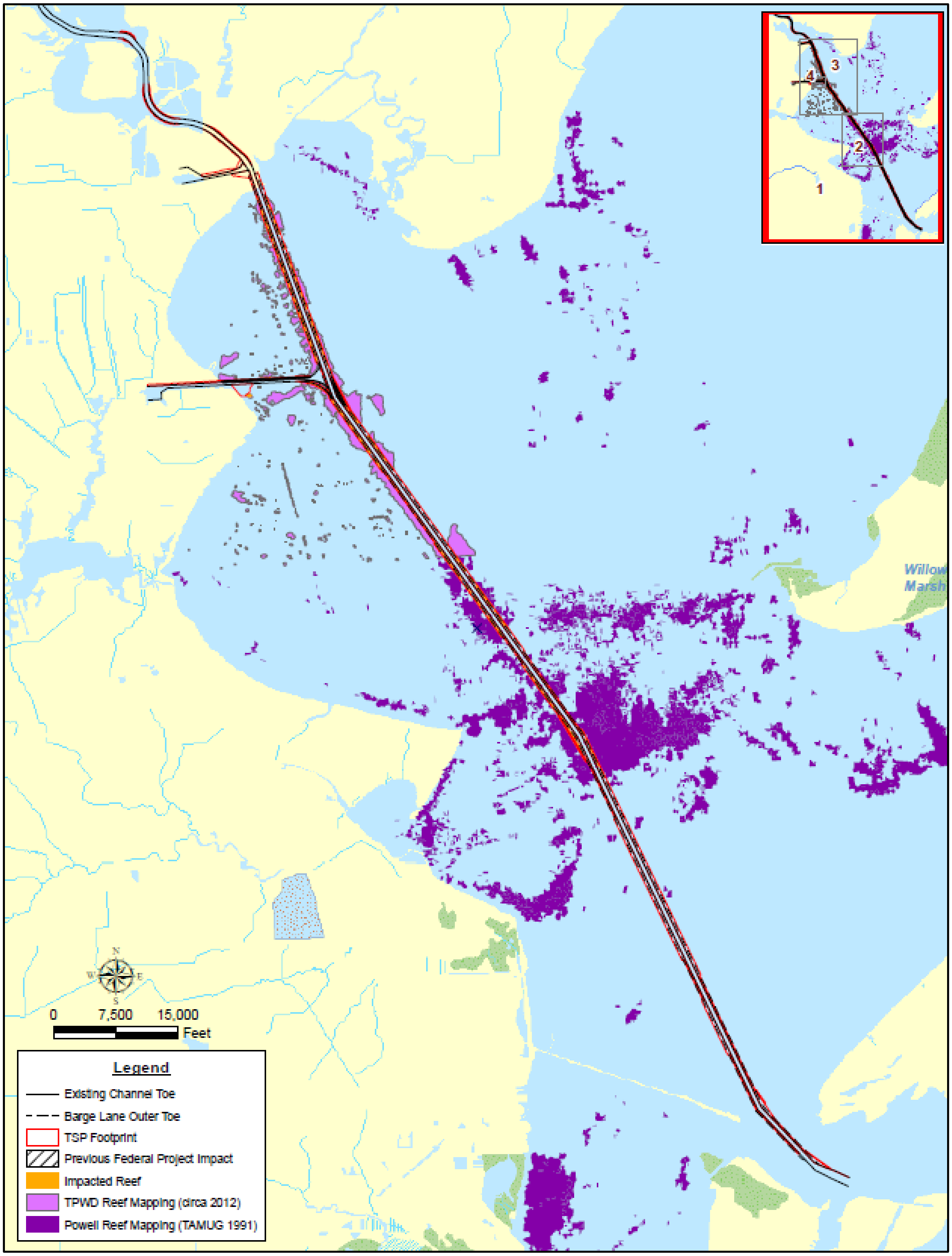

Figure 3 – Reef Impacts of the TSP – Main Panel

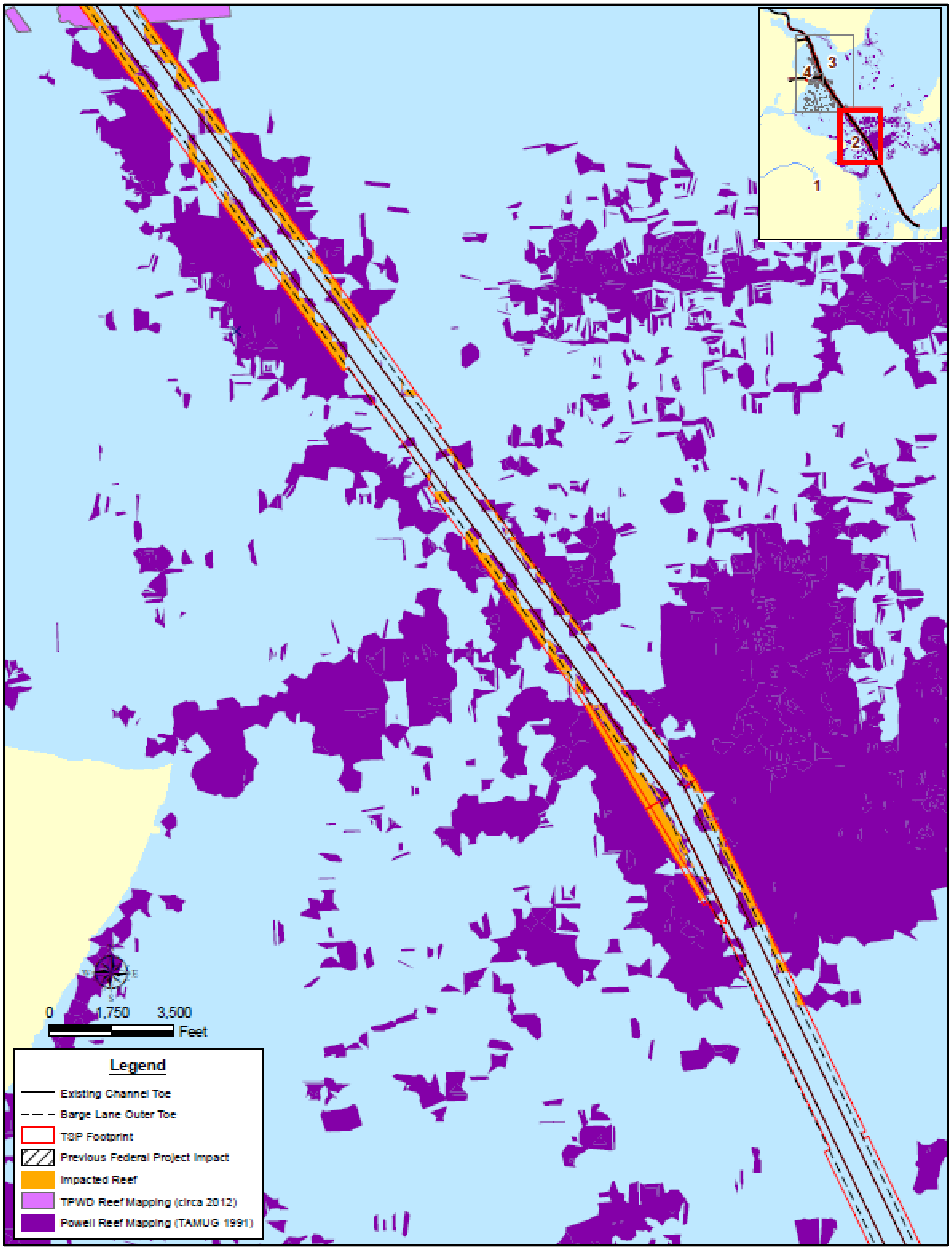

Figure 4 – Reef Impacts of the TSP – Lower Panel

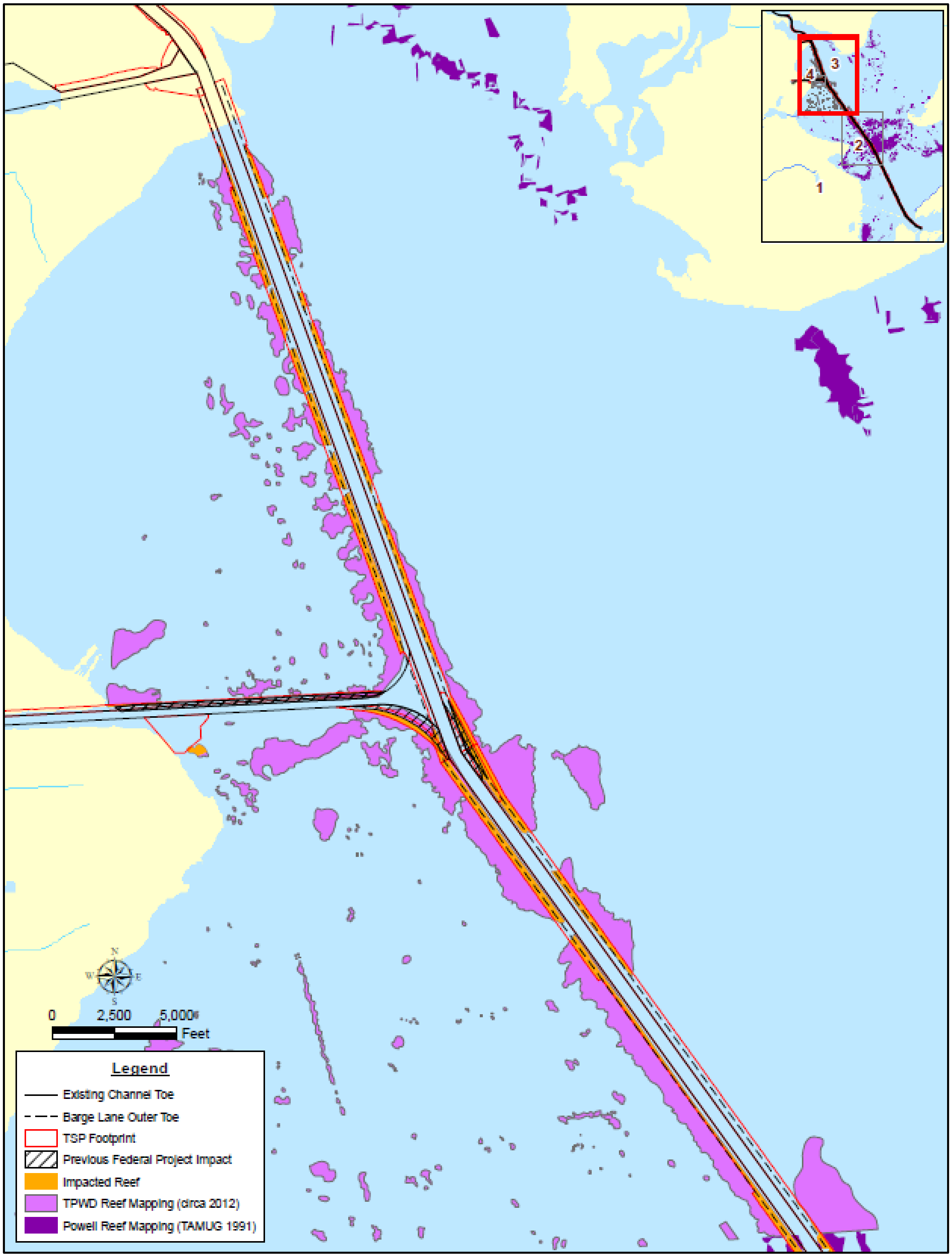

Figure 5– Reef Impacts of the TSP – Upper Panel

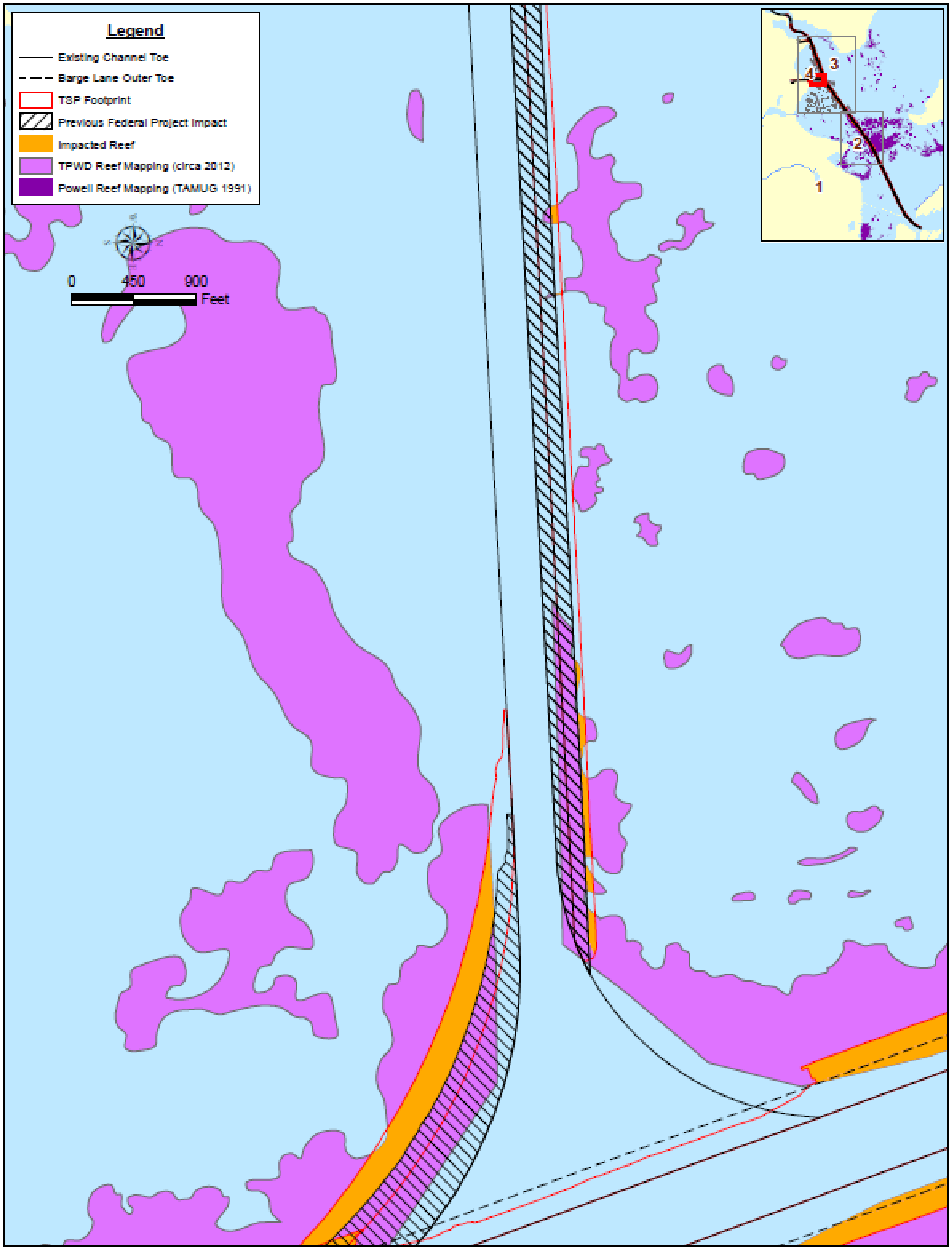

Figure 6 – Reef Impacts of the TSP – Bayport Panel

5.4 Indirect Impacts

Indirect impacts to oyster from turbidity from new work dredging required for construction of the TSP are expected to be minimal.

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 performed for the California Coastal Commission found that most studies indicated 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). Observations from this report included that sediment concentrations are greater at the bottom of the water column, and rapidly decrease with distance from the dredge. When properly operated, suspended concentration levels away from the cutterhead dissipate 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). One recent study measuring total suspended solids (TSS) concentrations during dredging of the Calcasieu Channel and Pass found no discernible differences in concentrations upstream, parallel to, and downstream of the dredge, indicating the dredging operation had no influence on TSS (USACE New Orleans District 2007). Results of earlier densitometry surveys from this study indicated silt suspension during maintenance dredging was confined to the deep parts of the channel.

The vast majority of suspended particles would settle close to the dredge, which greatly reduces the volume available for re-deposition at distances from the dredge. Therefore the amount of material that would be available for resettling on reef at distance would be expected to be small and only have minimal effects in terms of covering reef.

With the exception of a few smaller complexes, oyster reef in Upper Galveston Bay north of Redfish Reef, is almost exclusively located directly adjacent to the navigations channels of the HSC and BSC. This is clearly observed in the modern TPWD mapping and Powell historical reef mapping shown in **Figure 2**. This trend was corroborated in the side scan sonar data that was later ground truthed by divers for the BSC Improvements Project. The channel margins are covered with extensive reef. The HSC was widened and deepened under the HGNC LRR project between 1998 and 2008, and extensive HSC adjacent reef was still observed in the newer mapping and sonar data from the TPWD and the BSC Improvements Project. The FWCAR for the 1995 LRR described the channel margin as prime oyster producing area, from the 20-foot depth contour of the HSC to the edge of the old disposal berms developed from sidecast material during construction of the HSC earlier in the 20th century. This conclusion followed the findings of the GBNEP study which led to the historical Powell mapping (Powell at al. 1997). The study identified reef along the HSC was one of the 3 most noticeable areas of new accretion.

Considering the previous information discussed, and considering that these channels are periodically dredged for maintenance (which would involve higher percentages of unconsolidated fines), the new work dredging required for construction of the TSP and subsequent maintenance dredging would not be expected to result in reef losses due to turbidity effects. Only minimal impacts would occur, and pre- and post-construction monitoring for indirect turbidity impacts is not proposed for the new work dredging.

6.0 DETERMINATION OF CREDITS

In accordance with USACE planning policy, credit for mitigation was determined by using USACE-certified habitat models to determine functional losses from impacts and function 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 under the process mandated by this memo and was selected for use in this mitigation plan. This model is a modification of a 2012 suitability index model that follows the methodology in the USFWS habitat suitability indices (HSI) model for the Gulf of Mexico American Oyster (Cake 1983) Reefs in Galveston Bay are predominantly American oyster. The Swannack et al. model was used for the determination of HSI scores. OHSIM HSI scores were calculated using OHSIM indices formulas within the Habitat Evaluation and Assessment Tools (HEAT) software program developed by the ERDC Environmental Laboratory (Burks-Copes *et al.* 2012). The HEAT program provides an intuitive, flexible set of tools to quantify benefits and impacts of changing habitat communities, and ecosystem functions. The HEAT program allows entry of most any index model formulas, and calculates AAHUs under various with and without project scenarios and timelines. Through the use of HEAT, oyster HSI over time (e.g. AAHUs) was calculated based on the following four OHSIM variables:

- annual mean salinity (AS)
- minimum annual salinity (MAS)
- mean salinity during the spawning season (MSSS)
- percent of oyster cover (percent of Cultch)

These variables are used to calculate four oyster suitability indices (OSI) using formulas detailed in the model literature (Swannack *et al.* 2014). The resulting OSIs range from 0.0 to 1.0, with 0.0 denoting unsuitable habitat, while 1.0 represents optimal habitat. The four OSI are used in the following formula to obtain the Restoration Suitability Index (RSI) which is synonymous with the HSI:

$$RSI = (OSI_{AS} \times OSI_{MAS} \times OSI_{MSSS} \times OSI_{Cultch})^{\frac{1}{4}}$$

The HEAT program implements the concepts of impacts to habitats and the restoration of them, and the associated changes in habitat quality, through the use of different cover types to represent existing habitat, changed/degraded habitat, or restored habitat. These cover types have associated acreages and quality (e.g. HSI scores) that reflect the measured or assumed conditions of the model variables. Typically in a HEAT modeling exercise, the total acreage of habitat cover types is a constant, and individual degraded or restored cover types wax and wane according to the assumptions from impacts and restoration actions. For example, 100 acres of existing reef may change completely to 100 acres of degraded habitat devoid of reef at the year of impact, while at a mitigation site, 110 acres of a reefless cover type at the beginning (Year 1) becomes 110 acres of restored reef by Year 3. Because the three OHSIM salinity variables vary at different parts of the Bay and result in differing habitat qualities, cover types were defined according to the different salinity regimes. Also, a key assumption for the progression of the restored mitigation reef was adopted following consultation with the resource agencies during the initial oyster subcommittee meeting, explained following the bullets. The following were the general cover types defined to represent existing, impacted, and restored habitat, with a synopsis of key assumptions:

- Existing Reef (REEFMIDG, REEFRED, REEF BAYT) – Reef that would be impacted in the different salinity regimes represented by Mid-Galveston, Red, and Baytown station salinity data from the TWDB datasonde data described in Section 5.2 under Salinity.
    - Exists in the without-project condition through the 50-year period of analysis. Disappears in first year of the with-project (i.e. with dredging) condition
    - Values for the salinity variables were taken from the TWDB datasonde data
    - Acreages of mapped reef were broken into amounts for each salinity regime using GIS and station locations
    - Percent cultch coverage conservatively assumed to be 100%
- Degraded Habitat (CLAYNOREEF) – Bay bottom devoid of reef following the direct impacts of dredging, reflects a clay bottom with no oysters or hard substrate.
    - Appears in first year of the with-project (i.e. with dredging) condition in place of existing reef and exists for the rest of the 50-year period
    - Percent cultch coverage assumed to be 0%
    - Salinity regime does not matter since cultch index makes RSI zero anyway
- Pre-restoration Mitigation Site (MITMUD) – Bay bottom devoid of reef at a mitigation site before cultch is placed, indicative of a mud bottom with no hard substrate.
    - Exists in the without-mitigation project condition through the 50-year period of analysis. Disappears by the 3rd year of the with-mitigation project condition
    - Salinity regime does not matter since cultch index makes RSI zero anyway
    - Percent cultch coverage assumed to be 0%
- Post-restoration Mitigation Site (MITREEF)
    - Does not exist in the without-mitigation project condition through the 50-year period of analysis. Appears by the 3rd year of the with-mitigation project condition in place of MITMUD
    - Values for the salinity variables of the modeled mitigation sites were taken from the TWDB datasonde data. Two mitigation site scenarios were modeled, described three paragraphs below.

- Percent cultch coverage assumed to be 100%. Mitigation reef cultch would be placed at this density.

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 (MITREEF) appear in Year 3, to reflect the attainment of functional reef and the maximum relative score for the conditions being modeled.

The OHSIM formulas and OSI score curves were entered into HEAT. The existing reef acreages (shown in Table 4) and salinity variable values, as appropriate for the salinity regime for the various measures of the TSP, and the target year changes in cover type acreage described earlier, were also entered. HEAT was then run to calculate the change in AAHUs for existing reef being impacted, which is shown in Table 4. This defines the AAHUs that needed to be restored with mitigation. HEAT calculates the change in AAHUs through the full 50-year period, with net losses reflected as negative numbers.

Then, iteratively, an estimated acreage of mitigation reef was entered for the mitigation sites cover types, along with the target year changes in cover type acreage described earlier for mitigation cover types. The resulting positive AAHU changes were used to adjust the acreage until the AAHU loss from impacts were offset by the positive changes from mitigation reef acreages to result in a net AAHU change of zero. For this pre-TSP approval phase of planning, the following two mitigation site assumption scenarios were ran to provide a range of mitigation amounts that would be possible:

- Bayport site mitigation – This site provides the least optimal salinity according to the OHSIM model and would therefore result in identifying the most mitigation possible.

- San Leon or Dollar Reef sites mitigation – These sites provide the most optimal salinity according to the OHSIM model and would therefore result in identifying the least mitigation possible.

As discussed in the last paragraph of Section 1, a range of impacts and mitigation was identified because of the preliminary nature of the TSP. The specific mitigation sites will be determined in the next phase and habitat modeling re-conducted to recalculate the required mitigation amount. A summary of the range of mitigation amounts for the TSP by channel size option is shown in Table 5. This will be updated with the TSP refinement in the next planning phase.

Table 5: Mitigation Indicated by the OHSIM Model for the TSP

TSP Version	Impacts		Most Optimal Site (San Leon or Dollar Reef)			Least Optimal Site (Bayport)		
			Mitigation Required		Mitigation Ratio (mitigated/ impacted)	Mitigation Required		Mitigation Ratio (mitigated/ impacted)
	Acres (Net)	AAHUS	Acres	AAHUS		Acres	AAHUS	
820' Channel Option	538.4	434.0	486.6	434.0	0.904	631.9	434.0	1.17
650' Channel Option	469.4	378.2	427.0	378.2	0.910	550.7	378.2	1.17

7.0 PROPOSED MITIGATION METHOD AND MITIGATION WORK PLAN

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 will provide the hard substrate for natural recruitment and settlement of oysters during the spat set season. This beneficial use (BU) technique to restore oyster reef has been successfully used by the USACE and others in the Chesapeake Bay estuary and in New York/New Jersey Harbor. Several variations of this method have been used or proposed including use of contained dredged maintenance material vs dredged new work material, and elevation of relief to provide an intertidal bar vs subtidal reef. However, all have beneficially used dredged material to build relief capped by a thinner cultch layer. The previous mitigation technique used locally in Galveston Bay involved using rock or other hard substrate to build the base of the reef to provide relief off of bay bottom, and to provide the spat settlement cultch layer at the surface. This uses a lot of hard material for non-recruitment volume at significantly more cost than beneficially using dredged material. Using the dredged material to raise the bottom of the bay provides a means to beneficially use dredged material generated from the TSP, which helps fulfill the BU objective for this project, and reduces costs by using less rock material, helping to increase the navigation project net benefit.

7.1 Other Projects Implementing the Proposed Method

As mentioned, several projects have implemented or proposed this mitigation method in a variety of ways. However, two projects are most commensurate with the specific way this method is proposed to be implemented for the HSC ECIP, which is to use more robust or new work dredged material to build a stable mound or berm capped by a cultch veneer. The Slaughter Creek restoration project was a joint effort by NOAA, Maryland and the USACE whose construction was completed in June 1987 (Clarke *et al.* 1999). Approximately 14,000 cubic yards (CY) of dredged material consisting of 60 percent fine sand and 40 percent silt was deposited to build a 3-foot thick 2.1 acre mound capped by 2,256 cubic yards of oyster shell to provide an 8-inch thick cultch layer. The three year post construction monitoring of Slaughter Creek project showed that oyster spat recruitment and densities of juvenile oysters were above or equal to nearby natural oyster bars, and was deemed successful. The placement of shell over what was perceived to be soft material did not subside into the dredged material. Bathymetric surveys at one and two years post-construction demonstrated the dredged material mound with oyster veneer was still stable. Since Slaughter Creek reef's construction, Chesapeake Bay has experienced several hurricanes and tropical storms with varying surge effects in the bay, including Hurricane Isabel (2003), Tropical Storm Lee (2011), and Hurricane Sandy (2012) [Fincham 2010, Dennison *et al.* 2012]. The State of Maryland's annual reef survey of Chesapeake Bay still collects oysters for their survey at this site today (Smith 2014). It also appears on a recreational fishing website list of artificial reef coordinates (Mid Atlantic Fishing 2017). Despite the occurrence of several tropical events since its construction, the continued surveillance and use in recreational fishing indicate the reef still exists and is productive today.

Using cultch veneer over dredged material has also been approved on November 5, 2010 for oyster mitigation for the Matagorda Ship Channel Improvement Project (MSCIP) and EIS. The approved plan calls for creating approximately 163 acres of oyster reef over mercury-impacted bottom sediments within Lavaca Bay, Texas by hydraulically placing 1.4 million CY (MCY) of new work stiff clay material to construct 2-foot mound over the bottom sediments to provide a minimum of 1 feet of relief above surrounding bay bottom. This new work material would be capped with 3 inches of cultch material (crushed limestone or similar material) to create oyster reefs. The HSC ECIP would similarly use stiff new work clays to construct relief, and cap it with a cultch veneer.

7.2 Mitigation Work Plan

The following are elements of the mitigation work plan to implement the proposed mitigation method:

- Geographic boundaries of the project – The candidate mitigation sites and approximate boundaries are shown in **Figure 1**. The boundaries shown are nominal footprints that total approximately 194 acres. Mitigation will require consideration of additional acreage within the vicinity of these sites as needed to accommodate the final mitigation amount to be determined following the next planning phase. Site selection will also receipt of public and agency input during the agency and public review of the Draft EIS. Mitigation is proposed to occur at one or more of these sites, in the vicinity of these sites, or as determined following additional coordination with resource agencies and public following public agency review. Currently, between approximately 427 to 632 acres of mitigation are anticipated depending on the size increment of Bay widening justified and on the mitigation sites used, but will change with the refinement of the TSP in the next planning phase. The specific configuration and footprint of the mitigation sites will be determined during the next planning phase, and the PED phase, considering review of detailed local site condition information such as geotechnical information, presence and proximity of existing remnant reef, and consultation with resource agencies to determine the most desirable arrangement and location at or around these sites.
- Construction methods – The mitigation work plan proposes to add the necessary volume of clean, crushed limestone or other suitable hard substrate over the necessary volume of project-dredged new work materials to create the needed mitigation acreage. Stiff, new

work clays dredged from the construction of the TSP would be hydraulically placed to build the berm or mound to provide the needed relief.

- The specific final relief has not been determined, but would be at least 1 foot above the surrounding bay. Factors such as site-specific desirable elevation, available water depths, more detailed dredging planning such as desired material volumes, and geotechnical information on dredged materials would be considered to determine the target elevation above bay bottom. With the volume of new work material to be generated by TSP construction, having sufficient material to produce the target relief for the needed acreage will not be an issue.
- Dredged material would be hydraulically placed, and precautions and placement techniques would be used to prevent the dredged material from dispersing beyond the intended placement site and avoid impacting existing reef. Specific mitigation site planning would consider proposed control techniques and existing reef proximity. Such techniques could consider use of submerged diffusers, gravity downpipes (e.g. tremies or downspouts), baffles, or other implements that result in controlled dispersal. Proper sloping for stability will be determined for the side slope ratio of the mounds during PED.
- The cultch veneer would be clean crushed, limestone or concrete, or other suitable substrate as deemed acceptable by the TPWD. Both materials have been successfully used in Galveston Bay reef restoration including those by USACE, the NFS and TPWD. The cultch would most likely be barged in and then placed evenly over the dredged material. For planning purposes, a 6-inch thick cultch layer has been assumed in consideration of local reef restoration target relief for the recruitment layer that has been successfully implemented recently, including at Fisher's Reef for the NFS's BSC Improvements Project.

- Timing and sequence – The mitigation would be constructed concurrent or prior to the construction of the proposed channel modifications. There are portions of the TSP, such as widening in the lower Bay that would not impact reef and could allow mitigation construction prior to impacts. The timing for mitigation to occur concurrent with the construction and impacts was conservatively assumed in the habitat modeling described in Section 6. The final mitigation amount and ratio will be remodeled based on the selected mitigation sites and construction schedule, and mitigation will either occur concurrent or prior to construction. With the area and volume of material involved, it is anticipated the mitigation would be constructed in a phased approach in conjunction with the TSP construction. Seasonally, if possible, the mitigation construction would be timed to target completion before or during the spawning season to ensure recruitment of spat soon after the substrate is available. Spawning season is late spring to early fall in Galveston Bay. Ideally, completion would be timed before one of the two spat set peaks that typically occur in the Bay, the larger, first one being between April and June, and the second, smaller peak around August.
- Foundation – Proper analysis will be performed and measures taken to determine and provide vertical stability of the placed berm and cultch layer. Geotechnical studies and analysis during the post-ADM planning phase and PED of the final selected sites would be performed to position mitigation footprints at the selected site(s) to reduce risks of

settlement. Most of the candidate sites are areas of formerly exposed reef buried by Hurricane Ike-induced sedimentation. Experience during the BSC Improvements Project mitigation at Fisher's Reef, which was also former reef buried by Ike-induced sedimentation, indicates that settlement into soft surficial sediments was less than expected, possibly due to the underlying shell from the former reef.

- Other elements considered – Other mitigation work plan elements listed in 40 CFR 230.94(c)(7), such as source of water or methods to establish the desired plant community, are not applicable.

Construction details for the elements of the mitigation work plan will be developed during the PED phase of the mitigation project, as part of the development of plans and specifications for the procurement of services to construct the proposed mitigation. Final design dimensions and construction specifications will be shared and coordinated with TPWD, and other resource agencies, as requested.

8.0 MAINTENANCE PLAN

Once the cultch has been placed, no further maintenance of the site that is predictable would be required. The cultch should stay exposed for colonization by oyster larvae and other aquatic organisms. Post construction bathymetric surveys would confirm that the reef will be vertically stable. Periodic monitoring in Section 10 will confirm that substrate remains exposed. As discussed in Section 7, the mitigation method has been used in restoration with long term success. Also, 2 years of successful post-mitigation monitoring results for the NFS's Fisher's Reef mitigation in Galveston Bay with thicker cultch layers (>12") employed, and similarly restored over former reef, indicate long term settlement should not be an issue. The substrate will develop on its own into mature reef with market-size oysters expected in two to three years similar to that experienced with reef mitigation for the HGNC project. However, other unusual events, such as another major hurricane like Hurricane Ike could cover the area, as well as natural reefs. No specific long term maintenance for these unusual events is planned.

9.0 ECOLOGICAL PERFORMANCE STANDARDS

Pre-restoration and post-restoration side scan-sonar data would be collected and processed into ArcGIS data layers. This will determine the acres of reef habitat available for colonization. The purpose of pre-restoration side-scan sonar data is to determine the presence/absence of existing exposed reef within the mitigation site footprint, with the aim of confirming that existing reef is zero acres, since mitigation construction should avoid placing dredged material and cultch over existing reef. As a structural endpoint, the restored cultch acreage would be quantified from the post-restoration hard-bottom acreage indicated in the side-scan data, to determine the amount of hard bottom habitat restored that will be available for oyster recruitment.

10.0 MONITORING REQUIREMENTS

Monitoring of the restoration sites would be conducted pre- and post-restoration to assess the success of the mitigation. Criteria for restoration success would include one structural and one functional endpoint. The structural endpoint would be the number of hard-bottom acres restored. The functional endpoint will be a measure of the live oyster density or recruitment onto the cultch that will be determined in coordination with TPWD. The specific method and techniques will 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.

11.0 LONG-TERM MANAGEMENT PLAN

After the mitigation project is determined to be successful, management of the mitigation site area would be returned to the owners of the site and regulators of the bottom of Galveston Bay, which are the various governmental agencies including but not limited to TPWD. No specific long term management activities are planned. However, these reefs will be subject to the same regulations that govern Galveston Bay oyster reefs.

12.0 ADAPTIVE MANAGEMENT PLAN

Any time during the monitoring period, if the success of the mitigation plan appears not to be meeting the success criteria, the USACE would notify the TPWD and other resource agencies, so that the mitigation can be evaluated and measures pursued to address deficiencies of the mitigation. Discussions on meeting the success criteria would be included in each monitoring report. Corrective actions would depend on the assessed or probable cause of the failure and could include things like re-placing cultch if substrate has subsided or is otherwise not exposed, or seeding with oyster larvae if all other factors such as salinity and cultch were not at issue.

13.0 FINANCIAL ASSURANCES

The USACE is a U.S. federal agency under the Department of Defense and a major Army command made up of approximately 37,000 civilian and military personnel. The USACE is one of the world's largest public engineering, design, and construction management agencies. The Corps' missions are: 1) Planning, designing, building, and operating locks and dams; 2) Design and construction of flood protection systems; 3) Design and construction management of military facilities; and, 4) Environmental regulation and ecosystem restoration. This mission is required to be accomplished in a manner that 1) complies with all applicable Federal, State, and local environmental regulations, including those for mitigation, and 2) provides sufficient funds to cover the mitigation operational expenses and capital investments. USACE Civil Works project planning policy, including Engineer Regulation (ER) 1105-2-100, Planning Guidance Notebook (PGN), and the aforementioned USACE Civil Works CECW-PC Memorandum, explicitly require that all significant losses of significant resource from a proposed USACE project be mitigated. As a matter of policy and procedure, all Civil Works projects, or portions impacting resources requiring mitigation, would not get funded unless the mitigation is also funded. Therefore, projects would not be implemented without the required mitigation as part of the project. It is anticipated the mitigation funding source will be the same as that for the proposed project construction. It is anticipated that the project will be executed with funds appropriated by Congressional Approval of the President of the United States’ Budget proposed in a given fiscal year. The USACE has a long track record of successfully participating in and funding mitigation and ecosystem restoration (e.g. beneficial use) as part of its sponsored projects.

14.0 REPORTING

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.

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