Sabine Pass to Galveston Bay, Texas
Coastal Storm Risk Reduction and Ecosystem Restoration
Draft Integrated Feasibility Report and Environmental Impact Study

Draft Appendix C

Economic Analysis

September 2015

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1 COASTAL STORM RISK MANAGEMENT

1.1 PURPOSE

The purpose of this appendix is to describe the economic methodology, its associated assumptions, and the use of economic and engineering tools used to assess, evaluate, and ultimately conclude and recommend a plan for the Sabine Pass to Galveston Bay, Texas Coastal Storm Risk Management and Ecosystem Restoration Feasibility Study.

1.2 INITIAL SCREENING OF ALTERNATIVES

Prior to the Alternatives Milestone Meeting, development of an initial array of alternatives from a wide range of measures for three regions covering six counties along the Texas Gulf Coast that would address coastal storm risk management and ecosystem restoration. The initial study was scoped during a planning charrette in August 2012 to comply with SMART Planning guidelines. Following the first Alternatives Milestone Meeting (AMM) in July 2013, a determination was made that a study encompassing the three-region, six-county area could not be done within the constraints of SMART Planning. Options were developed in order to minimize risk as much as possible and while still adhering to the basic tenets of SMART Planning. The Galveston District developed an option for completing a study of low to moderate risk that would cost $4.4 million and would drop the Galveston region concentrating instead on the Brazoria and Sabine regions. The study also dropped any ecosystem restoration measures and would only analyze CSRM alternatives in Brazoria, Jefferson, and Orange Counties.

The initial array of alternatives can be found in Appendix B – Plan Formulation.

1.3 FINAL ARRAY OF ALTERNATIVES

The screening of the evaluation array along with the recommended study scope from the exemption resulted in the modification of a final array of alternative plans. The final array of alternative plans did not include Ecosystem Restoration (ER) measures because those are to be included in future interim feasibility studies, along with the Galveston region. Based on the successful Alternatives Milestone Meeting (AMM) that occurred on April 9, 2014, the final array of alternatives is shown in Table 1-1.

Table 1-1. Sabine Pass to Galveston Bay, TX - Final Array of Alternatives

Alternative Number	Alt Name / Description
No Action	No Action or Future Without Project (FWOP)
S5	Sabine Inland Barrier CSRM Focus (Neches Gate/Sabine Levees/Hurricane Flood Protection)

Alternative Number	Alt Name / Description
S11	Sabine Nonstructural Alternative/ Buyouts and Lone Star-type Conservation Plan
B2	Brazoria Coastal Barrier CSRM Focus (revised)
B5	Brazoria Nonstructural Alternative/ Buyouts and Lone Star-type Conservation Plan

An IPR was conducted on May 30, 2014, to discuss the results in the analysis supporting whether the Neches Gate should be dropped from further consideration. As a result of the decision to drop the Neches Gate and as means of clarifying the nomenclature for the final array, alternatives in the final array were renamed. The Sabine Inland Barrier Alternative has been split into two parts, one addressing the new levee system in Orange and Jefferson Counties, and the other addressing improvements to the existing Port Arthur hurricane flood protection (HFP). The Brazoria Coastal Barrier Coastal Storm Risk Management (CSRM) Focus has been renamed after its primary component – Freeport and Vicinity CSRM. Non-structural plans will be evaluated for both Brazoria and Sabine regions.

- Orange-Jefferson Coastal Storm Risk Management (CSRM)
- Freeport and Vicinity CSRM
- Port Arthur and Vicinity CSRM
- Brazoria and Sabine Non-Structural

1.4 REACH DETERMINATION

The determination of reaches for the initial array of alternatives was based on the original designation of the three regions with measures and the subsequent alternatives being assigned to the appropriate region. Following the approval of the exemption from SMART Planning and the successful concurrence of the final array of alternatives following the April 2014 AMM, reaches were developed for the areas according to the final array of alternatives. This was required since a different methodology would be employed for the optimization of any new proposed levees/floodwalls and for improvements to any of the existing hurricane flood protection systems (HFP). While the initial screening of alternatives used HEC-FIA with 1 % annual chance exceedance (ACE) depth grids in conjunction with HAZUS-MH data to determine without and with-project economic damages, the analysis for evaluating the final array would incorporate a risk-based analysis in compliance with ER-1105-2-101. The following describes the reaches that were established for evaluating the final array.

1.4.1 Orange-Jefferson CSRM

The initial configuration of new levees was based on alignments from the Orange County Flood Protection Planning Study (Orange Report), completed in 2012. Refinement of the alignments

was made in some areas to increase potential benefits, reduce costs, and reduce potential environmental impacts, and to protect critical infrastructure. Without-project storm surge values were used to optimize levee heights and further refinement of the alignment for identification of the National Economic Development (NED) Plan and TSP. As part of the identification of the NED and TSP, analysis was conducted to determine levee sections that are incrementally justified. Alternatives analysis was based on utilizing the without-project surge elevations and frequencies. Without-project storm surge and waves were based on previous work by FEMA and revised to current joint probability method – optimum sampling (JPM-OS) methods to the appropriate ACE values. Figure 1-1 displays the initial configuration to be evaluated for these new levees at Jefferson and Orange Counties following the exclusion of the Neches Gate from further consideration. The system was set up with three major components based on their location. The following lists the major features.

- Orange 1 – 3
- Jefferson Main
- Beaumont A – C

The Orange component runs along the north side of the Neches River and was divided into three sections; Orange 1 on the western end that primarily protects Rose City, Orange 2 which begins just east of Rose City and ends roughly halfway between Rose City and Bridge City, and Orange 3 which encompasses the remainder of the Orange County component. Orange 1 consists of approximately 27,000 linear feet (LF) of levee and 16,500 LF of floodwall (total of 8.2 miles). Orange 2 consists of approximately 34,600 LF of levee (6.6 miles), while Orange 3 consists of a combination of 113,600 LF of levee and 29,800 LF of floodwall (total of 27 miles).

The Jefferson Main component consists of approximately 41,700 LF of levee and 16,200 LF of floodwall (11 miles). Beaumont A is combination of 3,100 LF of levee and 200 LF of floodwall (0.6 mile). Beaumont B is 2,500 LF of levee (0.5 mile) and Beaumont C is 6,800 LF of levee (1.3 mile).

1.4.2 Port Arthur and Vicinity CSRM

The draft findings of the SQRA for the Freeport system (to be discussed next) were applied to the plan formulation for the Port Arthur because one has not yet been done for this system. For the Port Arthur system, the detailed description of the needs is similar to what will be presented in the Freeport HFPS section. However, the Port Arthur system is different because there are no known deferred maintenance issues for the Port Arthur system at this time.

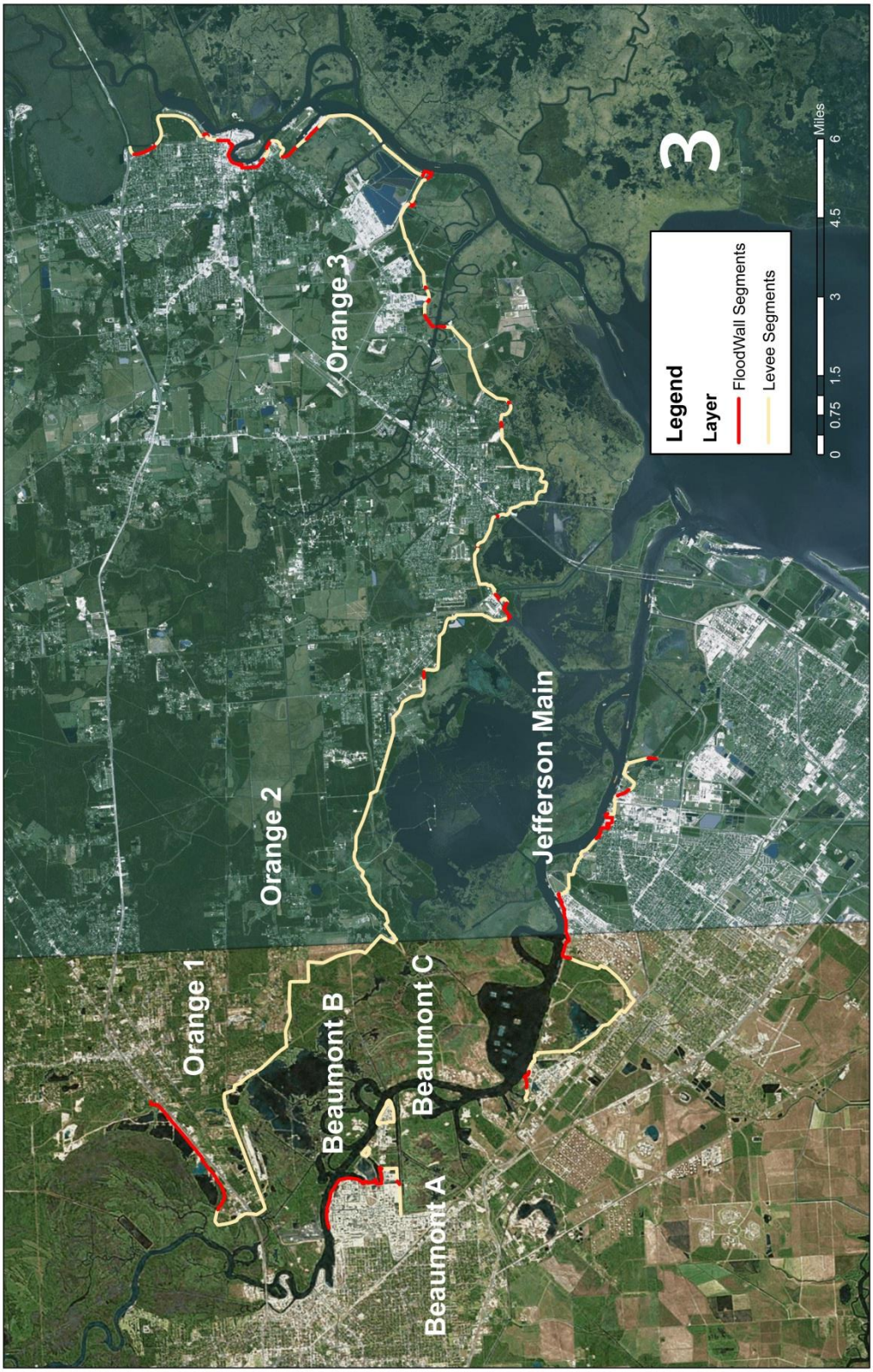


Figure 1-1. Configuration of the Orange-Jefferson CSRM

The formulation of alternatives for the Port Arthur and Vicinity CSRM began with defining reaches for the system. These were based on the failure locations identified by the levee safety program in the absence of a SQRA. Figure 1-2 displays the Port Arthur HFPS failure locations. These locations were included in formulation where improvements would positively impact the system's capacity for protection. The following lists the reaches at Port Arthur.

- Port Arthur 8feet-10feet I-Wall
- Port Arthur Closure Structure
- Port Arthur I-Wall Near Valero
- Port Arthur I-Wall Near Tank Farm

1.4.3 Freeport and Vicinity CSRM

The draft findings of the Semi-Quantitative Risk Assessment (SQRA) for the Freeport system show vulnerabilities primarily associated with floodwall and levee overtopping. Other performance issues identified during the SQRA were the result of deferred local sponsor maintenance, or alterations that local industrial stakeholders have constructed over time. Floodwall performance issues, at locations where the originally constructed floodwall is still in place and has been operated and maintained in an acceptable manner, are being evaluated to include stability and resiliency. Levee reaches that are non-uniform in height or otherwise susceptible to concentrated overtopping erosion during an event are being evaluated for raising or armoring to reduce the likelihood of breach.

The formulation of alternatives for the Freeport and Vicinity CSRM began with defining reaches for the system. These were based on the failure locations identified in the SQRA (Figure 1-3). These locations were then narrowed during formulation to those locations where improvements would positively impact the system's capacity for protection and to reduce any redundancies. For example, improvements to the Dow Barge Canal would negate any failures at the Dow Turning Basin. The following is the resulting list of reaches at the Freeport and Vicinity CSRM.

- Dow Barge Canal
- East Storm Levee
- Freeport Dock
- Old River at Dow Thumb
- Oyster Creek Levee
- South Storm Levee
- Tide Gate I-Wall

Figure 1-2. Port Arthur and Vicinity CSRM

Figure 1-3. Freeport and Vicinity CSRM

2 HEC-FDA ANALYSIS

2.1 ENGINEERING INPUTS

2.1.1 Stage-Probability Relationships

Water surface profiles representing stage-probability functions were imported into HEC-FDA utilizing data from Advanced Circulation model (ADCIRC) points for without-project storm surge and waves. This sub-set of 62 total storms (based on previous FEMA work and revised by ERDC using subject matter expertise for storms having the most effect on stage-frequency) was used in the revised to current JPM-OS simulation technique for the appropriate ACE values analysis. Mean water level, wave height and wave period responses were defined for each of the modeled return periods. In the absence of a Hydrologic Engineering Centers River Analysis System (HEC-RAS) stationing scheme which would also use a stage-discharge function, those ADCIRC points falling closest to the location of the levee/floodwall footprint were used to develop average ACE values for the seven events modeled by ERDC. For the existing Port Arthur and Freeport HFP systems, ADCIRC points representing average still water levels closest to the failure locations were used to quantify damages. An equivalent record length (15 years) for each study reach was used to generate a stage-probability relationship with uncertainty for the without-project and the with-project alternatives through the use of graphical analysis. The model used the eight stage-probability events together with the equivalent record length to define the full range of the stage-probability or stage-probability functions by interpolating between the data points. Values for the 0.999 and 0.5 % ACE were set at 0.25 and 1.0 feet respectively in order to make HEC-FDA operational. Table 2-1 lists these values used for each region. The ADCIRC points for the Orange-Jefferson CSRM are shown in Figure 2-1. Points for the Port Arthur CSRM are shown in Figure 2-2 and the ADCIRC points for the Freeport CSRM are in Figure 2-3.

Still water levels were used to determine the overall economic efficiency, since these are more reliable as a means of determining high-level overall economic efficiency, as opposed to also trying to incorporate low-probability wave run-up and/or overtopping that can be analyzed later and applied to specific locations where it is applicable along a levee/floodwall system in conjunction with any necessary interior drainage analysis on the final recommended plan.

Table 2-1. Average Still Water Elevations and Discharges at HEC-FDA Index Point

Orange-Jefferson

Exceedance Probability/Reach	*0.1 ACE*	*0.05 ACE*	*0.02 ACE*	*0.01 ACE*	*0.005 ACE*	*0.002 ACE*	*0.001 ACE*
Orange 1	3.62	5.05	6.69	7.76	8.66	9.66	10.35
Orange 2	3.6	5.36	7.24	8.52	9.6	10.77	11.57
Orange 3	2.78	4.25	6.11	7.51	8.64	9.81	10.57
Beaumont A	2.92	4.26	6	7.25	8.47	9.73	10.51
Beaumont B	2.71	3.88	5.62	6.86	7.94	9.07	10.34
Beaumont C	3.55	5.1	6.85	8.02	9	10.1	10.85
Jefferson Main	3.08	4.63	6.31	7.49	8.47	9.51	10.22

Port Arthur

Exceedance Probability/Reach	*0.1 ACE*	*0.05 ACE*	*0.02 ACE*	*0.01 ACE*	*0.005 ACE*	*0.002 ACE*	*0.001 ACE*
8ft-10ft I-Wall	2.85	4.31	6.98	9.25	10.94	12.68	13.81
Closure Structure	3.45	5.01	6.9	8.2	9.3	10.46	11.2
I-Wall Near Valero	3.87	5.97	8.47	10.47	12.61	14.77	16.08
I-Wall Near Tank Farm	3.77	5.72	8.1	9.99	12.02	14.08	15.31

Freeport Region

Exceedance Probability/Reach	*0.1 ACE*	*0.05 ACE*	*0.02 ACE*	*0.01 ACE*	*0.005 ACE*	*0.002 ACE*	*0.001 ACE*
South Storm Levee	4.21	6.68	9.59	11.63	13.71	16.31	17.93
Old River levee at Dow Thumb	4.43	7.08	10.15	12.41	14.69	17.43	18.97
Freeport Dock	4.47	7.17	10.3	12.63	14.97	17.79	19.38
Tide Gate	4.46	7.18	10.32	12.65	15.02	17.9	19.52
East Storm Levee	5.08	7.81	11.05	13.38	15.55	17.99	19.5
Dow Barge Canal	4.6	7.46	10.82	13.28	15.76	18.55	20.12
Oyster Creek	4.44	8.49	12.21	14.63	16.62	18.77	20.19

2.1.2 Fragility Curves

Fragility curves (the relationship between water surface stage on the exterior side of the levee versus the probability of levee failure) were developed based on the use of average still water levels for damage estimates. Fragility curves for the Freeport HFP system were initially developed as a result of the Freeport SQRA and were modified slightly due to the use of average still water levels for damage estimates. A similar approach was used for the development of the curves for the Port Arthur system. These curves for the Port Arthur and Freeport systems are listed in Tables 2-2 and 2-3, respectively.

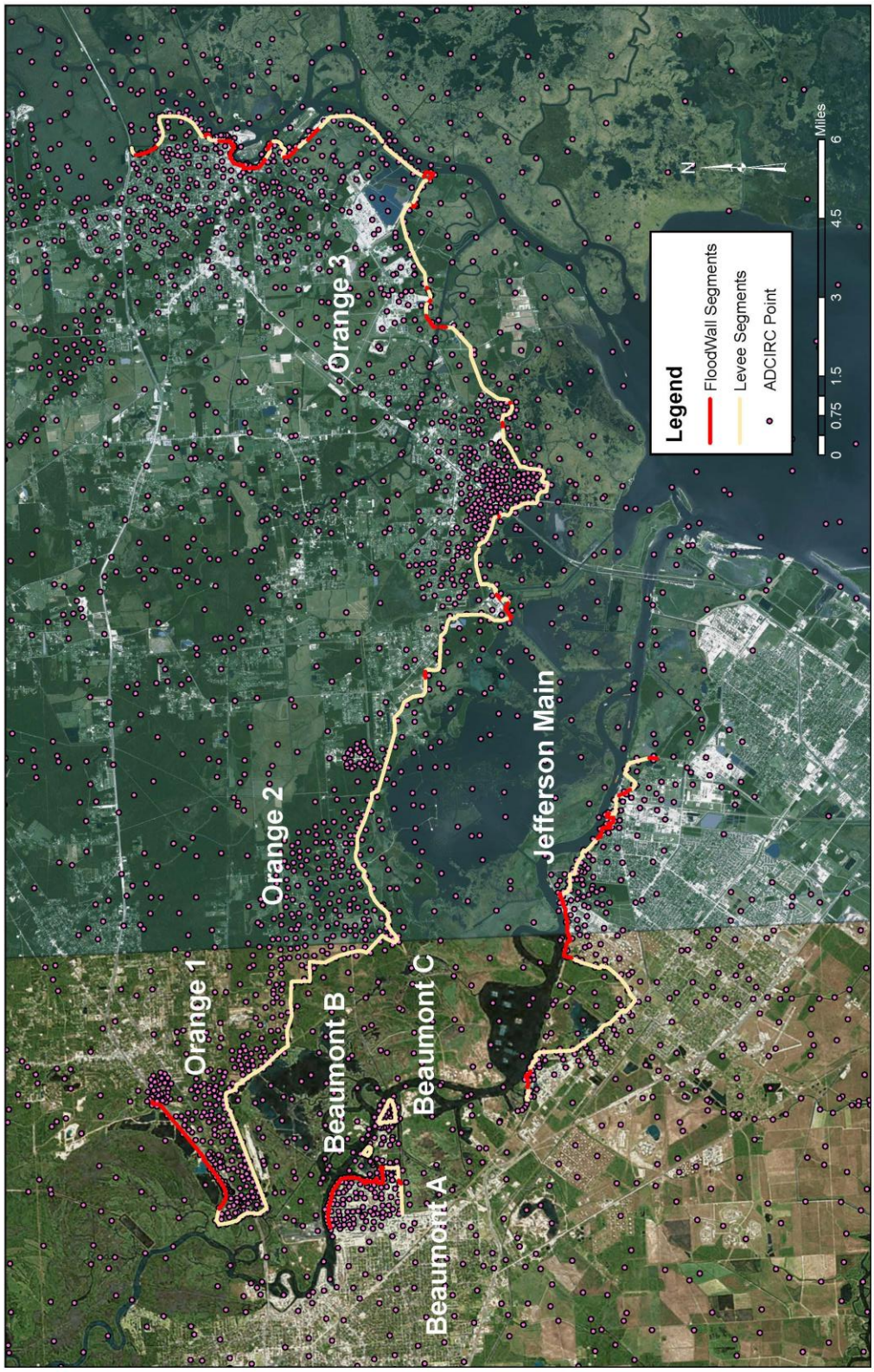


Figure 2-1. ADCIRC Points Orange-Jefferson CSRM

Figure 2-2. ADCIRC Points in Port Arthur and Vicinity CSRM

Figure 2-3. ADCIRC Points in Freeport and Vicinity CSRM

Table 2-2. Fragility Curves for Port Arthur and Vicinity CSRM

Stage/Location	Tank Farm	8ft-10ft I-Wall	I-Wall Near Valero	Closure Structure
14	**-**	**0.10**	**-**	**-**
14.5	**-**	**0.28**	**0.10**	**0.20**
15	**0.20**	**0.45**	**0.50**	**0.40**
15.5	**0.35**	**0.63**	**0.70**	**0.60**
16	**0.50**	**0.80**	**0.90**	**0.90**
16.5	**0.90**	**0.90**	**0.92**	**0.95**
17	**1.00**	**1.00**	**0.93**	**1.00**
17.5	**-**	**-**	**0.95**	**-**
18	**-**	**-**	**0.97**	**-**
18.5	**-**	**-**	**0.98**	**-**
19	**-**	**-**	**1.00**	**-**

Table 2-3. Fragility Curves for Freeport and Vicinity CSRM

Word 2010	Dow Barge Canal	East Storm	Oyster Creek Levee	Freeport Dock	Tide Gate I-Wall	Old River at Dow Thumb
10.5	-	-	0.03	-	0.04	0.04
11	-	-	0.06	-	0.08	0.08
11.5	-	-	0.1	-	0.11	0.11
12	-	-	0.13	-	0.15	0.15
12.5	-	-	0.16	0.05	0.19	0.19
13	-	-	0.19	0.75	0.23	0.23
13.5	-	-	0.23	1.00	0.26	0.26
14	-	-	0.26	1.00	0.3	0.3
14.5	-	0.08	0.29	1.00	0.34	0.34
15	-	0.15	0.32	1.00	0.38	0.38
15.5	-	0.23	0.35	-	0.41	0.41
16	-	0.3	0.39	-	0.45	0.45
16.5	-	0.38	0.42	-	0.6	0.68
17	-	0.45	0.45	-	0.75	1.00
17.5	-	0.54	0.68	-	1.00	-
18	-	0.63	1.00	-	-	-
18.5	-	0.72	-	-	-	-
19	-	0.81	-	-	-	-
19.5	-	1.00	-	-	-	-
20	-	-	-	-	-	-
20.5	0.11	-	-	-	-	-
21	0.23	-	-	-	-	-
21.5	0.34	-	-	-	-	-
22	0.45	-	-	-	-	-
22.5	0.53	-	-	-	-	-
23	0.6	-	-	-	-	-

Table 2-3, continued

Word 2010	Dow Barge Canal	East Storm	Oyster Creek Levee	Freeport Dock	Tide Gate I-Wall	Old River at Dow Thumb
23.5	0.68	-	-	-	-	-
24	0.75	-	-	-	-	-
24.5	0.83	-	-	-	-	-
25	1.00	-	-	-	-	-

2.2 ECONOMIC INPUTS

2.2.1 Ground Elevations

Centroids were created for each parcel to represent the structures associated with that parcel. Ground elevations were derived from data processed using U.S. Geological Survey Digital Elevation Model (DEM) 0.05m elevation data for the appropriate Gulf Coast Counties. These data were obtained from Texas Natural Resources Information System (TNRIS). Residential structures received a 0.5-foot floor correction while industrial, commercial, and public structures received floor corrections from 0 to 5 feet. The point at which damages for many high-value industrial and commercial structures is reflected in the ground elevation making floor correction was necessary.

2.2.2 Structure Inventory

All three study areas can be described as being relatively fully developed. As discussed under the study area demographics, Brazoria is expected to be the one county among the three that is expected to grow at a rate outpacing the State. Orange and Jefferson Counties are expected to grow at rates well below that of the State of Texas. For the purpose of this analysis, housing stock is assumed to remain relatively constant over the period of analysis. Since commercial and industrial make up a substantial amount of the structure inventory, those developments that are expected to come online with a reasonable amount of certainty and in the relatively near future are include in the inventory. The structure inventory was derived from data obtained from each of the appropriate appraisal districts for the 2015 tax appraisal year (Table 2-4). These data were not adjusted to reflect market nor a replacement cost less depreciation value. Because of this, structures in many cases may be undervalued. Due to tax abatements and incentives given to large industrial developers and due to the competitive nature of the petrochemical industry in the region, many high-value industrial and commercial properties are not listed on the tax appraisal rolls. In these instances, square footage values were developed from those properties that were listed on the tax rolls based on square footage values of similar structures from appraisal data. Therefore, a certain amount of uncertainty exists for these values in many cases, which could lead to an over- or underestimation of damages. Two separate structure files with a high degree of overlap were created for the system since failures would impact slightly different numbers of

structures. One structure file was used for a failure at the Dow Barge Canal and another for the remaining reaches. The following tables and figures depict the structure files used in the damage analyses. Parcels representing the structures at risk for the Orange-Jefferson CSRM are in Figure 2-4, while the parcels representing the structures at risk for the Port Arthur and Freeport CSRM are in Figures 2-5, 2-6, and 2-7 respectively.

Table 2-4. Structure and Content Values of Inventoried Structures by CSRM and Type 2015 Price and Development Levels

Orange-Jefferson CSRM

Orange County				
Category Name	**Count**	**Structure Value**	**Content Value**	**Total**
Commercial	268	$109,778,000	$109,203,000	$218,981,000
Industrial	20	$1,711,063,000	$1,711,061,000	$3,422,124,000
Multi-Family	193	$23,828,000	$23,828,000	$47,656,000
Mobile	699	$10,573,000	$10,573,000	$21,146,000
Public	214	$76,324,000	$83,913,000	$160,237,000
Vehicles	16,045	$200,448,000	$0	$200,448,000
Single-Family	12,734	$1,038,476,000	$1,038,443,000	$2,076,919,000
Grand Total	27,135	$3,170,490,000	$2,977,021,000	$6,147,511,000
Jefferson County				
Category Name	**Count**	**Structure Value**	**Content Value**	**Total**
Commercial	893	$319,062,000	$431,769,000	$750,831,000
Industrial	22	$662,341,000	$827,820,000	$1,490,161,000
Multi-Family	226	$186,264,000	$186,264,000	$372,528,000
Public	140	$124,284,000	$136,882,000	$261,166,000
Vehicles	15,954	$167,781,000	$0	$167,781,000
Single-Family	12,662	$2,539,056,000	$2,538,915,000	$5,077,971,000
Grand Total	26,605	$3,998,788,000	$4,121,650,000	$8,120,438,000

Port Arthur and Vicinity CSRM

Category Name	Count	Structure Value	Content Value	Total
Commercial	1,152	$5,190,935,000	$8,777,567,000	$13,968,502,000
Industrial	9	$201,486,000	$338,497,000	$539,983,000
Multi-Family	269	$69,382,000	$69,382,000	$138,764,000
Public	452	$217,266,000	$228,574,000	$445,840,000
Vehicles	26,431	$350,231,000	$0	$350,231,000
Single-Family	20,977	$1,911,200,000	$1,911,068,000	$3,822,268,000
Grand Total	43,968	$7,869,963,000	$11,325,088,000	$19,195,051,000

Freeport and Vicinity CSRM

Dow Barge Canal				
Category Name	**Count**	**Structure Value**	**Content Value**	**Total**
Commercial	903	$117,426,000	$156,275,000	$273,701,000
Industrial	45	$5,557,849,000	$9,339,639,000	$14,897,488,000
Multi-Family	375	$68,916,000	$69,123,000	$138,039,000
Mobile	6	$135,000	$135,000	$270,000
Public	207	$225,032,000	$248,092,000	$473,124,000
Vehicles	8,832	$185,858,000	$0	$185,858,000
Single-Family	8,826	$377,405,000	$377,572,000	$754,977,000
Grand Total	19,194	$6,532,621,000	$10,190,836,000	$16,723,457,000
Lower Reaches				
Category Name	**Count**	**Structure Value**	**Content Value**	**Total**
Commercial	244	$39,019,000	$30,565,000	$69,584,000
Industrial	5	$13,383,000	$22,406,000	$35,789,000
Multi-Family	117	$13,168,000	$13,168,000	$26,336,000
Public	76	$28,620,000	$29,784,000	$58,404,000
Vehicles	2,323	$38,847,000	$0	$38,847,000
Single-Family	1,844	$74,744,000	$74,744,000	$149,488,000
Grand Total	4,132	$207,781,000	$170,667,000	$378,448,000

2.2.3 Vehicle Inventory

The number of vehicles associated with a residence was estimated based on the average number of vehicles per residence characteristic of the study area, and the probability of their being present at the time of a flood. This value is 1.26 vehicles per residence. Values were based on the national average price of new and used vehicles as reported by the U.S. Bureau of Transportation Statistics (BTS) prices for new vehicles. The most recent price reported by BTS is $13,105. Adjusting this value based on the percent difference in median income for each county compared to the median income for the U.S., the resulting value for Orange County vehicles was set at $15,411 and $13,251 for Jefferson County. Vehicle values for Brazoria were set at $21,044.

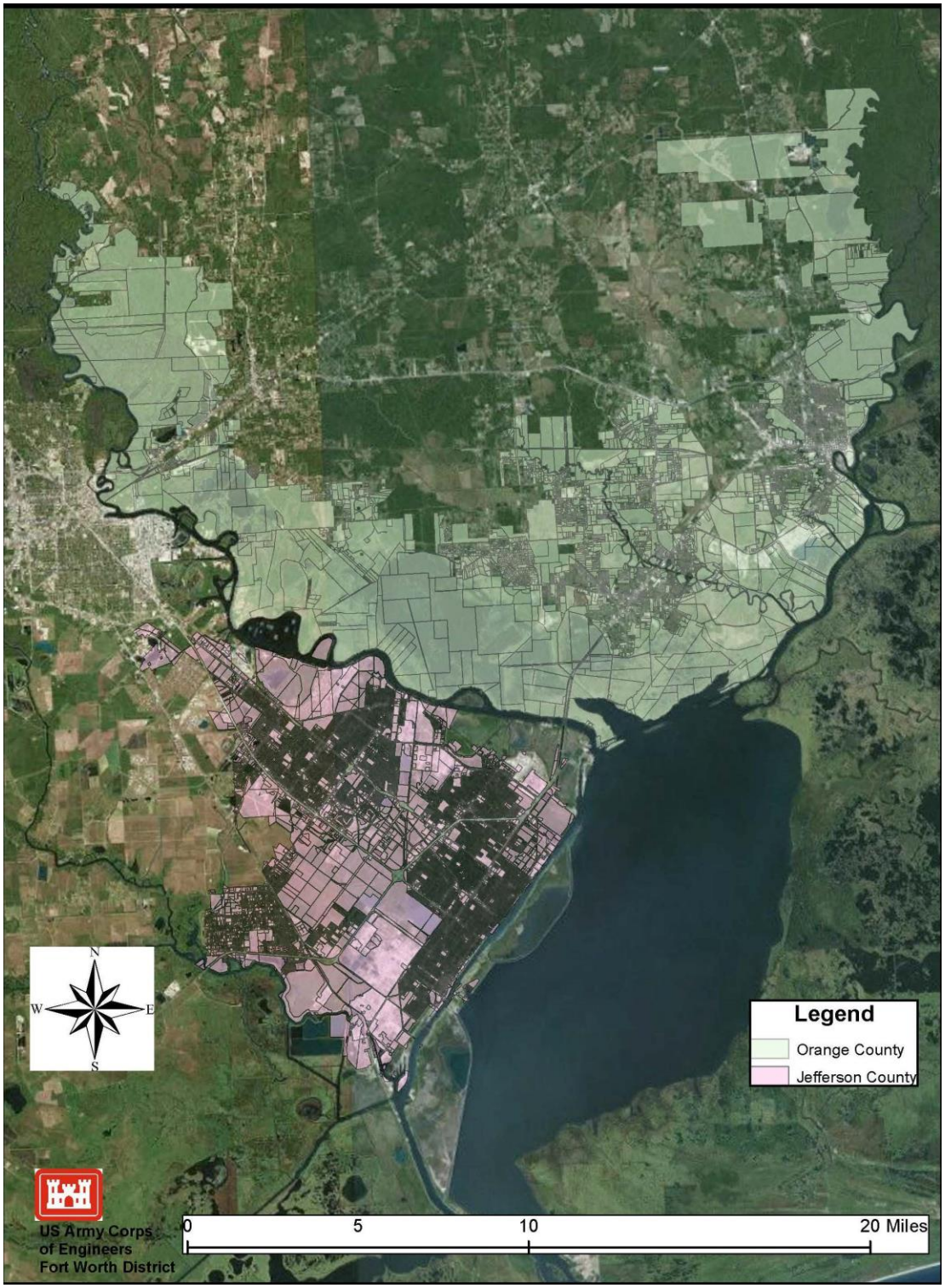


Figure 2-4. Orange-Jefferson CSRM Structures at Risk (Parcels)

Figure 2-5. Port Arthur and Vicinity CSRM Structures at Risk

Figure 2-6. Freeport and Vicinity CSRM Structures at Risk – Dow Barge Canal Reach

Figure 2-7. Freeport and Vicinity CSRM Structures at Risk – Remaining Reaches

2.2.4 Depth-Damage Functions

Depth-damage functions were obtained from the New Orleans District from the Plaquemines Parish study. These functions reflect saltwater inundation for short durations. The functions cover the following structure types:

1STY-SLAB	One-Story Single -Family Residential Slab Foundation
2STY- SLAB	To-Story single -Family Residential Slab Foundation
AUTO	Automobiles
EAT	Restaurants
GROC	Grocery Stores
MOBHOM	Mobile Homes
MULT	Multi-Family Residential
PROF	Professional Businesses
PUBL	Public & Semi Public Structures
REPA	Repairs & Home Use
RETA	Retail & Personal Services
WARE	Warehouse & Contractor Services

Graphical representations for these for these functions are depicted at the end of this appendix.

2.3 FUTURE WITHOUT-PROJECT STRUCTURE AND CONTENT DAMAGES

2.3.1 Methodology Overview

The methodology employed for this economic analysis is in accordance with current principles and guidelines and standard economic practices, as outlined in the Planning Guidance Notebook – ER 1105-2-100. Economic analysis is conducted at a given price level using the current Federal discount rate and a period of analysis of 50 years. Per the Planning Guidance Notebook, flood events will be expressed in probabilistic terms rather than the classic “x-Year” event. For example, the 100-Year event will be called a 1 % ACE (equivalent to the HEC-FDA term Annual Exceedance Probability Event). Other equivalent probabilities can be obtained by dividing 1 by the year occurrence interval; the 500-year event is 1/500 = 0.2 % ACE, and so forth.

A risk-based analysis (RBA) procedure has been used to evaluate without-project flood damages in the study area. Guidance for conducting RBA is included in Corps Engineering Regulation

1105-2-101, Risk-Based Analysis for Evaluation of Hydrology/Hydraulics, Geotechnical Stability and Economics in Flood Damage Reduction Studies (January 3, 2006).

The guidance specifies that the derivation of expected annual flood damage must take into account the uncertainty in hydrologic, hydraulic, and economic factors. Risk and uncertainty are intrinsic in water resource planning and design. They arise from measurement errors and the inherent variability of complex physical, social and economic situations. Best estimates of key variables, factors, parameters and data components are developed, but are often based on short periods of record, small sample sizes, measurements subject to error, and innate residual variability in estimating methods. RBA explicitly and analytically incorporates these uncertainties by defining key variables in terms of probability distributions, rather than single-point estimates. The focus of RBA is to concentrate on the uncertainties of variables having the largest impact on study conclusions.

The following are the primary sources of uncertainty for coastal storm damage analysis studies:

- Stage/Probability
- Geo-technical Features
- Structure Elevation
- Structure and Content Values
- Inundation Depth/Percent Damage

The Army Corps of Engineers Hydrologic Engineering Center has developed software specifically designed for conducting risk based analysis, referred to as the HEC-FDA Program. Version 1.2.5 was used for this analysis. This program applies Monte Carlo simulation process, whereby the expected value of damages is determined explicitly through a numerical integration technique accounting for uncertainty in the basic parameters described above. For this analysis, the number of Monte Carlo simulations is set at 100 with the minimum and maximum number of intervals set at 20 and 30 respectively. Data requirements for the program include:

- Structure data, including structure I.D., category (single or multi-family residential, commercial, industrial, and public), stream location, ground and/or first floor elevation, structure value and content value. These data were developed in a Microsoft Excel spreadsheet and imported into the HEC-FDA program
- Hydrologic and hydraulic data, including water surface profiles and stage/probability relationships
- Depth-Damage functions

2.3.2 Future Without-Project Condition Expected Annual Damages

Estimates of Expected Annual Damages (EAD) under future without-project conditions were calculated, using the risk and uncertainty model, through integration of frequency-damage data. The future expected annual damages shown here are projected over the project life of 50 years. Table 2-5 shows a breakdown of where these damages are predicted to occur for each CSRM. Tables 2-6, 2-7, and 2-8 break down the number of structures by event in each reach of the three project areas along with the corresponding still water level for that event.

For the Orange 1, Orange 2, and Orange 3 alternative reaches, significant damages start at approximately the 1% ACE; the depth of flooding at the 1% ACE is approximately 8 feet. In the Jefferson Main alternative reach, significant damages start between the 2% and 1% ACE; the depth of flooding between the 2% and 1% ACE is approximately 6.5 feet and 7.5 feet. For the Beaumont A, Beaumont B and Beaumont C the significant damages start at the 1% ACE; the depth of flooding is approximately 7.5 feet.

The estimated start of damages for the Port Arthur and Vicinity alternative reaches is approximately 15 feet, which corresponds to an estimated high probability of failure of the existing HFPS based on the fragility curves. Flooding depths approximate the stage on the exterior side of the existing HFPS, and goes up to approximately 14 feet for the 0.1% ACE.

The estimated start of damages for the Freeport and Vicinity alternative reaches is approximately 15 feet, which corresponds to an estimated high probability of failure of the existing HFPS based on the fragility curves. Flooding depths approximate the stage on the exterior side of the existing HFPS, and goes up to approximately 19 feet for the 0.1% ACE.

2.4 ALTERNATIVE ANALYSIS

2.4.1 Orange-Jefferson CSRM

As agreed at the Alternative Milestone Meeting (AMM), future without-project (FWOP) damages were run with a rough order of magnitude costs to identify NED benefits. Costs representing a linear foot in both length and height for both levees and floodwalls were developed. The costs per linear foot of levee were estimated at $237.50 and floodwalls were estimated at $475.00. These costs included contingency, engineering and design, and constriction management. Real estate costs were also included with commercial and residential estimates of $100,000 per acre, industrial at $70,000 per acre, undeveloped land at $9,000 per acre, and marsh at $750. Operation, Maintenance, Repair, Replacement and Rehabilitation

Table 2-5. Expected Annual Damages Future Without-Project Condition (2015 price level)

	Damage Categories							
Reach	**Commercial**	**Industrial**	**Multifamily**	**Mobile**	**Public**	**POV**	**SFR**	**Total**
Orange Jefferson CSRM								
Orange 1	$73,000	$0	$0	$7,000	$10,000	$33,000	$190,000	$312,000
Orange 2	$0	$0	$0	$4,000	$0	$10,000	$54,000	$68,000
Orange 3	$21,833,000	$0	$93,000	$98,000	$409,000	$969,000	$6,585,000	$29,987,000
Beaumont A	$0	$6,937,000	$0	$0	$0	$0	$0	$6,937,000
Beaumont B	$0	$23,000	$0	$0	$0	$0	$0	$23,000
Beaumont C	$0	$262,000	$0	$0	$0	$0	$0	$262,000
Jefferson Main	$4,600,000	$929,000	$4,834,000	$0	$1,824,000	$536,000	$15,509,000	$28,231,000
Port Arthur CSRM								
8ft-10ft I-Wall	$19,302,000	$560,000	$83,000	$0	$368,000	$275,000	$2,824,000	$23,413,000
Closure Structure	$3,128,000	$86,000	$13,000	$0	$59,000	$44,000	$453,000	$3,784,000
I-Wall Near Valero	$50,798,000	$1,587,000	$228,000	$0	$975,000	$726,000	$7,553,000	$61,867,000
I-Wall Near Tank Farm	$31,139,000	$1,012,000	$143,000	$0	$599,000	$446,000	$4,670,000	$38,009,000
Freeport CSRM								
Dow Barge Canal	$3,070,000	$145,903,000	$884,000	$2,000	$4,815,000	$3,088,000	$8,897,000	$166,660,000
East Storm Levee	$346,000	$247,000	$99,000	$0	$233,000	$191,000	$587,000	$1,701,000
Freeport Dock	$768,000	$583,000	$217,000	$0	$549,000	$456,000	$1,387,000	$3,960,000
Old River at Dow Thumb	$489,000	$367,000	$139,000	$0	$349,000	$290,000	$882,000	$2,517,000
South Storm Levee	$52,000	$37,000	$15,000	$0	$35,000	$28,000	$87,000	$254,000
Tide Gate I-Wall	$541,000	$406,000	$154,000	$0	$387,000	$321,000	$977,000	$2,785,000
Oyster Creek	$744,000	$553,000	$211,000	$0	$526,000	$436,000	$1,329,000	$3,800,000

Table 2-6. Structures by Event for Orange-Jefferson CSRM

Orange 1							
Event (ACE)	0.1	0.05	0.02	0.01	0.005	0.002	0.001
Elevation (MSL Ft.)	3.62	5.05	6.69	7.76	8.66	9.66	10.35
Damage Category							
Commercial	0	1	1	1	1	1	7
Industrial	0	0	0	0	0	0	0
Multifamily	0	0	0	0	0	0	0
Mobile	2	2	7	7	8	8	19
Public	0	0	2	2	2	2	4
Vehicles	0	11	13	72	81	87	202
Single-Family	2	14	23	82	92	98	232
Grand Total	4	28	46	164	184	196	464

Orange 2							
Event (ACE)	0.1	0.05	0.02	0.01	0.005	0.002	0.001
Elevation (MSL Ft.)	3.60	5.36	7.24	8.51	9.60	10.77	11.57
Damage Category							
Commercial	0	0	1	1	1	1	1
Industrial	0	0	0	0	0	0	0
Mobile	0	0	4	4	4	11	11
Public	0	0	0	0	0	0	0
Vehicles	0	3	15	16	18	40	42
Single-Family	1	3	15	17	17	35	36
Grand Total	1	6	35	38	40	87	90

Orange 3							
Event (ACE)	0.1	0.05	0.02	0.01	0.005	0.002	0.001
Elevation (MSL Ft.)	2.78	4.25	6.11	7.51	8.64	9.81	10.57
Damage Category							
Commercial	0	3	4	42	48	51	198
Industrial	0	1	1	6	6	6	8
Multifamily	0	3	3	99	102	111	180
Mobile	0	20	23	167	173	185	385
Public	2	5	6	70	76	79	166
Vehicles	8	267	319	3,157	3,345	3,506	9,180
Single-Family	11	287	347	3,247	3,404	3,621	9,146
Grand Total	21	586	703	6,788	7,154	7,559	19,263

Jefferson Main							
Event (ACE)	0.1	0.05	0.02	0.01	0.005	0.002	0.001
Elevation (MSL Ft.)	3.08	4.63	6.31	7.49	8.47	9.51	10.22
Damage Category							
Commercial	0	20	22	153	160	164	240
Industrial	0	0	1	3	3	3	4
Multifamily	0	9	10	31	31	31	55
Public	1	5	5	22	22	22	32
Vehicles	0	267	348	1909	1974	2047	2097
Single-Family	0	290	388	1940	2010	2078	3418
Grand Total	1	591	774	4,058	4,200	4,345	5,846

Table 2-6, continued

Beaumont A							
Event (ACE)	0.1	0.05	0.02	0.01	0.005	0.002	0.001
Elevation (MSL Ft.)	2.92	4.26	6.00	7.25	8.47	9.73	10.51
Damage Category							
Commercial	0	0	0	0	0	0	0
Industrial	0	0	0	1	1	1	2
Multifamily	0	0	0	0	0	0	0
Public	0	0	0	0	0	0	0
Grand Total	0	0	0	1	1	1	2

Beaumont B							
Event (ACE)	0.1	0.05	0.02	0.01	0.005	0.002	0.001
Elevation (MSL Ft.)	2.71	3.88	5.62	6.86	7.94	9.07	10.34
Damage Category							
Industrial	0	0	0	0	1	1	1
Grand Total	0	0	0	0	1	1	1

Beaumont C							
Event (ACE)	0.1	0.05	0.02	0.01	0.005	0.002	0.001
Elevation (MSL Ft.)	3.55	5.09	6.85	8.02	9.00	10.10	10.85
Damage Category							
Industrial	1	1	1	1	1	1	1
Grand Total	1	1	1	1	1	1	1

Table 2-7. Structures by Event for Port Arthur CSRM

8ft-10ft I-Wall							
Event (ACE)	0.1	0.05	0.02	0.01	0.005	0.002	0.001
Elevation (MSL Ft.)	2.85	4.31	6.98	9.25	10.94	12.68	13.81
Damage Category							
Commercial	50	549	938	956	1,050	1,057	1,143
Industrial	0	4	6	7	9	9	9
Multifamily	15	119	215	217	249	252	261
Public	16	189	399	401	435	437	445
Vehicles	939	9,129	12,007	16,998	19,478	19,584	20,538
Single Family	1,197	9,262	16,626	16,947	19,378	19,492	20,443
Grand Total	2,217	19,252	30,191	35,526	40,599	40,831	42,839

Closure Structure							
Event (ACE)	0.1	0.05	0.02	0.01	0.005	0.002	0.001
Elevation (MSL Ft.)	3.45	5.01	6.90	8.20	9.30	10.46	11.20
Damage Category							
Commercial	518	562	938	948	956	1,050	1,050
Industrial	3	5	6	7	7	9	9
Multifamily	114	119	215	216	217	247	250
Public	186	192	399	400	401	435	435
Vehicles	1,269	9,340	11,949	16,847	17,003	19,449	19,495
Single Family	9,002	9,493	16,611	16,793	16,955	19,348	19,392
Grand Total	11,092	19,711	30,118	35,211	35,539	40,538	40,631

I-Wall Near Valero							
Event (ACE)	0.1	0.05	0.02	0.01	0.005	0.002	0.001
Elevation (MSL Ft.)	3.87	5.97	8.47	10.47	12.61	14.77	16.08
Damage Category							
Commercial	535	637	950	1,050	1,056	1,144	1,146
Industrial	4	5	7	9	9	9	9
Multifamily	117	124	217	247	252	261	262
Public	188	315	400	435	437	445	446
Vehicles	8,981	9,682	16,888	19,450	19,581	20,611	20,680
Single Family	9,126	11,610	16,838	19,348	19,484	20,500	20,582
Grand Total	18,951	22,373	35,300	40,539	40,819	42,970	43,125

I-Wall Near Tank Farm							
Event (ACE)	0.1	0.05	0.02	0.01	0.005	0.002	0.001
Elevation (MSL Ft.)	3.77	5.72	8.10	9.99	12.02	14.08	15.31
Damage Category							
Commercial	531	572	946	1,050	1,052	1,143	1,144
Industrial	3	5	7	9	9	9	9
Multifamily	116	123	216	246	250	261	261
Public	188	208	400	434	436	445	446
Vehicles	1,580	9,585	16,836	17,114	19,549	20,564	20,636
Single Family	9,102	9,749	16,781	19,319	19,445	20,464	20,530
Grand Total	11,520	20,242	35,186	38,172	40,741	42,886	43,026

Table 2-8. Structures by Event for Freeport CSRM

Dow Barge Canal							
Event (ACE)	**0.1**	**0.05**	**0.02**	**0.01**	**0.005**	**0.002**	**0.001**
Elevation (MSL Ft.)	4.60	7.46	10.82	13.28	15.76	18.55	20.12
Damage Category							
Commercial	242	284	288	289	289	289	289
Industrial	11	13	14	14	14	14	14
Multifamily	111	115	115	115	115	115	115
Mobile	0	0	2	2	2	2	2
Public	59	62	65	65	65	65	65
Vehicles	2,342	2,566	2,605	2,606	2,607	2,607	2,607
Single Family	2,348	2,571	2,605	2,607	2,607	2,607	2,607
Grand Total	5,113	5,611	5,694	5,698	5,699	5,699	5,699

Oyster Creek							
Event (ACE)	**0.1**	**0.05**	**0.02**	**0.01**	**0.005**	**0.002**	**0.001**
Elevation (MSL Ft.)	4.44	8.49	12.21	14.63	16.62	18.77	20.19
Damage Category							
Commercial	206	239	242	243	243	243	243
Industrial	3	3	3	3	3	3	3
Multifamily	114	117	117	117	117	117	117
Public	62	68	70	70	70	70	70
Vehicles	1,656	1,821	1,845	1,846	1,846	1,846	1,846
Single Family	1,657	1,820	1,843	1,844	1,844	1,844	1,844
Grand Total	3,698	4,068	4,120	4,123	4,123	4,123	4,123

Freeport Dock							
Event (ACE)	**0.1**	**0.05**	**0.02**	**0.01**	**0.005**	**0.002**	**0.001**
Elevation (MSL)	4.47	7.17	10.30	12.63	14.97	17.79	19.38
Damage Category							
Commercial	206	238	242	242	243	243	243
Industrial	3	3	3	3	3	3	3
Multifamily	114	117	117	117	117	117	117
Public	62	68	70	70	70	70	70
Vehicles	1,656	1,816	1,831	1,845	1,846	1,846	1,846
Single Family	1,657	1,816	1,843	1,843	1,844	1,844	1,844
Grand Total	3,698	4,058	4,106	4,120	4,123	4,123	4,123

Tide Gate							
Event (ACE)	**0.1**	**0.05**	**0.02**	**0.01**	**0.005**	**0.002**	**0.001**
Elevation (MSL Ft.)	4.46	7.18	10.32	12.65	15.02	17.90	19.52
Damage Category							
Commercial	206	238	242	242	243	243	243
Industrial	3	3	3	3	3	3	3
Multifamily	114	117	117	117	117	117	117
Public	62	68	70	70	70	70	70
Vehicles	1,656	1,816	1,832	1,845	1,846	1,846	1,846
Single Family	1,657	1,816	1,843	1,843	1,844	1,844	1,844
Grand Total	3,698	4,058	4,107	4,120	4,123	4,123	4,123

Old River at Dow							
Event (ACE)	**0.1**	**0.05**	**0.02**	**0.01**	**0.005**	**0.002**	**0.001**
Elevation (MSL Ft.)	4.43	7.08	10.15	12.41	14.69	17.43	18.97
Damage Category							
Commercial	206	238	242	242	243	243	243
Industrial	3	3	3	3	3	3	3
Multifamily	114	117	117	117	117	117	117
Public	62	68	70	70	70	70	70
Vehicles	1,656	1,814	1,828	1,845	1,846	1,846	1,846
Single Family	1,657	1,816	1,843	1,843	1,844	1,844	1,844
Grand Total	3,698	4,056	4,103	4,120	4,123	4,123	4,123

East Storm Levee							
Event (ACE)	**0.1**	**0.05**	**0.02**	**0.01**	**0.005**	**0.002**	**0.001**
Elevation (MSL Ft.)	5.08	7.81	11.05	13.38	15.55	17.99	19.50
Damage Category							
Commercial	209	238	242	243	243	243	243
Industrial	3	3	3	3	3	3	3
Multifamily	115	117	117	117	117	117	117
Public	65	68	70	70	70	70	70
Vehicles	1,661	1,820	1,845	1,845	1,846	1,846	1,846
Single Family	1,666	1,819	1,843	1,844	1,844	1,844	1,844
Grand Total	3,719	4,065	4,120	4,122	4,123	4,123	4,123

South Storm Levee							
Event (ACE)	**0.1**	**0.05**	**0.02**	**0.01**	**0.005**	**0.002**	**0.001**
Elevation (MSL Ft.)	4.21	6.68	9.59	11.63	13.71	16.31	17.93
Damage Category							
Commercial	205	238	241	242	243	243	243
Industrial	3	3	3	3	3	3	3
Multifamily	114	117	117	117	117	117	117
Public	62	68	69	70	70	70	70
Vehicles	1,654	1,686	1,824	1,845	1,846	1,846	1,846
Single Family	1,657	1,814	1,825	1,843	1,844	1,844	1,844
Grand Total	3,695	3,926	4,079	4,120	4,123	4,123	4,123

Table 2-9. Economic Performance of Orange-Jefferson CSRM
(FY 2015 Price Level/3.375 percent interest rate)

	Orange 1 New Levee					Orange 2 New Levee					Orange 3 New Levee			
	10 - Foot	**11 - Foot**	**12 - Foot**	**13 - Foot**		**10 - Foot**	**11 - Foot**	**12 - Foot**	**13 - Foot**		**10 - Foot**	**11 - Foot**	**12 - Foot**	**13 - Foot**
INVESTMENT														
Estimated First Cost	$32,300,000	$46,617,000	$60,935,000	$75,252,000		$32,870,000	$41,088,000	$49,305,000	$57,523,000		$205,338,000	$246,811,000	$288,284,000	$329,762,000
Annual Interest Rate	3.375%	3.375%	3.375%	3.375%		3.375%	3.375%	3.375%	3.375%		3.375%	3.375%	3.375%	3.375%
Project Life (years)	50	50	50	50		50	50	50	50		50	50	50	50
Construction Period (months)	36	36	36	36		36	36	36	36		36	36	36	36
Interest During Construction	$1,647,000	$2,377,000	$3,108,000	$3,838,000		$1,676,000	$2,095,000	$2,515,000	$2,934,000		$10,472,000	$12,587,000	$14,702,000	$16,818,000
Investment Cost	$33,947,000	$48,995,000	$64,043,000	$79,090,000		$34,546,000	$43,183,000	$51,820,000	$60,456,000		$215,810,000	$259,398,000	$302,986,000	$346,580,000
Interest	$1,146,000	$1,654,000	$2,161,000	$2,669,000		$1,166,000	$1,457,000	$1,749,000	$2,040,000		$7,284,000	$8,755,000	$10,226,000	$11,697,000
Amortization	$269,000	$388,000	$508,000	$627,000		$274,000	$342,000	$411,000	$479,000		$1,711,000	$2,056,000	$2,402,000	$2,747,000
O&M ($/year)*											$4,084,000	$4,084,000	$4,084,000	$4,084,000
TOTAL ANNUAL COSTS	**$1,415,000**	**$2,042,000**	**$2,669,000**	**$3,296,000**		**$1,440,000**	**$1,800,000**	**$2,160,000**	**$2,520,000**		**$13,078,000**	**$14,895,000**	**$16,711,000**	**$18,528,000**
Without Project EAD	$312,000	$312,000	$312,000	$312,000		$68,000	$68,000	$68,000	$68,000		$29,987,000	$29,987,000	$29,987,000	$29,987,000
Residual EAD	$62,000	$39,000	$23,000	$12,000		$32,000	$26,000	$20,000	$16,000		$8,171,000	$5,242,000	$3,044,000	$1,654,000
Storm Reduction Benefits	$250,000	$273,000	$289,000	$300,000		$36,000	$42,000	$48,000	$52,000		$21,816,000	$24,745,000	$26,943,000	$28,333,000
TOTAL BENEFITS	**$250,000**	**$273,000**	**$289,000**	**$300,000**		**$36,000**	**$42,000**	**$48,000**	**$52,000**		$21,816,000	$24,745,000	$26,943,000	$28,333,000
NET BENEFITS	**($1,165,000)**	**($1,769,000)**	**($2,380,000)**	**($2,996,000)**		**($1,404,000)**	**($1,757,000)**	**($2,112,000)**	**($2,467,000)**		**$8,738,000**	**$9,851,000**	**$10,232,000**	**$9,804,000**
BENEFIT-COST RATIO	**0.2**	**0.1**	**0.1**	**0.1**		**0.0**	**0.0**	**0.0**	**0.0**		**1.7**	**1.7**	**1.6**	**1.5**

*For Mitigation

Table 2-9. Economic Performance of Orange-Jefferson CSRM (continued)
(FY 2015 Price Level/3.375 percent interest rate)

	Beaumont A New Levee					Beaumont B New Levee					Beaumont C New Levee		
	11 - Foot	**12 - Foot**	**13 - Foot**	**14 - Foot**		**11 - Foot**	**12 - Foot**	**13 - Foot**	**14 - Foot**		**11 - Foot**	**12 - Foot**	**13 - Foot**
INVESTMENT													
Estimated First Cost	$62,661,000	$70,202,000	$77,743,000	$85,284,000		$1,695,000	$2,295,000	$2,895,000	$3,494,000		$15,793,000	$16,078,000	$19,007,000
Annual Interest Rate	3.375%	3.375%	3.375%	3.375%		3.375%	3.375%	3.375%	3.375%		3.375%	3.375%	3.375%
Project Life (years)	50	50	50	50		50	50	50	50		50	50	50
Construction Period (months)	36	36	36	36		36	36	36	36		36	36	36
Interest During Construction	$3,196,000	$3,580,000	$3,965,000	$4,349,000		$86,000	$117,000	$148,000	$178,000		$805,000	$820,000	$969,000
Investment Cost	$65,857,000	$73,782,000	$81,708,000	$89,634,000		$1,782,000	$2,412,000	$3,042,000	$3,673,000		$16,599,000	$16,898,000	$19,977,000
Interest	$2,223,000	$2,490,000	$2,758,000	$3,025,000		$60,000	$81,000	$103,000	$124,000		$560,000	$570,000	$674,000
Amortization	$522,000	$585,000	$648,000	$711,000		$14,000	$19,000	$24,000	$29,000		$132,000	$134,000	$158,000
TOTAL ANNUAL COSTS	**$2,745,000**	**$3,075,000**	**$3,405,000**	**$3,736,000**		**$74,000**	**$101,000**	**$127,000**	**$153,000**		**$692,000**	**$704,000**	**$833,000**
Without Project EAD	$6,937,000	$6,937,000	$6,937,000	$6,937,000		$23,000	$23,000	$23,000	$23,000		$262,000	$262,000	$262,000
Residual EAD	$1,449,000	$870,000	$494,000	$259,000		$7,000	$4,000	$3,000	$1,000		$12,000	$7,000	$4,000
Storm Reduction Benefits	$5,488,000	$6,067,000	$6,442,000	$6,677,000		$17,000	$19,000	$21,000	$22,000		$249,000	$255,000	$258,000
TOTAL BENEFITS	**$5,488,000**	**$6,067,000**	**$6,442,000**	**$6,677,000**		**$17,000**	**$19,000**	**$21,000**	**$22,000**		**$249,000**	**$255,000**	**$258,000**
NET BENEFITS	**$2,743,000**	**$2,992,000**	**$3,037,000**	**$2,942,000**		**($58,000)**	**($82,000)**	**($106,000)**	**($131,000)**		**($442,000)**	**($449,000)**	**($574,000)**
BENEFIT-COST RATIO	**2.0**	**2.0**	**1.9**	**1.8**		**0.2**	**0.2**	**0.2**	**0.1**		**0.4**	**0.4**	**0.3**

Table 2-9. Economic Performance of Orange-Jefferson CSRM (continued)
(FY 2015 Price Level/3.375 percent interest rate)

	Jefferson Main New Levee			
	10 - Foot	**11 - Foot**	**12 - Foot**	**13 - Foot**
INVESTMENT				
Estimated First Cost	$46,948,000	$65,726,000	$87,674,000	$104,747,000
Annual Interest Rate	3.375%	3.375%	3.375%	3.375%
Project Life (years)	50	50	50	50
Construction Period (months)	36	36	36	36
Interest During Construction	$2,394,000	$3,352,000	$4,471,000	$5,342,000
Investment Cost	$49,342,000	$69,078,000	$92,145,000	$110,089,000
Interest	$1,665,000	$2,331,000	$3,110,000	$3,715,000
Amortization	$391,000	$548,000	$730,000	$873,000
O&M ($/year)*	$371,000	$371,000	$371,000	$371,000
TOTAL ANNUAL COSTS	**$2,428,000**	**$3,250,000**	**$4,212,000**	**$4,960,000**
Without Project EAD	$28,231,000	$28,231,000	$28,231,000	$28,231,000
Residual EAD	$4,207,000	$2,520,000	$1,440,000	$776,000
Flood Reduction Benefits	$24,025,000	$25,711,000	$26,791,000	$27,456,000
TOTAL BENEFITS	**$24,025,000**	**$25,711,000**	**$26,791,000**	**$27,456,000**
NET BENEFITS	**$21,597,000**	**$22,461,000**	**$22,580,000**	**$22,496,000**
BENEFIT-COST RATIO	**9.9**	**7.9**	**6.4**	**5.5**

* For Mitigation

(OMRR&R) (with the exception of mitigation) was not taken into account, since these are expected to be proportional among alternatives and would not impact the ranking of alternatives. Mitigation was estimated using the Wetlands Value Assessment Model (WVA), and preliminary wetland mitigation costs were developed for use in plan comparison. These costs were based on compensation for a loss of 85.2 Average Annual Habitat Units (AAHUs) from forested wetlands and 181.7 AAHUs from coastal wetlands and applied to only the Orange 3 and Jefferson Main sections, since Beaumont B and C were already not economically viable, and to Beaumont A because they were small. The same costs were applied to all analyzed levee heights and did not vary. Since the alignment may change as a result of public, technical, and policy review, conceptual mitigation plans and preliminary cost estimates were developed to support TSP plan comparison and selection. The primary determinant in differentiating benefits is the scale of the levee being proposed along with the associated cost for that levee/floodwall height.

Table 2-9 displays the economic evaluation for a range of levee/floodwall heights modifications based on the beginning at 10 feet mean sea level (MSL) up to 13 feet MSL NAVD88. They

show the economic performance of the Orange 1 , 2, and 3 with new levees and the economic performance of Jefferson Main with new levee as well as Beaumont A, B, and C with new levees. All are calculated at a FY 2015 price level and interest rate.

Based on the information provided in the preceding tables the alternative with the highest net benefits for the Orange-Jefferson CSRM is a levee/floodwall at a height of 12 feet at Orange 3 with Orange 1 and 2 being removed from further consideration. For Beaumont, B and C are removed from consideration and the alternative with the highest net benefits for this area is a 13-foot levee/floodwall at Beaumont A. At Jefferson Main, the alternative with the highest net benefits is a 12-foot levee/floodwall. Residual economic damages in the reaches where an alternative is considered range from $1.7 to $8.1 million in Orange 3. At Beaumont A, annual residual economic damages run from $0.3 to $1.5 million. For the Jefferson Main reach, residual economic damages run from $0.8 to $4.2 million annually.

While both of the 12-foot raises at Orange 3 and Jefferson Main produce higher net benefits than the 11-foot raises, ER-1105-2-100 states "Where two cost-effective plans produce no significantly different levels of net benefits, the less costly plan is to be the NED plan, even though the level of outputs may be less" (Appendix G, pp. G-7 to G-8). The same scenario exists for the 13-foot Raise at Beaumont A versus the 12-foot raise. Based on this guidance, the 11-foot raise at Orange 3 and Jefferson Main and the 12-foot raise at Beaumont A are included as part of the TSP.

2.4.2 Port Arthur and Vicinity CSRM

Just as with the alternative selection with the Freeport CSRM and the Orange-Jefferson CSRM, FWOP damages will have rough order of magnitude costs to identify the NED. Parametric costs were estimated for the first-added resiliency features. The same costs per linear foot both length and height for both levees and floodwalls used for Orange-Jefferson were used for the next added 1- and 2-foot raises to the system. No environmental impacts were identified, and no mitigation costs were included in the comparison. The primary determinant in differentiating benefits lies in the without project damages which is based on the fragility curve at each potential failure location. Additional determinants include the raise of the levee being proposed along with the associated costs associated with those required features, allowing for the removal of the fragility curve in the analysis and the costs for the increases in the levee/floodwall height.

Just as with the Freeport system, costs for any modifications above these resiliency and raise options begin to escalate significantly since reconstruction would be required for providing additional protection from these features. These additional costs include highway raises, gravity

structures, closure structure replacement, replacement of I-wall, and additional pump stations, which are not incrementally justified.

The following tables display the economic evaluation for a range of alternatives beginning with "No Fail" resiliency measures (meaning that the levee/floodwall will not fail prior to overtopping) followed by raises to each reach. All are calculated at a FY 2015 price level and interest rate.

Based on the information provided in Table 2-10, the NED components for the Port Arthur and Vicinity CSRM are generally a "No Fail, One-Foot Raise" for the system. Net benefits for each reach range from $2.9 million to $50.7 million. Residual economic damages for the Port Arthur CSRM range from $3.3 to $10.0 million for 8-foot to10-foot I-Wall, $0.2 to $1.0 million at the Closure Structure, $7.1 to $16.3 million at the I-Wall near Valero, and $10.9 to $25.1 million at the Tank Farm.

2.4.3 Freeport and Vicinity CSRM

Just as with the alternative selection for the Orange-Jefferson CSRM, FWOP damages will have rough order of magnitude costs to identify NED benefits. The same costs per linear foot both length and height for both levees and floodwalls used for Orange-Jefferson were used for the next added 1- and 2-foot raises to the system. No environmental impacts were identified, and no mitigation costs were included in the comparison.

Costs for any modifications above these resiliency and raise options begin to escalate significantly since reconstruction would be required for providing additional protection from these features. These additional costs include features such as high performance turf reinforcement mats, replacement of the Tide gate, gravity structures, intake structures, and rebuilding the dock and floodwalls, which are not incrementally justified.

Table 2-11 displays the economic evaluation for a range of alternatives beginning with "No Fail" resiliency measures followed by raises to each reach. All are evaluated at a FY 2015 price level and interest rate. Just as with the Port Arthur CSRM, the primary determinant in differentiating benefits lies in the without-project damages, which is based on the fragility curve at each potential failure location. Additional determinants include the raise of the levee being proposed along with the associated costs associated with those required features, allowing for the removal of the fragility curve in the analysis and the costs for the increases in the levee/floodwall height.

Table 2-10. Economic Performance of Port Arthur and Vicinity CSRM
(FY 2015 Price Level/3.375 percent interest rate)

	8ft-10ft I-Wall Raise			Closure Structure Raise			I-Wall Raise Near Valero			I-Wall Raise Near Tank Farm		
	No Fail	**1-Foot Raise**	**2 -Foot Raise**	**No Fail**	**1- Foot Raise**	**2-Foot Raise**	**No Fail**	**1-Foot Raise**	**2-Foot Raise**	**No Fail**	**1-Foot Raise**	**2-Foot Raise**
INVESTMENT												
Estimated First Cost	$3,330,000	$8,915,000	$66,744,000	$3,804,000	$10,654,000	$22,822,000	$7,655,000	$8,948,000	$312,523,000	$2,756,000	$4,627,000	$188,878,000
Annual Interest Rate	3.375%	3.375%	3.375%	3.375%	3.375%	3.375%	3.375%	3.375%	3.375%	3.375%	3.375%	3.375%
Project Life (years)	50	50	50	50	50	50	50	50	50	50	50	50
Construction Period (months)	36	36	36	36	36	36	36	36	36	36	36	36
Interest During Construction	$170,000	$455,000	$3,404,000	$194,000	$543,000	$1,164,000	$390,000	$456,000	$15,938,000	$141,000	$236,000	$9,633,000
Investment Cost	$3,500,000	$9,370,000	$70,148,000	$3,998,000	$11,197,000	$23,986,000	$8,045,000	$9,404,000	$328,461,000	$2,897,000	$4,863,000	$198,511,000
Interest	$118,000	$316,000	$2,367,000	$135,000	$378,000	$810,000	$272,000	$317,000	$11,086,000	$98,000	$164,000	$6,700,000
Amortization	$28,000	$74,000	$556,000	$32,000	$89,000	$190,000	$64,000	$75,000	$2,604,000	$23,000	$39,000	$1,574,000
TOTAL ANNUAL COSTS	**$146,000**	**$391,000**	**$2,924,000**	**$167,000**	**$467,000**	**$1,000,000**	**$335,000**	**$392,000**	**$13,689,000**	**$121,000**	**$203,000**	**$8,273,000**
Without Project EAD	$23,413,000	$23,413,000	$23,413,000	$3,784,000	$3,784,000	$3,784,000	$61,867,000	$61,867,000	$61,867,000	$38,009,000	$38,009,000	$38,009,000
Residual EAD	$9,962,000	$5,730,000	$3,274,000	$995,000	$408,000	$156,000	$16,379,000	$10,813,000	$7,101,000	$25,130,000	$16,874,000	$10,893,000
Flood Reduction Benefits	$13,451,000	$17,683,000	$20,138,000	$2,788,000	$3,375,000	$3,628,000	$45,488,000	$51,054,000	$54,766,000	$12,879,000	$21,135,000	$27,116,000
TOTAL BENEFITS	**$13,451,000**	**$17,683,000**	**$20,138,000**	**$2,788,000**	**$3,375,000**	**$3,628,000**	**$45,488,000**	**$51,054,000**	**$54,766,000**	**$12,879,000**	**$21,135,000**	**$27,116,000**
NET BENEFITS	**$13,305,000**	**$17,292,000**	**$17,215,000**	**$2,622,000**	**$2,908,000**	**$2,628,000**	**$45,153,000**	**$50,662,000**	**$41,076,000**	**$12,758,000**	**$20,932,000**	**$18,843,000**
BENEFIT-COST RATIO	**92.1**	**45.2**	**6.9**	**16.7**	**7.2**	**3.6**	**135.8**	**130.2**	**4.0**	**106.4**	**104.1**	**3.3**

Table 2-11. Economic Performance of Freeport and Vicinity CSRM
(FY 2015 Price Level/3.375 percent interest rate)

	Dow Barge Canal Protection		Oyster Creek Levee Raise				East Storm Levee Raise				Freeport Dock Floodwall Raise		
	No Fail - Closure Structure		No Fail	1-Foot Raise	2 Foot Raise		No Fail	1-Foot Raise	2- Foot Raise		Partial Fail	No Fail	1-Foot Raise
INVESTMENT													
Estimated First Cost	$130,000,000		$1,663,000	$4,869,000	$54,244,000		$3,415,000	$6,530,000	$26,402,000		$1,500,000	$2,850,000	$150,000,000
Annual Interest Rate	3.375%		3.375%	3.375%	3.375%		3.375%	3.375%	3.375%		3.375%	3.375%	3.375%
Project Life (years)	50		50	50	50		50	50	50		50	50	50
Construction Period (months)	36		36	36	36		36	36	36		36	36	36
Interest During Construction	$6,630,000		$85,000	$248,000	$2,766,000		$174,000	$333,000	$1,346,000		$76,000	$145,000	$7,650,000
Investment Cost	$136,630,000		$1,748,000	$5,117,000	$57,010,000		$3,590,000	$6,863,000	$27,748,000		$1,576,000	$2,995,000	$157,650,000
Interest	$4,611,000		$59,000	$173,000	$1,924,000		$121,000	$232,000	$937,000		$53,000	$101,000	$5,321,000
Amortization	$1,083,000		$14,000	$41,000	$452,000		$28,000	$54,000	$220,000		$12,000	$24,000	$1,250,000
TOTAL ANNUAL COSTS	**$5,694,000**		**$73,000**	**$213,000**	**$2,376,000**		**$150,000**	**$286,000**	**$1,156,000**		**$66,000**	**$125,000**	**$6,570,000**
Without Project EAD	$166,660,000		$3,800,000	$3,800,000	$3,800,000		$1,701,000	$1,701,000	$1,701,000		$3,960,000	$3,960,000	$3,960,000
Residual EAD	$47,052,000		$1,717,000	$1,272,000	$933,000		$782,000	$581,000	$425,000		$3,771,000	$1,742,000	$1,333,000
Storm Reduction Benefits	$119,608,000		$2,083,000	$2,527,000	$2,866,000		$919,000	$1,121,000	$1,276,000		$189,000	$2,218,000	$2,627,000
TOTAL BENEFITS	**$119,608,000**		**$2,083,000**	**$2,527,000**	**$2,866,000**		**$919,000**	**$1,121,000**	**$1,276,000**		**$189,000**	**$2,218,000**	**$2,627,000**
NET BENEFITS	**$113,914,000**		**$2,010,000**	**$2,314,000**	**$490,000**		**$769,000**	**$835,000**	**$120,000**		**$123,000**	**$2,093,000**	**($3,944,000)**
BENEFIT-COST RATIO	**21.0**		**28.5**	**11.9**	**1.2**		**6.1**	**3.9**	**1.1**		**2.9**	**17.7**	**0.4**

Table 2-11. Economic Performance of Freeport and Vicinity CSRM (continued)
(FY 2015 Price Level/3.375 percent interest rate)

	Old River Levee Raise at Dow Thumb				South Storm Levee Raise			Tide Gate I-Wall Raise		
	No Fail	1-Foot Raise	2- Foot Raise		1-Foot Raise	2- Foot Raise		No Fail	1-Foot Raise	2- Foot Raise
INVESTMENT										
Estimated First Cost	$7,581,000	$8,294,000	$92,088,000		$3,325,000	$6,650,000		$1,720,000	$3,800,000	$35,644,000
Annual Interest Rate	3.375%	3.375%	3.375%		3.375%	3.375%		3.375%	3.375%	3.375%
Project Life (years)	50	50	50		50	50		50	50	50
Construction Period (months)	36	36	36		36	36		36	36	36
Interest During Construction	$387,000	$423,000	$4,696,000		$170,000	$339,000		$88,000	$194,000	$1,818,000
Investment Cost	$7,968,000	$8,717,000	$96,784,000		$3,495,000	$6,989,000		$1,808,000	$3,994,000	$37,462,000
Interest	$269,000	$294,000	$3,266,000		$118,000	$236,000		$61,000	$135,000	$1,264,000
Amortization	$63,000	$69,000	$767,000		$28,000	$55,000		$14,000	$32,000	$297,000
TOTAL ANNUAL COSTS	**$332,000**	**$363,000**	**$4,034,000**		**$146,000**	**$291,000**		**$75,000**	**$166,000**	**$1,561,000**
Without Project EAD	$2,517,000	$2,517,000	$2,517,000		$254,000	$254,000		$2,785,000	$2,785,000	$2,785,000
Residual EAD	$1,215,000	$913,000	$679,000		$182,000	$127,000		$1,184,000	$897,000	$675,000
Storm Reduction Benefits	$1,302,000	$1,604,000	$1,838,000		$72,000	$127,000		$1,601,000	$1,888,000	$2,110,000
TOTAL BENEFITS	**$1,302,000**	**$1,604,000**	**$1,838,000**		**$72,000**	**$127,000**		**$1,601,000**	**$1,888,000**	**$2,110,000**
NET BENEFITS	**$969,000**	**$1,241,000**	**($2,196,000)**		**($74,000)**	**($164,000)**		**$1,526,000**	**$1,721,000**	**$549,000**
BENEFIT-COST RATIO	**3.9**	**4.4**	**0.5**		**0.5**	**0.4**		**21.4**	**11.4**	**1.4**

Based on the information provided in the preceding table, the NED components for the Freeport and Vicinity CSRM are generally a "No Fail, One-Foot Raise" for the system. The exception is a "No Fail" closure structure at the Dow Barge Canal and a "No Fail" floodwall at Freeport Dock. No further consideration is given to the South Storm Levee, since neither of the two potential raises analyzed is economically justified. A "no fail" alternative was not analyzed, since this levee was not expected to fail prior to overtopping and it also has the highest crest elevation of 21 feet MSL. Residual economic damages are $47.1 million at the Dow Barge Canal, range from $0.9 to 1.7 million at the Oyster Creek Levee, range from $0.4 to $0.8 million at the East Storm Levee, $1.3 to $3.8 at Freeport Dock, $0.7 to $1.2 million at Old River Levee at the Dow thumb, and $0.7 to $1.2 million at the Tide Gate I-Wall.

2.4.4 Brazoria and Sabine Non-Structural

Surveys of aerial imagery for the three counties were done to look for the potential for buyouts. Buyouts would be ancillary to the implementation of new levees/floodwalls in Orange and Jefferson Counties and to the enhancement of features in the Freeport and Port Arthur systems. Buyout opportunities in Brazoria are virtually non-existent and very limited in both Orange and Jefferson Counties. Several structures in Jefferson have the potential for being bought out. All of these structures, however, are commercial and buying out these structures is very unlikely to be the economically viable. Figure 2-8 shows the potential for buyouts in Orange County. There are approximately 20 residential structures that could be potentially economically viable and are currently being evaluated. While some of the parcels appeared to have no structures located on them, inspection of county appraisal records in many cases showed improvements on many of these parcels. Visual inspections of aerial photos and further inspection of the appraisal records showed that many of these were agricultural improvements and would therefore not be subject to any permanent evacuation analysis. A quantitative analysis was conducted to determine the viability of any proposed evacuation. Water surface profiles and stage/probability functions were developed from the ADCIRC points that intersected those parcels of interest and imported into HEC-FDA along with depth-damage functions and structure files representing these structures of interest and evaluated. The original list of 20 structures was whittled down to six. Four of these structures were in the 2 % ACE, with the other two being in the 0.05 % ACE. Without-project EADs were estimated for these structures which totaled $8,700. Costs for buying out these structures were low-balled to include merely the appraised value of the structure plus $10,000 to demolish the structure. Annual costs for evacuating all six were $21,700, creating net benefits of -$13,000. Buying only the four in the 2 % ACE produced net benefits of -$8,600. Based on this analysis, any potential buyouts to be included in the TSP are eliminated. The results of the analysis are captured in Table 2-12.

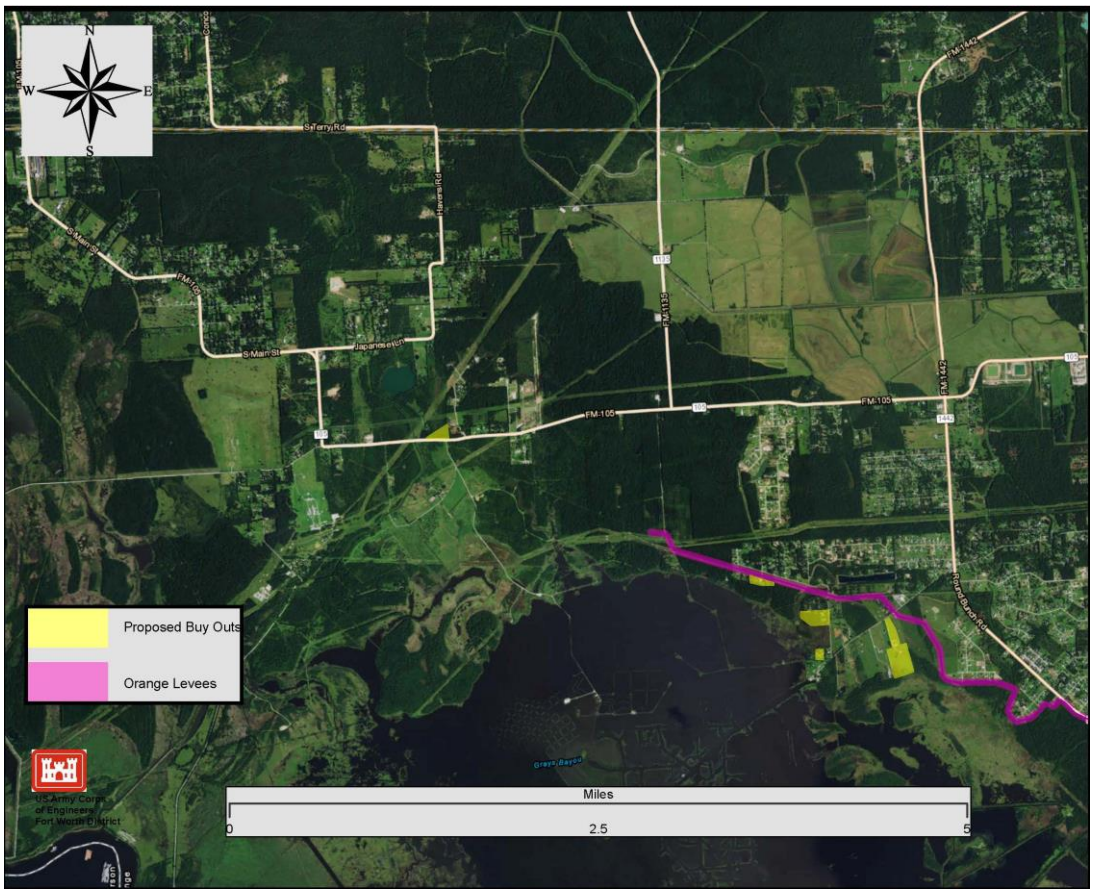


Figure 2-8. Potential Orange County Buyouts

Table 2-12. Non-structural Analysis

	0.02 to 0.01 % ACE Buyout	Total Buyout
INVESTMENT		
Estimated First Cost	$396,400	$511,900
Annual Interest Rate	3.375%	3.375%
Project Life (years)	50	50
Construction Period (months)	12	12
Interest During Construction	$7,200	$9,300
Investment Cost	$403,600	$521,200
Interest	$13,600	$17,600
Amortization	$3,200	$4,100
TOTAL ANNUAL COSTS	**$16,800**	**$21,700**
Without Project EAD	$8,700	$8,700
Residual EAD	$500	$0
Flood Reduction Benefits	$8,200	$8,700
TOTAL BENEFITS	**$8,200**	**$8,700**
NET BENEFITS	**($8,600)**	**($13,000)**
BENEFIT-COST RATIO	**0.5**	**0.4**

2.5 RISK PERFORMANCE OF PROPOSED ACTIONS

Engineer Regulation 1105-2-101 states that risk and uncertainty are intrinsic in water resources planning and design with inaccuracy in all measured or estimated values in project planning and design to some varying degrees. Invariably, the true values are different from any single, point values presently used in project formulation, evaluation, and design. The best estimates of key variables, factors, parameters, and data components in the planning and design of flood damage reduction projects are considered the "most likely" values. These values, however, are frequently based on small periods of record, sample sizes, and measurements that are subject to error.

The ER also states that risk analyses “captures and quantifies the extent of the risk and uncertainty in the various planning and design components of an investment project. The total effect of uncertainty on the project's design and economic viability can be examined and conscious decisions made reflecting an explicit tradeoff between risks and costs. Risk analysis can be used to compare plans in terms of the variability of their physical performance, economic success, and residual risks.”

Engineer Manual 1110-2-1619 identifies a number of potential sources of uncertainty. These include (1) uncertainty about future hydrologic events such as steam flow and rainfall; (2) uncertainty arising from the use of simplified models to describe complex hydraulic phenomena; (3) economic and social uncertainty, particularly the relationship between depth and inundation damage, inaccuracies in estimates of structure values and locations, and the predictability of how the public will respond to a flood; and (4) uncertainty about structural and geotechnical performance of water-control measures when subjected to rare storm events.

Uncertainty in the hydrology and hydraulics is addressed primarily by utilizing graphical exceedance probability functions which sets confidence limits for discharges at each discrete exceedance probability based on the equivalent record length. Uncertainty for hydrology and hydraulics is also addressed by assigning distributions to stage-damage functions. In the case of this study, the equivalent record length is set at 30 years and the error for the stage-damage functions is set at 0.5 feet. No fragility curves are assigned to the proposed levee, since flooding durations are short and it would be overtopped regardless for those rare events. Economic uncertainties are similarly managed with normal distributions with standard errors assigned to the depth-damage functions and by defining uncertainty parameters for first floor corrections, structure and content values. Uncertainties are further handled by changing, if necessary, the number of Monte Carlo simulations and by varying the range of ordinates in the aggregated stage-damage functions.

HEC-FDA produces project performance reports to display the hydrologic and hydraulic performance of a particular plan. Table 2-13 shows the project performance for the proposed levee raise. For the future without-project condition, the expected annual exceedance probability (AEP) for the Orange Jefferson CSRM ranges from 2.8 percent for Beaumont A to 11.4 percent for Jefferson Main. For the Port Arthur CSRM, the expected AEP ranges from 0.0 percent for the Closure Structure to 0.2 percent for the I-Wall near Valero. For the Freeport CSRM, the expected AEP ranges from 0.1 percent for the South Storm Levee to 6.0 percent for the Dow Barge Canal. Implementing the TSP reduces these expected AEP substantially.

The lack of any long-term performance of the existing conditions at the Orange-Jefferson CSRM shows that the area where levees/floodwalls are being proposed has anywhere from a 76 percent to 99.8 chance of being inundated in 50 years and a virtually zero chance of not being exceeded by the 0.2 percent event. The long-term risk for the existing Port Arthur system is somewhat less, but the long-term risk for the existing Freeport system has a wide variation from the different potential failure locations ranging from 3.7 percent for the South Storm Levee to 95.5 percent for the Dow Barge Canal. Long-term risk is reduced considerably for all three CSRMs with implementation of the TSP. The non-exceedance probability for the 0.2 % ACE also increases substantially with the implementation of the TSP. These results are also all listed in Table 2-13.

2.5.1 Performance of the Tentatively Selected Plan under Relative Sea Level Change

An analysis was conducted in order to assess how the TSP might perform under various relative sea level change (RSLC) scenarios. As part of this analysis, H&H determined what engineering guidance would need to be for levee/floodwall heights based on EC 1110-2-6067 and CFR 2000 Title 44 and additional guidance for the three CSRMs to address the projected 50-year RSLC under low, intermediate, and high scenarios. These required heights were averaged so that they could be compared to the recommended heights specified in the TSP. Table 2-14 shows these required engineering heights in the left side of the table, while the right side specifies the recommend heights based on the criteria to determine the TSP and the difference between the two sets of criteria. Under the three RSLC scenarios, the TSP addresses relative sea level change well for the Port Arthur and Freeport CSRMs. The Orange-Jefferson CSRM shows deficiencies ranging from 2.24 to 4.77 feet. These results are also in Table 2-14.

Table 2-13. Project Performance for the Tentatively Selected Plan

Without Project

		Long-Term Risk (years)			Assurance by Event					
Damage Reach	**Expected AEP**	**10**	**30**	**50**	**10%**	**4%**	**2%**	**1%**	**0.4%**	**0.2%**
Orange -Jefferson CSRM										
Orange 3	7.7%	55.0%	86.4%	98.2%	85.4%	11.4%	2.1%	0.5%	0.2%	0.0%
Beaumont A	2.8%	24.8%	50.9%	75.9%	100.0%	77.7%	35.3%	13.0%	3.8%	1.8%
Jefferson Main	11.4%	70.2%	95.1%	99.8%	55.7%	5.3%	1.3%	0.4%	0.2%	0.0%
Port Arthur CSRM										
8ft-10ft I-Wall	0.1%	0.5%	1.2%	2.4%	100.0%	100.0%	100.0%	99.8%	94.2%	82.7%
Closure Structure	0.0%	0.0%	0.1%	0.1%	100.0%	100.0%	100.0%	100.0%	99.5%	98.0%
I-Wall Near Valero	0.2%	2.3%	6.8%	11.0%	100.0%	100.0%	99.9%	97.1%	75.4%	55.9%
I-Wall Near Tank Farm	0.1%	1.1%	2.7%	5.2%	100.0%	100.0%	100.0%	99.3%	87.2%	70.7%
Freeport CSRM										
Dow Barge Canal	6.0%	46.3%	78.9%	95.5%	83.6%	59.4%	43.1%	27.2%	12.3%	6.9%
East Storm Levee	0.5%	4.7%	11.3%	21.3%	100.0%	99.9%	97.1%	84.8%	59.2%	42.4%
Freeport Dock	1.2%	10.9%	25.1%	43.8%	100.0%	99.1%	84.2%	52.7%	21.6%	11.3%
Old River at Dow Thumb	0.7%	7.1%	16.8%	30.8%	100.0%	98.9%	91.8%	75.9%	46.4%	29.3%
South Storm Levee	0.1%	0.7%	2.2%	3.7%	100.0%	100.0%	100.0%	100.0%	97.7%	89.4%
Tide Gate I-Wall	0.8%	7.4%	17.5%	32.0%	100.0%	98.7%	91.0%	74.5%	44.9%	27.8%
Oyster Creek	0.6%	6.2%	14.9%	27.5%	100.0%	99.8%	94.2%	76.1%	49.7%	34.8%

Table 2-13. Project Performance for the Tentatively Selected Plan (continued)

With Project

		Long-Term Risk (years)			Assurance by Event					
Damage Reach	**Expected AEP**	**10**	**30**	**50**	**10%**	**4%**	**2%**	**1%**	**0.4%**	**0.2%**
Orange -Jefferson CSRM										
Orange 3 New Levee (11-Foot)	0.2%	1.7%	1.7%	4.1%	100.0%	100.0%	100.0%	98.8%	87.0%	72.5%
Beaumont A New Levee (12-Foot)	0.1%	0.8%	2.1%	4.1%	100.0%	100.0%	100.0%	99.9%	95.9%	86.9%
Jefferson Main New Levee (11-Foot)	0.1%	0.8%	1.9%	3.8%	100.0%	100.0%	100.0%	99.7%	96.1%	89.3%
Port Arthur CSRM										
8- to 10-foot I-Wall Raise (1-foot)	0.4%	0.4%	1.2%	2.0%	100.0%	100.0%	100.0%	100.0%	99.8%	98.3%
Closure Structure Raise (1-foot)	0.0%	0.4%	1.1%	2.1%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
I-Wall Raise Near Valero (1-foot)	0.1%	0.5%	1.6%	2.7%	100.0%	100.0%	100.0%	100.0%	99.0%	94.3%
I-Wall Raise Near Tank Farm (1-foot)	0.1%	0.7%	2.1%	3.6%	100.0%	100.0%	100.0%	100.0%	97.4%	89.5%
Freeport CSRM										
Dow Barge Canal Gate Structure	0.6%	5.8%	16.4%	25.9%	100.0%	100.0%	97.7%	80.9%	45.2%	27.1%
East Storm Levee Raise (1-foot)	0.2%	1.6%	4.8%	7.9%	100.0%	100.0%	100.0%	98.7%	87.3%	72.7%
Freeport Dock (No Fail)	0.5%	4.8%	11.5%	21.7%	100.0%	100.0%	98.9%	87.0%	53.5%	32.9%
Old River Levee Raise at Dow Thumb (1-foot)	0.3%	2.5%	7.4%	12.1%	100.0%	100.0%	99.9%	97.3%	77.1%	55.6%
South Storm Levee	-	-	-	-	-	-	-	-	-	-
Tide Gate I-Wall - 1-foot	0.3%	2.5%	6.1%	11.9%	100.0%	100.0%	100.0%	97.5%	77.6%	55.8%
Tide Gate I-Wall Raise (1-foot)	0.3%	3.3%	8.0%	15.4%	100.0%	100.0%	99.5%	92.3%	69.8%	52.3%

Table 2-14. Tentatively Selected Plan Relative Sea Level Change Project Performance

	Engineering Criteria - FT NAVD				TSP Project Performance				
	Without RSLC	***Low RSLC***	***Intermediate RSLC***	***High RSLC***	***Recommended Height - TSP***	***Surplus/ Deficit (Without)***	***Surplus/ Deficit (Low)***	***Surplus/Deficit (Intermediate)***	***Surplus/ Deficit (High)***
Orange-Jefferson Floodwall	12.50	13.43	13.98	15.77	11.00	-1.50	-2.43	-2.98	-4.77
Orange-Jefferson Levee	12.33	13.24	13.83	15.59	11.00	-1.33	-2.24	-2.83	-4.59
Port Arthur Floodwall	13.25	16.10	16.72	18.25	19.00	5.75	2.90	2.28	0.75
Port Arthur Levee	12.94	13.86	14.43	16.20	18.00	5.06	4.14	3.58	1.80
Dow Barge Canal	15.85	16.58	17.15	18.93	26.00	10.15	9.43	8.85	7.08
Freeport Levee	16.42	17.13	17.66	19.45	20.75	4.33	3.63	3.09	1.30
Oyster Creek	16.41	16.41	16.41	16.41	19.00	2.59	2.59	2.59	2.59

2.5.2 Life Safety Considerations

The population at risk (PAR) is displayed by project area is included in Table 2-15. The PAR was developed based on the 2010 census blocks that intersect the damageable properties in the project areas. This population reflects the residential population that may be exposed to flood risk. This does not include transportation routes for evacuation or those at work in commercial or industrial areas. The PAR the same is due to the fact that virtually the same structures being protected by the levee at Jefferson Main are also being protected by the existing hurricane flood protection system at Port Arthur. In the case of Jefferson Main, the levee is protecting against surge coming up the Neches River. For Port Arthur, damages are being quantified from the failure locations along the HFPS. In the case of Beaumont A – C, all three reaches fall within the same census block.

Table 2-15. Population at Risk by CSRM

CSRM	Population at Risk
Orange-Jefferson	
Orange 1	17,014
Orange 2	13,952
Orange 3	60,044
Beaumont A	2,078
Beaumont B	2,078
Beaumont C	2,078
Jefferson Main	116,762
Port Arthur	116,762
Freeport	16,559

Broad warnings as storm systems develop are coordinated through various agencies, such as the National Weather Service, which provides reports to the essential print and electronic media outlets. The National Weather Service generally releases tropical storm watches 48 hours in advance of any anticipated onset of tropical storm force winds. Since outside preparedness activities become difficult once winds reach tropical storm force, warnings are issued 36 hours in advance of any anticipated onset of tropical storm force winds. The Texas Department of Public Safety's Division of Emergency Management coordinates the state emergency management program, as well as implementing the Texas Emergency Tracking Network (ETN), part of a comprehensive data-management system that provides real-time information before, during, and after a disaster. Orange and Jefferson Counties are members of the Southeast Texas Altering Network, which can alert users of emergencies, plant operations, traffic, and weather information or other outreach from emergency management. Both counties as well as Brazoria, also have emergency management departments that engage their respective cities, including specific evacuation plans and processes.

2.5.3 Critical Infrastructure

The following describes the existing critical infrastructure in each project area. Critical infrastructure listed here includes industrial and manufacturing facilities as well as public facilities. This is a qualitative discussion of the future without-project condition focused on the impacts associated with potential storm surge flooding. The inventory of critical infrastructure came from information derived from the Homeland Security Infrastructure Program (HSIP), an infrastructure geospatial data inventory. The critical infrastructure is reported for the project areas by type (school, chemical manufacturing, etc.). A North American Industry Classification System (NAICS) code is included in the full listing of the inventory is at the end of this appendix. The project areas are listed by county; Orange-Jefferson CSRM includes Orange and Jefferson County; Port Arthur and Vicinity CSRM includes Jefferson County; Freeport includes Brazoria County.

Orange – Jefferson CSRM (Orange and Jefferson County)

Public Facilities – Orange County

- 20 Schools
- 14 Law enforcement
- 2 Hospitals/6 nursing homes
- 11 Fire stations

Industrial and Manufacturing – Orange County

- 20 Chemical manufacturing
- 5 Electric generation
- 0 Petroleum refining
- 1 Airport

Public Facilities – Jefferson County

- 42 Schools
- 19 Law enforcement
- 13 Hospitals/7 nursing homes
- 26 Fire stations

Industrial and Manufacturing – Jefferson County

- 54 Chemical manufacturing
- 1 Electric generation
- Petroleum refining
- 1 Airport

Some of the significant industrial and manufacturing facilities located in Orange-Jefferson CSRM include Exxon Mobil, DuPont, Honeywell, Firestone, Petrochemical, Chevron, Phillips, Laxness, Solvay Solexis, and Entergy. Exxon Mobil, located in Beaumont, Texas, on the Neches River, processes 345,000 barrels of crude oil per day and produces 2.5 billion gallons of gasoline annually.

Port Arthur and Vicinity CSRM (Jefferson County)

Public Facilities – Jefferson County

- 42 Schools
- 19 Law enforcement
- 13 Hospitals/7 nursing homes
- 26 Fire stations

Industrial and Manufacturing – Jefferson County

- 54 Chemical manufacturing
- 1 Electric generation
- Petroleum refining
- 1 Airport

Significant industrial and manufacturing facilities located in the Port Arthur and Vicinity CSRM include Valero, Premcor, Total, Motiva Enterprises and Huntsman Petrochemical. Jack Brooks Regional Airport is also in the project area. Motiva is the largest petroleum refinery in the United States, with a capacity of approximately 600,000 barrels of crude oil per day.

Freeport and Vicinity CSRM (Brazoria County)

Public Facilities – Brazoria County

- 6 Schools
- 3 Law enforcement
- 0 Hospitals/0 nursing homes
- 2 Fire stations

Industrial and Manufacturing – Brazoria County

- 24 Chemical manufacturing
- 0 Electric generation
- 0 Petroleum refining

Significant industrial and manufacturing facilities located in the Freeport and Vicinity CSRM include Petroleum Reserve, Dow Chemical, Freeport LNG, Huntsman Gulf Chemicals, Phillips 66 Liquefied Petroleum Gas (LPG) Terminal, SI Group, and NALCO. A detailed description of each critical facility is not provided here; however, to explain one in some detail, Dow Chemical is the largest integrated chemical manufacturing complex in the western hemisphere. The Freeport site produces 44 percent of Dow's products sold in the U.S. and 20 percent of the company's products sold globally. A listing of these facilities is located at the end of this appendix.

2.6 CONCLUSION AND IDENTIFICATION OF THE TSP

The primary planning objective to select the TSP is to reduce economic damage for the 50-year period of analysis. The TSP also meets the Federal objective of maximizing net benefits. Alternatives were evaluated to show reductions in expected annual damages towards a plan that maximizes net benefits. To that end, the following summarizes each of the CSRMs with their respective alternatives with the highest net benefits to be included in the TSP.

2.6.1 Orange-Jefferson CSRM

- Orange 3 New Levee – 11-Foot Levee/Floodwall
- Jefferson Main New Levee –11-Foot Levee/Floodwall
- Beaumont A New Levee –12-Foot Levee/Floodwall

2.6.2 Port Arthur and Vicinity CSRM

- 8-10 ft I-Wall Raise (1-Foot)
- Closure Structure Raise (1-Foot)
- I-Wall Raise Near Valero (1-Foot)
- I-Wall Raise Near Tank Farm (1-Foot)

2.6.3 Freeport and Vicinity CSRM

- Dow Barge Canal Gate Structure
- Oyster Creek Levee Raise (1-Foot)
- East Storm Levee Raise (1-Foot)
- Freeport Dock No Fail
- Old River Levee Raise at Dow Thumb (1-Foot)
- Tide Gate I-Wall Raise (1-Foot)

The following tables display each of the maximized NED alternatives which comprise the TSP beginning with the Orange-Jefferson CSRM, then the Port Arthur and Vicinity CSRM, and finally the Freeport and Vicinity CSRM (Tables 2-16 through 2-18).

Table 2-16. TSP for Orange-Jefferson CSRM
(FY 2015 Price Level/3.375 percent interest rate)

	Orange 3	Jefferson Main	Beaumont A
	11 - Foot	11 - Foot	12 - Foot
INVESTMENT			
Estimated First Cost	$246,811,000	$65,726,000	$70,202,000
Annual Interest Rate	3.375%	3.375%	3.375%
Project Life (years)	50	50	50
Construction Period (months)	36	36	36
Interest During Construction	$12,587,000	$3,352,000	$3,580,000
Investment Cost	$259,398,000	$69,078,000	$73,782,000
Interest	$8,755,000	$2,331,000	$2,490,000
Amortization	$2,056,000	$548,000	$585,000
O&M ($/year)*	$4,084,000	$371,000	
TOTAL ANNUAL COSTS	**$14,895,000**	**$3,250,000**	**$3,075,000**
Without Project EAD	$29,987,000	$28,231,000	$6,937,000
Residual EAD	$5,242,000	$2,520,000	$870,000
Storm Reduction Benefits	$24,745,000	$25,711,000	$6,067,000
TOTAL BENEFITS	$24,745,000	**$25,711,000**	**$6,067,000**
NET BENEFITS	**$9,851,000**	**$22,461,000**	**$2,992,000**
BENEFIT-COST RATIO	**1.7**	**7.9**	**2.0**

Table 2-17. TSP for Port Arthur and Vicinity CSRM
(FY 2015 Price Level/3.375 percent interest rate)

	8ft-10ft I-Wall	Closure Structure	I-Wall Near Valero	I-Wall Near Tank Farm
	1-Foot Raise	1-Foot Raise	1-Foot Raise	1-Foot Raise
INVESTMENT				
Estimated First Cost	$8,915,000	$10,654,000	$8,948,000	$4,627,000
Annual Interest Rate	3.375%	3.375%	3.375%	3.375%
Project Life (years)	50	50	50	50
Construction Period (months)	36	36	36	36
Interest During Construction	$455,000	$543,000	$456,000	$236,000
Investment Cost	$9,370,000	$11,197,000	$9,404,000	$4,863,000
Interest	$316,000	$378,000	$317,000	$164,000
Amortization	$74,000	$89,000	$75,000	$39,000

	8ft-10ft I-Wall	Closure Structure	I-Wall Near Valero	I-Wall Near Tank Farm
	1-Foot Raise	1-Foot Raise	1-Foot Raise	1-Foot Raise
TOTAL ANNUAL COSTS	**$391,000**	**$467,000**	**$392,000**	**$203,000**
Without Project EAD	$23,413,000	$3,784,000	$61,867,000	$38,009,000
Residual EAD	$5,730,000	$408,000	$10,813,000	$16,874,000
Flood Reduction Benefits	$17,683,000	$3,375,000	$51,054,000	$21,135,000
TOTAL BENEFITS	**$17,683,000**	**$3,375,000**	**$51,054,000**	**$21,135,000**
NET BENEFITS	**$17,292,000**	**$2,908,000**	**$50,662,000**	**$20,932,000**
BENEFIT-COST RATIO	**45.2**	**7.2**	**130.2**	**104.1**

As stated earlier, the TSP for the Orange-Jefferson CSRM includes a 113,600 LF of levee and 29,800 LF of floodwall (total of 27 miles) combination at a levee crest of 11 feet MSL at Orange 3. This has an estimated first cost of $246.8 million annualized to $14.9 million. Total annual benefits are $24.7 million which produces $9.85 million in annual net benefits and benefit-to-cost ratio of 1.7. Also included are a 41,700 LF of levee and 16,200 LF of floodwall (11 miles) combination at Jefferson Main with 11-foot crest elevation and an estimated first cost of $65.7 million with annual costs of $3.3 million. Total annual benefits come to $25.7 million, leaving an estimate of $22.5 million in net benefits and 7.9 benefit-to-cost ratio. Finally, it also includes a combination of 3,100 LF of levee and 200 LF of floodwall (0.6 mile) with a 12-foot crest elevation with first cost of $70.2 million, annual costs of $3.1 million, annual benefits of $6.1 million, and annual net benefits of $3.0 million, and a 2.0 benefit-to-cost ratio.

Table 2-18. TSP for Freeport and Vicinity CSRM
(FY 2015 Price Level/3.375 percent interest rate)

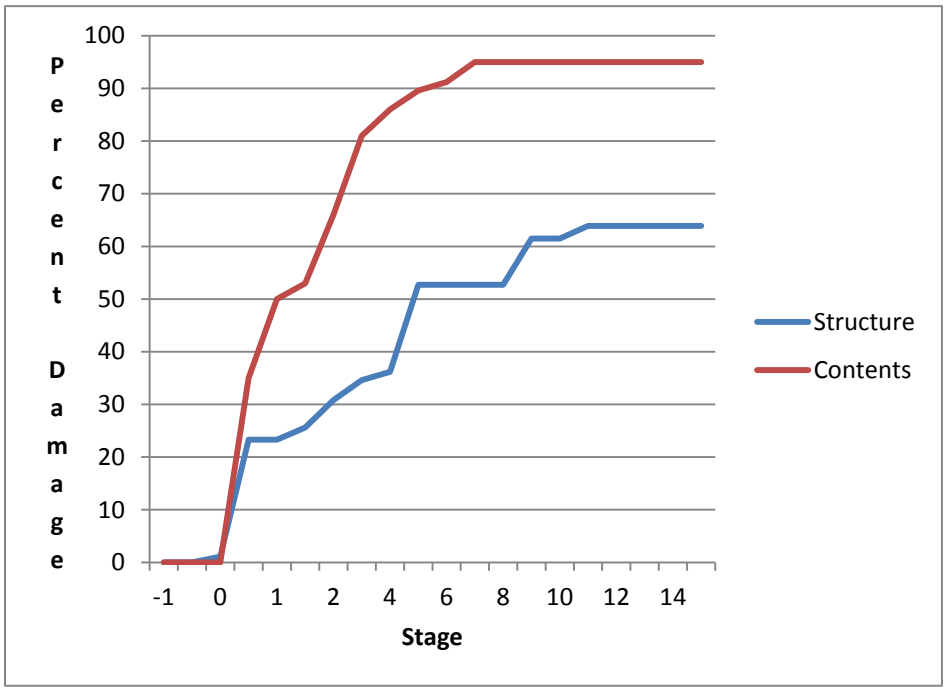
	Dow Barge Canal	Oyster Creek Levee	East Storm Levee	Freeport Dock	Old River Levee at Dow Thumb	Tide Gate I-Wall
	No Fail - Closure Structure	**1-Foot Raise**	**1-Foot Raise**	**No Fail**	**1-Foot Raise**	**1-Foot Raise**
INVESTMENT						
Estimated First Cost	$130,000,000	$4,869,000	$6,530,000	$2,850,000	$8,294,000	$3,800,000
Annual Interest Rate	3.375%	3.375%	3.375%	3.375%	3.375%	3.375%
Project Life (years)	50	50	50	50	50	50
Construction Period (months)	36	36	36	36	36	36
Interest During Construction	$6,630,000	$248,000	$333,000	$145,000	$423,000	$194,000
Investment Cost	$136,630,000	$5,117,000	$6,863,000	$2,995,000	$8,717,000	$3,994,000
Interest	$4,611,000	$173,000	$232,000	$101,000	$294,000	$135,000
Amortization	$1,083,000	$41,000	$54,000	$24,000	$69,000	$32,000
TOTAL ANNUAL COSTS	**$5,694,000**	**$213,000**	**$286,000**	**$125,000**	**$363,000**	**$166,000**
Without Project EAD	$166,660,000	$3,800,000	$1,701,000	$3,960,000	$2,517,000	$2,785,000
Residual EAD	$47,052,000	$1,272,000	$581,000	$1,742,000	$913,000	$897,000
Storm Reduction Benefits	$119,608,000	$2,527,000	$1,121,000	$2,218,000	$1,604,000	$1,888,000
TOTAL BENEFITS	**$119,608,000**	**$2,527,000**	**$1,121,000**	**$2,218,000**	**$1,604,000**	**$1,888,000**
NET BENEFITS	**$113,914,000**	**$2,314,000**	**$835,000**	**$2,093,000**	**$1,241,000**	**$1,721,000**
BENEFIT-COST RATIO	**21.0**	**11.9**	**3.9**	**17.7**	**4.4**	**11.4**

The TSP for the Port Arthur and Vicinity CSRM includes a one-foot raise above the existing elevation of 8-foot to 10-foot I-Wall, 7,500 LF of 15-foot wide scour pad, and 2,000 LF of levee raised one foot. First costs are $8.9 million, annual costs are $0.4 million, and annual benefits are $17.7 million. Net benefits are $17.3 million with a benefit-to-cost ratio of 45.2. Next is a one-foot raise above the existing elevation at the Port Arthur Closure Structure. The structure would be replaced and 300 LF of 100-foot wide scour pad along with 12,000 LF of levee raised one foot. First costs are $10.7 million, annual costs are $0.5 million, annual benefits of $3.4 million with net benefits of $2.9 million, and a benefit-to-cost ration of 7.2. Next is another one-foot raise above the existing elevation at the I-Wall near Valero with 5,000 LF of 15-foot scour pad and 3,000 LF of levee raised one foot. First costs are $8.9 million annualized to $0.4 million, with annual benefits of $51.1 million. Net benefits are $50.7 million and the benefit-to-cost ratio us 130.2. Finally, the TSP would include a one-foot raise above the existing elevation near the Port Arthur Tank Farm and have 1,800 LF of 15-foot-wide scour pad and 7,000 feet of levee raised one foot. First costs are $4.6 million, annual costs are $0.2 million with annual benefits of $21.1 million. Net benefits are $20.9 million with a 104.1 benefit-to-cost ratio.

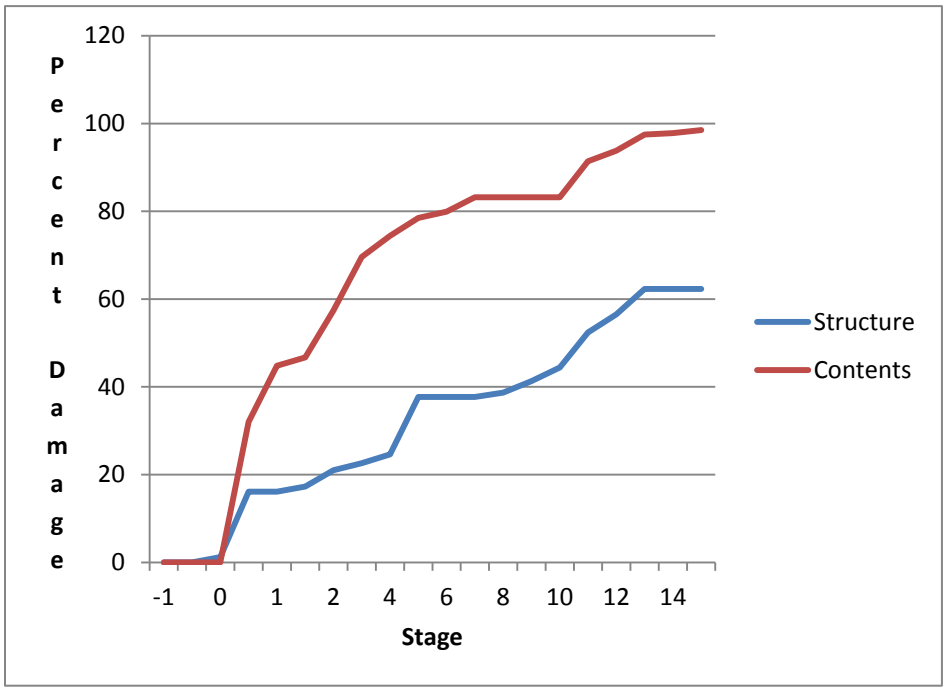
The TSP for the Freeport and Vicinity CSRM includes a No-Fail closure structure at the Dow Barge Canal with two sector gates approximately 500 feet long and 80 feet in width for vessel traffic with an estimated first cost of $130 million, annual costs of $5.7 million, annual benefits of $119.6 million and $113.9 in annual net benefits. The benefit-to-cost ratio is 21. Also included are a one-foot raise above the existing elevation at the Oyster Creek Levee 10,000 LF in length. First costs are $4.9 million, annual costs are $0.2 million, annual benefits of $2.5 million and net benefits of $2.3 million, with a benefit-to-cost ration of 11.9. Next, it would include a one-foot raise above the existing elevation at the East Storm Levee and 13,115 LF of High Performance Turf Reinforcement Mat (HPTRM). First costs are $6.5 million, annual costs are $0.3 million, annual benefits are $1.1, and net benefits of $0.8 million with a 3.9 benefit-to cost ratio. Next is a 3,000 LF of No-Fail floodwall at Freeport Dock with first costs of $2.9 million, annual costs of $0.1 million and annual benefits of $2.2 million. Net benefits are $2.1 million and the benefit to-cost ratio is 17.7. Next would be a one-foot raise above the existing elevation at the Old River Levee at the Dow Thumb with a distance of 3,000 LF. First costs are $8.3 million, annual costs $0.4 million, annual benefits are $1.6 million, and net benefits are $1.2 million with a benefit-to-cost ratio of 4.4. Finally, it would also include a reconstructed I-Wall raised one foot above the existing elevation, 700 LF in length. It would also have 2,000 LF of levee raised one foot. First costs are $3.8 million, annual costs are $0.2 million, annual benefits are $1.9 million with $1.7 million in net benefits, and a 11.4 benefit-to-cost ratio.

2.7 DEPTH DAMAGE FUNCTIONS

One Story Residence – Slab Foundation



Two Story Residences – Slab Foundation



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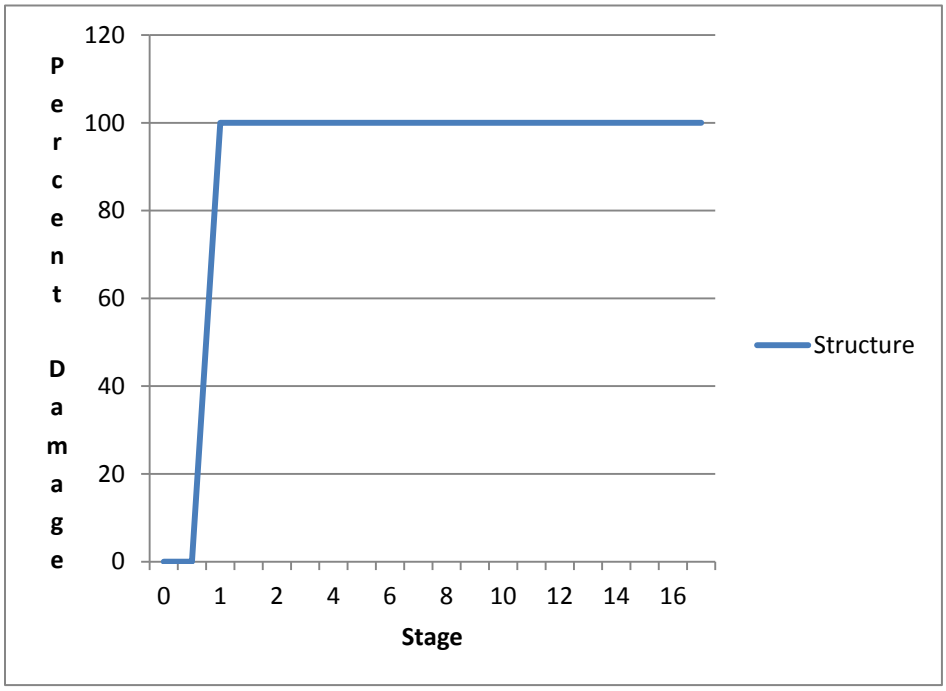
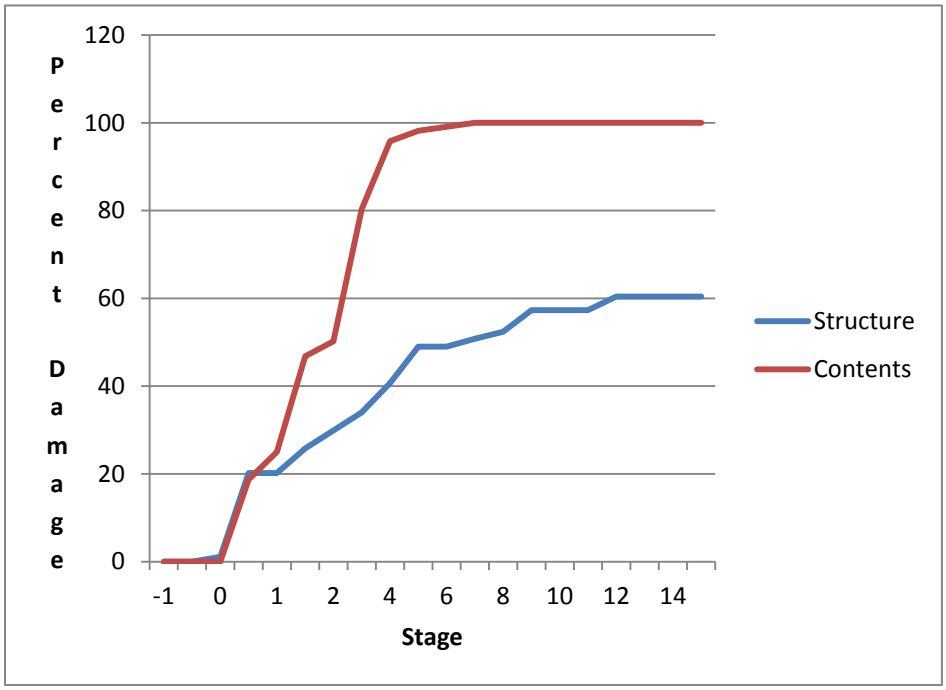
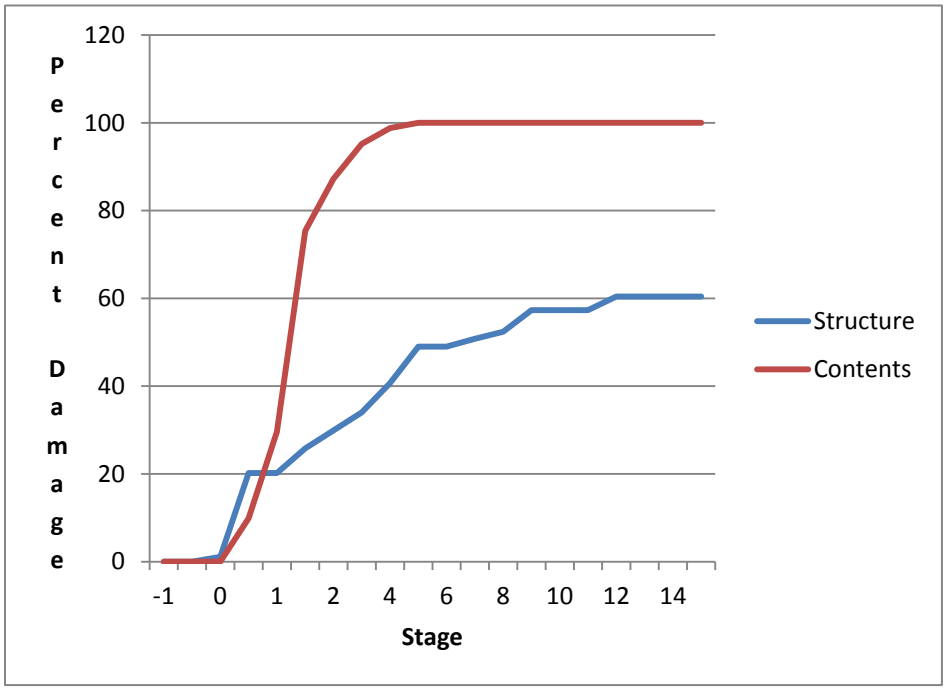


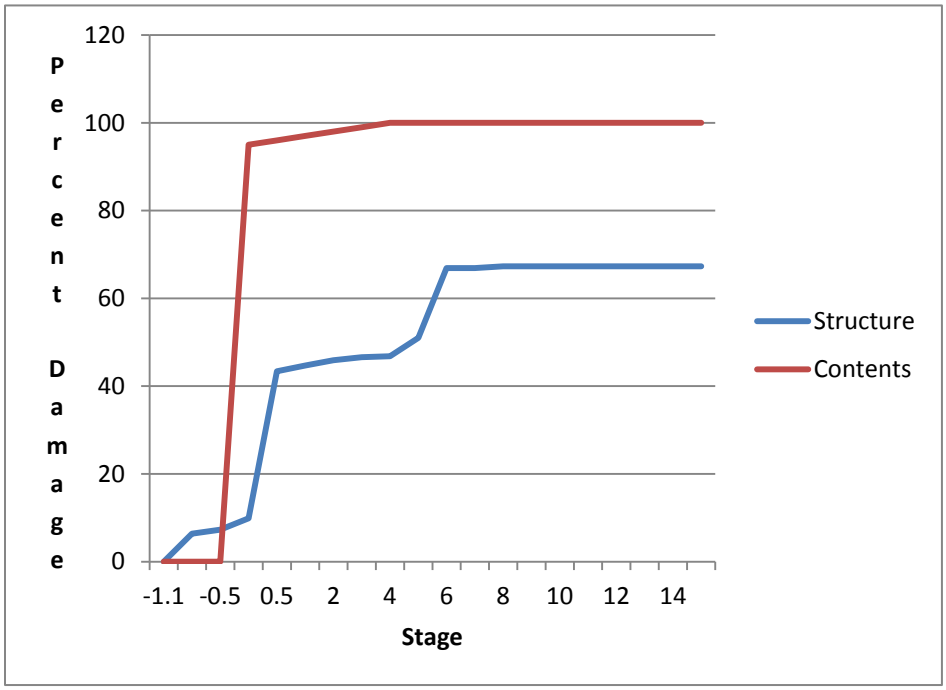
Eating Establishments



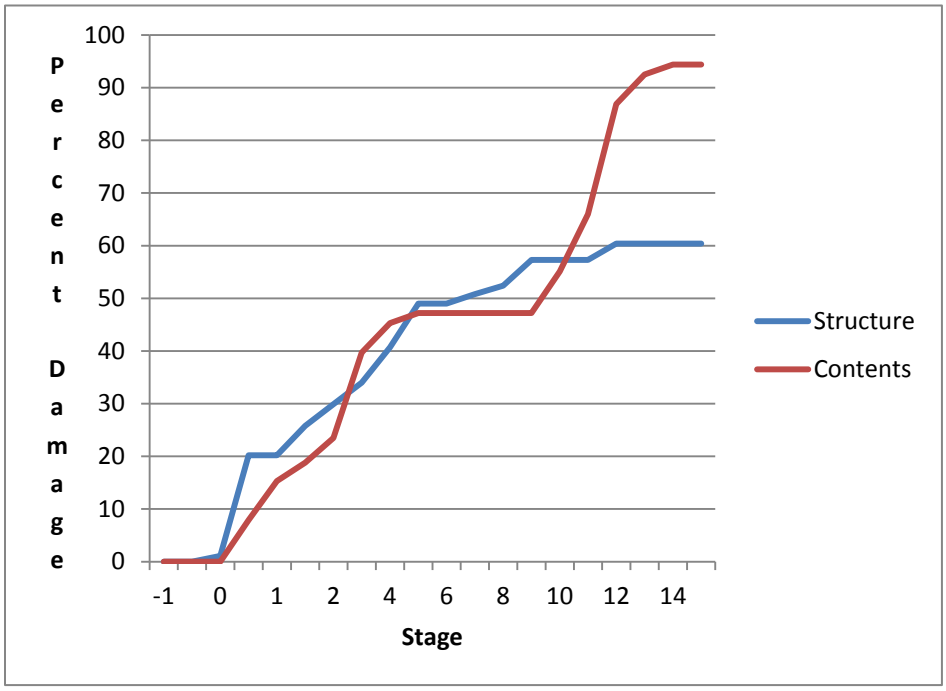
Grocery Stores



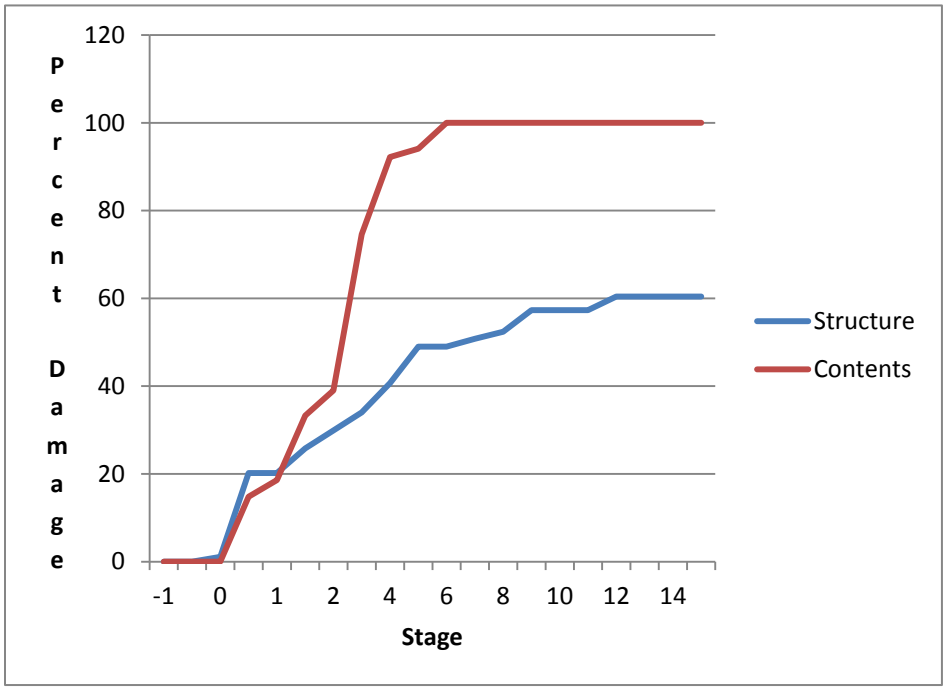
Mobile Residence



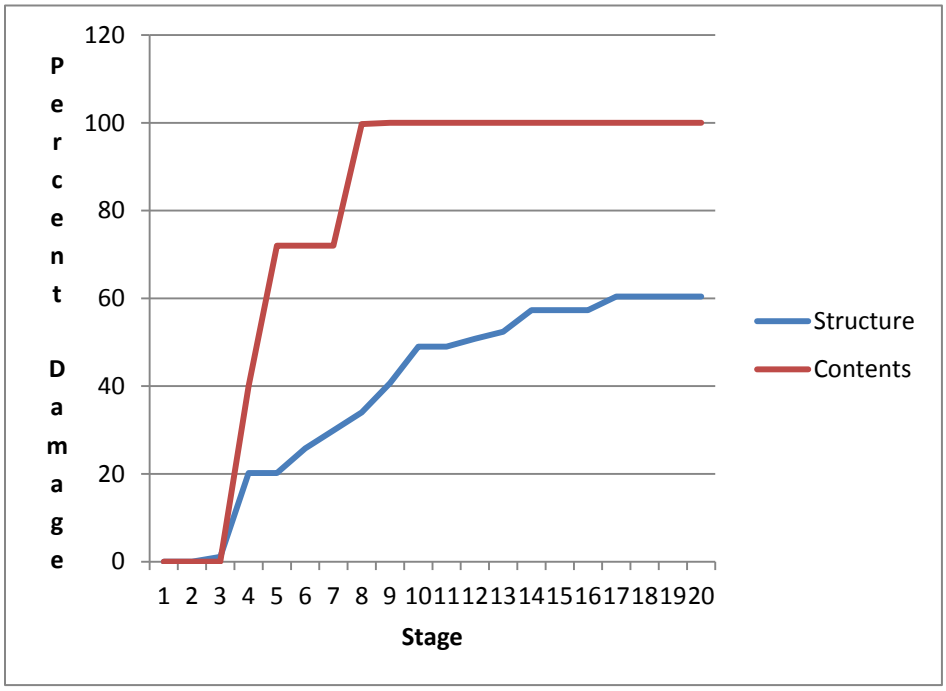
Multi-Family Residence



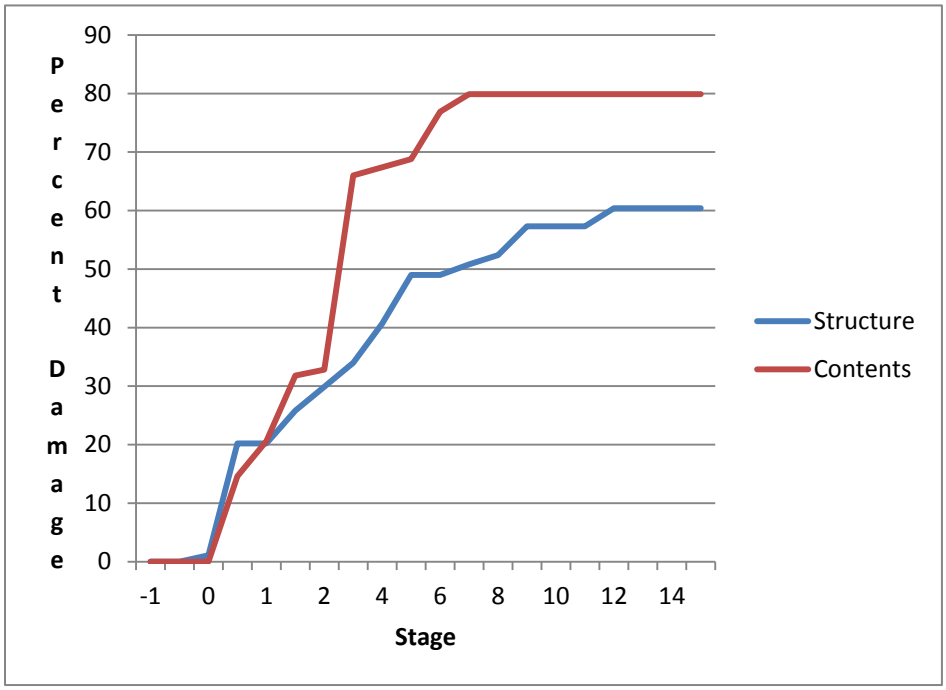
Professional Buildings



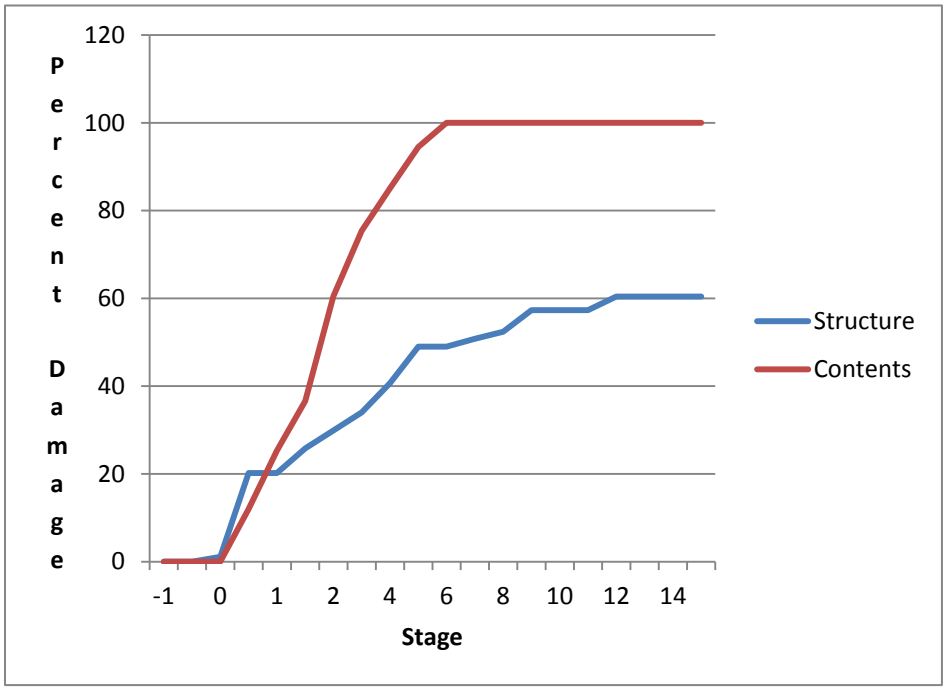
Public Buildings



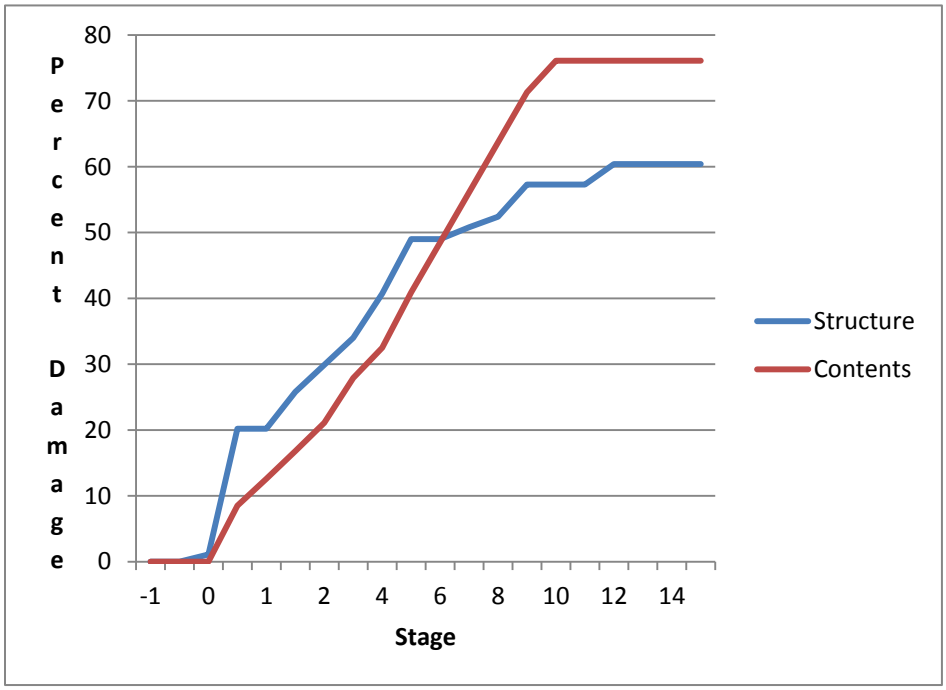
Repair



Retail



Warehouse



2.8 LISTING OF CRITICAL INFRASTRUCTURE BY COUNTY

2.8.1 Orange

Chemical Manufacturing		
Business Name	**City**	**NAICS Category**
DuPont Sabine River Works	Orange	Pesticide and Other Agricultural Chemical Manufacturing
Solvay America Inc.	Orange	All Other Basic Inorganic Chemical Manufacturing
Latex Supply Inc.	Orange	All Other Basic Inorganic Chemical Manufacturing
Red Bird Supply, Inc.	Orange	Soap and Other Detergent Manufacturing
A Schulman Inc.	Orange	Plastics Material and Resin Manufacturing
Alloy Polymers, Inc.	Orange	Plastics Material and Resin Manufacturing
Clark & Company Inc.	Orange	All Other Basic Inorganic Chemical Manufacturing
Bourg Distributing Inc.	Bridge City	Polish and Other Sanitation Good Manufacturing
Hyett Manufacturing and Instrument Company, Inc.	Bridge City	All Other Basic Inorganic Chemical Manufacturing
Chevron Phillips Chemical Company LP	Orange	Plastics Material and Resin Manufacturing
Fine Line Colognes	Orange	Toilet Preparation Manufacturing
Lanxess Corporation Rubber Division	Orange	Synthetic Rubber Manufacturing
Invista S.A.R.L.	West Orange	Plastics Material and Resin Manufacturing
Chem32 LLC	West Orange	All Other Basic Inorganic Chemical Manufacturing
E. I. DuPont De Nemours and Company	Orange	Plastics Material and Resin Manufacturing
Nitrogen National	Orange	Industrial Gas Manufacturing
Lanxess Corp	Orange	All Other Basic Organic Chemical Manufacturing
Invista Capital Management, LLC	Orange	All Other Basic Organic Chemical Manufacturing
Invista S.A.R.L.	Orange	Plastics Material and Resin Manufacturing
Chevron Phillips Chemical Company LP	Orange	Plastics Material and Resin Manufacturing
Electric Generation		
Engineered Carbons Echo Cogeneration	Little Cypress	
Entergy Texas	Bridge City	
AirLiquide - Sabine Cogeneration LP	West Orange	
DuPont - Sabine River Works	West Orange	
SRW Cogeneration	West Orange	
Hospitals		
Harbor Hospital of Southeast Texas	Orange	
Memorial Hermann Baptist Orange Hospital	Orange	

Nursing Homes	
Golden Years Assisted Living	Orange
Orange Villa Nursing and Rehabilitation	Orange
Pinehurst Nursing and Rehabilitation	Orange
Sabine House	Orange
The Meadows of Orange	Orange
Answered Prayer	Orange
Schools	
Little Cypress Jr. High	Orange
Bridge City High School	Bridge City
Bridge City Middle School	Bridge City
Little Cypress-Mauriceville High School	Orange
Little Cypress Elementary School	Orange
Little Cypress Intermediate	Orange
Oak Forest Elementary	Vidor
Vidor Middle School	Vidor
West Orange-Stark Elementary	Orange
West Orange-Stark Middle School	Orange
West Orange-Stark High School	Orange
North Early Learning Center	Orange
Orangefield Elementary	Orangefield
Orangefield High School	Orangefield
Orangefield Jr. High	Orangefield
Hatton Elementary	Bridge City
Bridge City Elementary	Bridge City
Bridge City Intermediate	Bridge City
OISD DAEP	Bridge City
Tekeo Academy of Accelerated Studies	Orange
Law Enforcement	
Orange County Sheriff Dept./Orange County Jail	Orange
Bridge City ISD Police Dept.	Bridge City
Orange Police Dept.	Orange
Rose City Police Dept.	Rose City
Vidor ISD Police Dept.	Vidor
Pine Forest Police Dept.	Vidor
Pinehurst Police Dept.	Orange
Vidor Police Dept.	Vidor
West Orange Police Dept.	Orange
Bridge City Police Dept.	Bridge City
Orange County Constable - Precinct 1	Orange
Orange County Constable - Precinct 2	Orange
Orange County Constable - Precinct 3	Orange
Orange County Constable - Precinct 4	Vidor

Fire Departments	
Bridge City Volunteer Fire and Rescue - Orangefield Station	Orange
Orange County Emergency Services District Station 1	Vidor
Orange County Emergency Services District Station 2	Vidor
Pinehurst Volunteer Fire Dept.	Orange
West Orange Volunteer Fire Dept.	West Orange
Little Cypress Fire and Rescue Station 1	Orange
Bridge City Volunteer Fire and Rescue	Bridge City
McLewis Volunteer Fire Dept.	Orange
City of Orange Fire Dept. Station 1	Orange
City of Orange Fire Dept. Station 2	Orange
City of Orange Fire Dept. Station 3	Orange
Airport	
Orange County Airport	Orange

2.8.2 Jefferson

Chemical Manufacturing		
Business Name	**City**	**NAICS Category**
Air Liquide America L.P.	Port Neches	Industrial Gas Manufacturing
Air Liquide America L.P.	Beaumont	Industrial Gas Manufacturing
Air Liquide Industrial U.S. LP	Nederland	Industrial Gas Manufacturing
Air Products and Chemicals, Inc.	Port Arthur	Industrial Gas Manufacturing
Arkema, Inc.	Beaumont	All Other Basic Inorganic Chemical Manufacturing
Ashland Elastomers LLC	Port Neches	Synthetic Rubber Manufacturing
Ashland Inc.	Port Neches	All Other Basic Organic Chemical Manufacturing
BASF Petro Chemicals	Port Arthur	All Other Miscellaneous Chemical Product and Preparation Manufacturing
BASF Petro Chemicals	Port Arthur	All Other Miscellaneous Chemical Product and Preparation Manufacturing
BASF Corporation	Beaumont	All Other Basic Organic Chemical Manufacturing
BASF Corporation	Port Arthur	All Other Basic Organic Chemical Manufacturing
Brock Specialty Services, Ltd.	Beaumont	All Other Basic Inorganic Chemical Manufacturing
Calabrian Corporation	Port Neches	All Other Basic Organic Chemical Manufacturing

Chemical Manufacturing		
Business Name	**City**	**NAICS Category**
Chemtrade Refinery Services Inc.	Beaumont	All Other Basic Inorganic Chemical Manufacturing
Chemtreat, Inc.	Nederland	All Other Miscellaneous Chemical Product and Preparation Manufacturing
Chevron Phillips Chemical Company LP	Port Arthur	All Other Miscellaneous Chemical Product and Preparation Manufacturing
DuPont Performance Elastomers L.L.C.	Nederland	Synthetic Rubber Manufacturing
Elegant Designer Essences	Port Arthur	Toilet Preparation Manufacturing
Elixir Incense	Port Arthur	All Other Miscellaneous Chemical Product and Preparation Manufacturing
Ethyl Additives Corporation	Port Arthur	All Other Basic Organic Chemical Manufacturing
Faubion Veterinary Clinic	Nederland	Pharmaceutical Preparation Manufacturing
Flint Hills Resources Port Arthur LLC	Port Arthur	All Other Basic Organic Chemical Manufacturing
G V C Holdings Inc.	Port Neches	Synthetic Rubber Manufacturing
Huntsman Corporation	Port Neches	Plastics Material and Resin Manufacturing
In Your Element Photography	Port Neches	All Other Basic Inorganic Chemical Manufacturing
Ineos Americas LLC	Port Arthur	All Other Miscellaneous Chemical Product and Preparation Manufacturing
J & M Resources	Port Arthur	Toilet Preparation Manufacturing
J F D Enterprises, Inc.	Groves	Toilet Preparation Manufacturing
Kbr Technical Services, Inc.	Beaumont	All Other Miscellaneous Chemical Product and Preparation Manufacturing
Kmtex	Port Arthur	All Other Basic Inorganic Chemical Manufacturing
La Designs	Port Arthur	Toilet Preparation Manufacturing
Nature's Secret	Port Arthur	Medicinal and Botanical Manufacturing
Neo Fuels	Port Arthur	Petrochemical Manufacturing
Oci Partners LP	Nederland	Cyclic Crude, Intermediate, and Gum and Wood Chemical Manufacturing
Pd Glycol LP	Beaumont	Plastics Material and Resin Manufacturing
Penny's Style	Port Arthur	Toilet Preparation Manufacturing
Perfume Palace	Port Arthur	Toilet Preparation Manufacturing
Praxair, Inc.	Groves	Industrial Gas Manufacturing
Pro Star Industries, Inc.	Port Arthur	Polish and Other Sanitation Good Manufacturing
Rbf Port Neches LLC	Port Neches	Petrochemical Manufacturing
Reliable Polymer Services, LP	Port Arthur	Synthetic Rubber Manufacturing
Sally Beauty Supply LLC	Port Arthur	Toilet Preparation Manufacturing
Savage Services Corporation	Port Arthur	All Other Basic Inorganic Chemical Manufacturing

Chemical Manufacturing		
Business Name	**City**	**NAICS Category**
Scan Tech, Inc.	Nederland	All Other Miscellaneous Chemical Product and Preparation Manufacturing
Service Offshore, Inc.	Beaumont	Paint and Coating Manufacturing
Smith and Thome Cardiovascular Consultants, L.L.P.	Port Arthur	Pharmaceutical Preparation Manufacturing
Sophia's International LLC	Port Neches	Toilet Preparation Manufacturing
Sunrose Scents	Nederland	Toilet Preparation Manufacturing
Texas Brine Company LLC	Beaumont	All Other Basic Inorganic Chemical Manufacturing
Texas Petrochemicals LP	Port Neches	All Other Basic Organic Chemical Manufacturing
Texas Petrochemicals LP	Port Neches	All Other Basic Organic Chemical Manufacturing
The Chemours Company Fc LLC	Beaumont	Synthetic Rubber Manufacturing
The Valspar Corporation	Beaumont	Paint and Coating Manufacturing
Worldwide Sorbent Products, Inc.	Port Arthur	Plastics Material and Resin Manufacturing
Petroleum Refining		
Exxon Mobil Refining & Supply Co.	Beaumont	
Total Petrochemicals Inc.	Port Arthur	
Motiva Enterprises LLC	Port Arthur	
Premcor Refining Group	Port Arthur	
Valero Refining Co.	Port Arthur	
Electric Generation	**City**	
JCO Oxides Olefins Plant	Port Neches	
Entergy Texas	Beaumont	
Public Schools	**City**	
Al Price State Juvenile Correctional Facility	Beaumont	
Jefferson County Youth Academy	Beaumont	
Preschool Center	Groves	
Groves Elementary	Groves	
Groves Middle School	Groves	
Van Buren Elementary	Groves	
Highland Park Elementary	Nederland	
Nederland High School	Nederland	
Alternative Education School	Nederland	
Helena Park Elementary	Nederland	
Hillcrest Elementary	Nederland	
Lanham Elementary	Nederland	
Central Middle School	Nederland	
Wilson Middle School	Nederland	
Dowling Elementary	Port Arthur	
Houston Elementary	Port Arthur	

Chemical Manufacturing		
Business Name	**City**	**NAICS Category**
Port Arthur Alternative Center	Port Arthur	
Stilwell Tech Center	Port Arthur	
Memorial High School	Port Arthur	
Tekeo Academy of Accelerated Studies	Port Arthur	
DeQueen Elementary	Port Arthur	
Jefferson Middle School	Port Arthur	
Lee Elementary	Port Arthur	
Travis Elementary	Port Arthur	
Tyrrell Elementary	Port Arthur	
Wheatley School Of Early Childhood Programs	Port Arthur	
Lincoln Middle School	Port Arthur	
Taft Elementary	Port Arthur	
Austin Middle School	Port Arthur	
Tekeo Academy of Accelerated Studies	Port Arthur	
Tekeo Academy of Accelerated Studies	Port Arthur	
Bob Hope School	Port Arthur	
Performing Arts School Of Technology	Port Arthur	
Staff Sergeant Lucien Adams Elementary	Port Arthur	
Washington Elementary	Port Arthur	
Memorial 9th Grade Academy at Austin	Port Arthur	
Woodcrest Elementary	Port Neches	
Port Neches Elementary	Port Neches	
Port Neches Middle School	Port Neches	
Port Neches-Groves High School	Port Neches	
Ridgewood Elementary	Port Neches	
Alter School	Port Neches	
Nursing Homes	**City**	
Gulf Healthcare Center	Port Arthur	
Magnolia Manor	Groves	
Oak Grove Nursing Home	Groves	
Senior Rehabilitation and Skilled Nursing Center	Port Arthur	
Cypress Glen East Nursing and Rehabilitation	Port Arthur	
Cypress Glen Nursing and Rehabilitation	Port Arthur	
Rose House	Port Arthur	
Hospitals	**City**	
Beaumont Bone and Joint Institute	Beaumont	
Christus Spohn Hospital - Saint Elizabeth	Beaumont	
Christus Spohn Hospital - Saint Mary	Port Arthur	
Dubuis Hospital of Beaumont	Beaumont	
Dubuis Hospital of Port Arthur	Port Arthur	

Chemical Manufacturing		
Business Name	**City**	**NAICS Category**
HealthSouth Rehabilitation Hospital - Beaumont	Beaumont	
Kate Dishman Rehabilitation Hospital	Beaumont	
Memorial Hermann Baptist Hospital	Beaumont	
Memorial Hermann Baptist Hospital - Behavioral Health Center	Beaumont	
Mid-Jefferson Extended Care Hospital	Nederland	
Promise Hospital of Southeast Texas	Nederland	
Renaissance Hospital - Groves	Groves	
The Medical Center of Southeast Texas	Port Arthur	
Law Enforcement	**City**	
Lamar University Police Dept.	Beaumont	
Beaumont Police Dept.	Beaumont	
Groves Police Dept.	Groves	
Port of Beaumont Port Authority Police Dept.	Beaumont	
Port Neches Police Department	Port Neches	
Bureau of Alcohol Tobacco & Firearms - Beaumont Field Office	Beaumont	
US Customs and Border Protection - Port of Entry - Port Arthur	Port Arthur	
Port Arthur Police Dept.	Port Arthur	
Jefferson County Sheriff's Office	Beaumont	
Beaumont ISD Police Dept.	Beaumont	
Nederland Police Department	Nederland	
Texas Dept. of Public Safety	Beaumont	
Jefferson County Constable - Precinct 1	Beaumont	
Jefferson County Constable - Precinct 2	Port Arthur	
Jefferson County Constable - Precinct 4	Beaumont	
Jefferson County Constable - Precinct 6	Beaumont	
Jefferson County Constable - Precinct 7	Beaumont	
Jefferson County Constable - Precinct 8	Port Arthur	
US Marshal's Service - Beaumont	Beaumont	
Fire Departments	**City**	
Port Arthur Fire Dept. Central Station	Port Arthur	
Beaumont Fire and Rescue Station 1	Beaumont	
Nederland Fire and Rescue	Nederland	
Beaumont Fire and Rescue Station 10	Beaumont	
Beaumont Fire and Rescue Station 11	Beaumont	
Beaumont Fire and Rescue Station 14	Beaumont	
Beaumont Fire and Rescue Station 2	Beaumont	
Beaumont Fire and Rescue Station 3	Beaumont	
Beaumont Fire and Rescue Station 4	Beaumont	

Chemical Manufacturing		
Business Name	**City**	**NAICS Category**
Beaumont Fire and Rescue Station 5	Beaumont	
Beaumont Fire and Rescue Station 6	Beaumont	
Beaumont Fire and Rescue Station 7	Beaumont	
Beaumont Fire and Rescue Station 7	Beaumont	
Beaumont Fire and Rescue Station 9	Beaumont	
Groves Fire Dept.	Groves	
Jefferson Volunteer Fire Dept.	Nederland	
LaBelle - Fannett Volunteer Fire/Emergency Medical Services - Substation	Beaumont	
Lamar Institute of Technology Regional Fire Academy	Beaumont	
Port Arthur Fire Dept. Station 1	Port Arthur	
Port Arthur Fire Dept. Station 2	Port Arthur	
Port Arthur Fire Dept. Station 3	Port Arthur	
Port Arthur Fire Dept. Station 4	Port Arthur	
Port Arthur Fire Dept. Station 5	Port Arthur	
Port Arthur Fire Dept. Station 6	Port Arthur	
Port Arthur Fire Dept. Station 8	Port Arthur	
Port Neches Fire Dept.	Port Arthur	

2.8.3 Brazoria

Chemical Manufacturing		
Business Name	**City**	**NAICS Category**
L C Huntsman-Cooper	Freeport	Plastics Material and Resin Manufacturing
Ineos Americas LLC	Freeport	All Other Basic Inorganic Chemical Manufacturing
K-Bin, Inc.	Freeport	Plastics Material and Resin Manufacturing
Air Liquide Large Industries U.S. LP	Freeport	Industrial Gas Manufacturing
Air Liquide Industrial U.S. LP	Freeport	Industrial Gas Manufacturing
S F Sulphur Company	Freeport	All Other Basic Inorganic Chemical Manufacturing
Nalco Energy Services L P	Freeport	All Other Miscellaneous Chemical Product and Preparation Manufacturing
Services Enterprise	Freeport	Polish and Other Sanitation Good Manufacturing
Air Liquide America L.P.	Freeport	Industrial Gas Manufacturing
Shintech Incorporated	Freeport	Plastics Material and Resin Manufacturing
Air Liquide Large Industries U.S. LP	Freeport	Industrial Gas Manufacturing
Air Liquide Large Industries U.S. LP	Freeport	Industrial Gas Manufacturing
Samdac Industries	Freeport	Plastics Material and Resin Manufacturing
Si Group, Inc.	Freeport	Petrochemical Manufacturing

Chemical Manufacturing		
Business Name	**City**	**NAICS Category**
The Dow Chemical Company	Freeport	All Other Basic Inorganic Chemical Manufacturing
Avon	Freeport	Toilet Preparation Manufacturing
Solvay USA, Inc.	Freeport	All Other Basic Inorganic Chemical Manufacturing
The Dow Chemical Company	Freeport	Plastics Material and Resin Manufacturing
Matheson Tri-Gas, Inc.	Freeport	Industrial Gas Manufacturing
Vencorex U.S., Inc.	Freeport	All Other Basic Organic Chemical Manufacturing
Vencorex U.S., Inc.	Freeport	All Other Basic Organic Chemical Manufacturing
BASF Corporation	Freeport	All Other Basic Organic Chemical Manufacturing
Ineos	Freeport	All Other Miscellaneous Chemical Product and Preparation Manufacturing
Americas Styrenics LLC	Freeport	Plastics Material and Resin Manufacturing
Schools	**City**	
Brazosport High School	Freeport	
OA Fleming Elementary	Freeport	
Freeport Intermediate	Freeport	
Jane Long Elementary	Freeport	
Velasco Elementary	Freeport	
O'Hara Lanier Middle School	Freeport	
Fire Departments	**City**	
Oyster Creek Volunteer Fire Dept.	Freeport	
Freeport Fire and Emergency Medical Services Dept.	Freeport	
Law Enforcement	**City**	
Freeport City Marshals Office	Freeport	
Freeport Police Dept.	Freeport	
Brazoria County Constable - Precinct 1	Freeport	

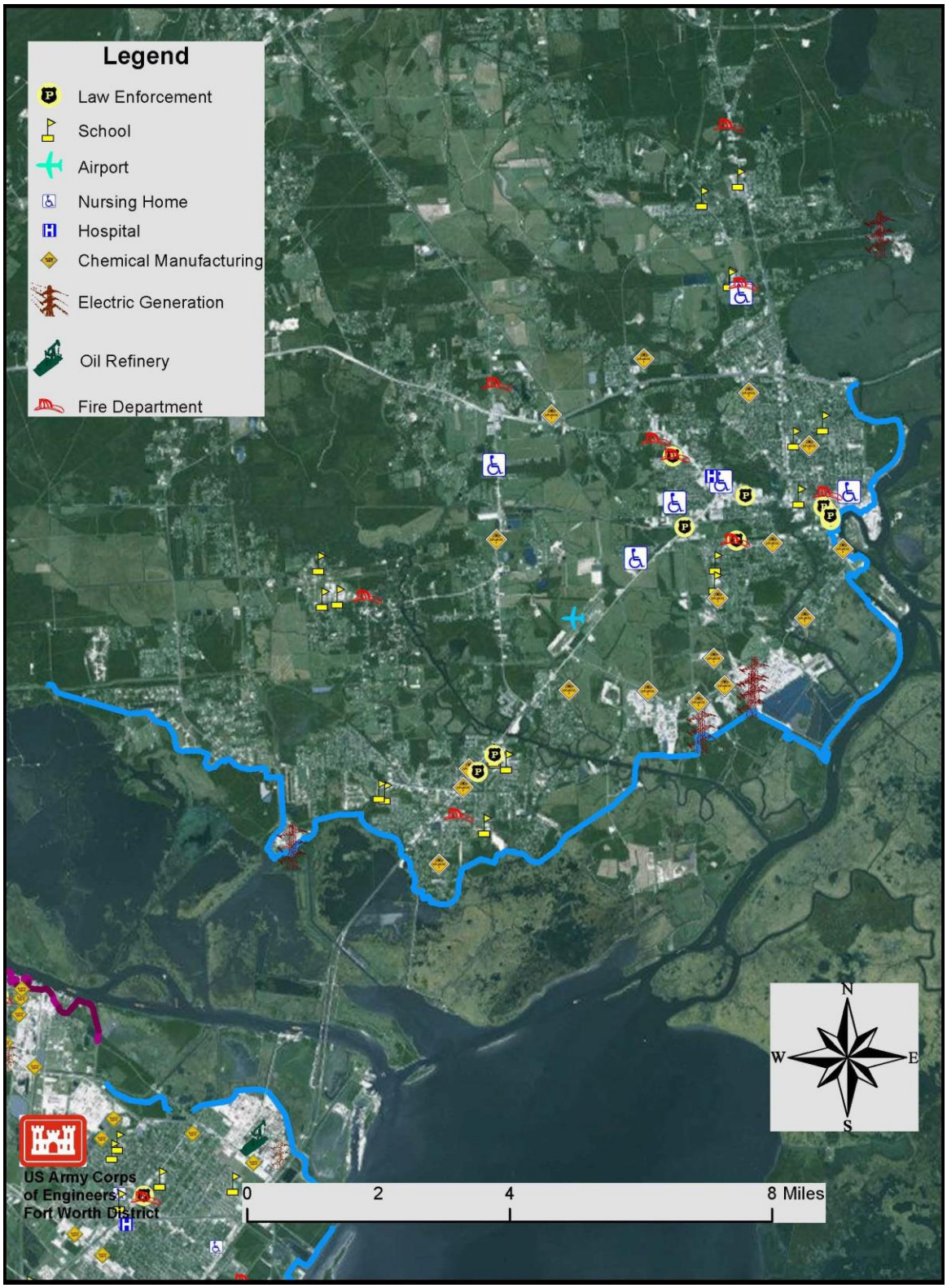


Figure 2-9. Orange County Critical Infrastructure

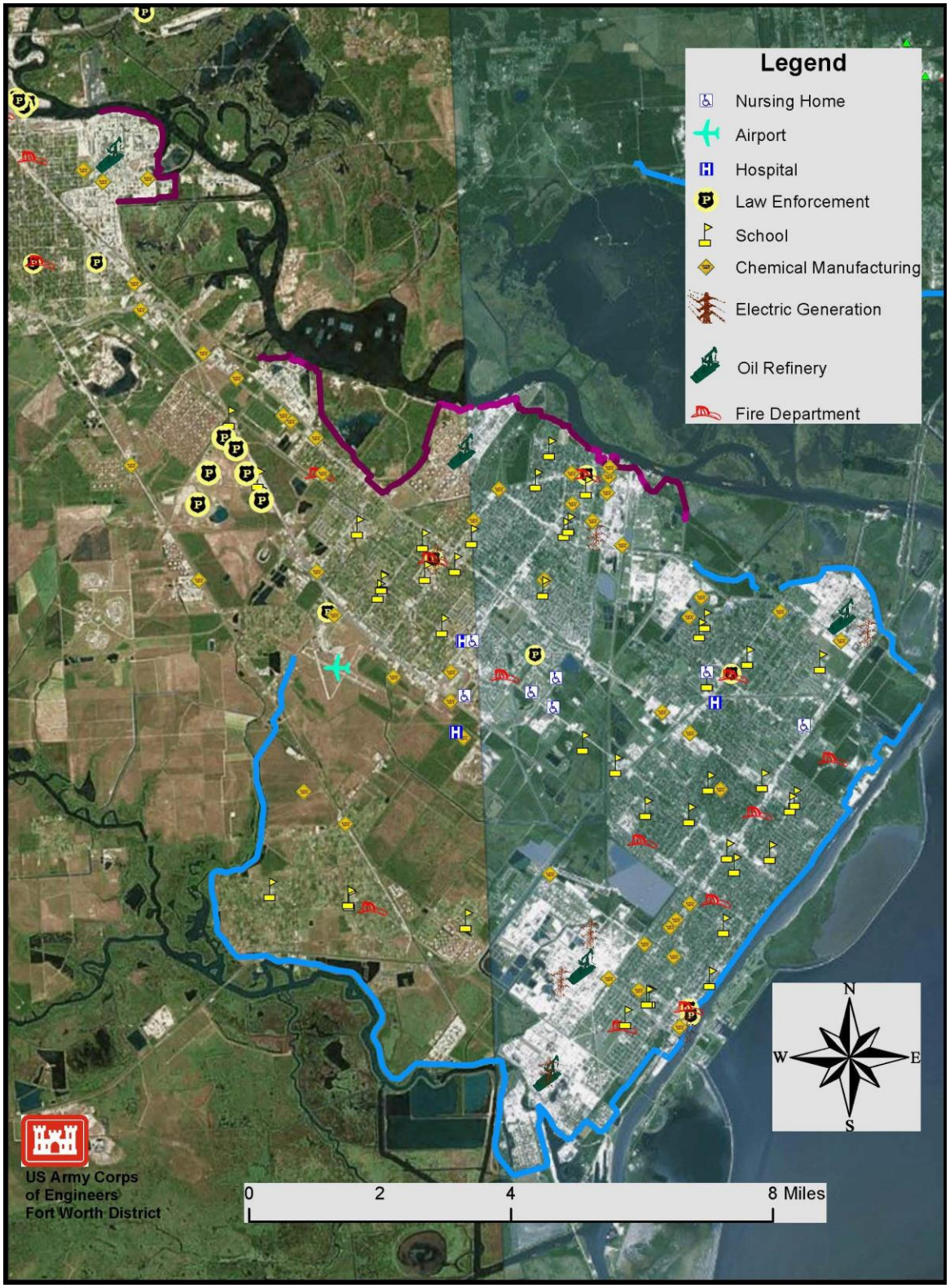


Figure 2-10. Jefferson County Critical Infrastructure

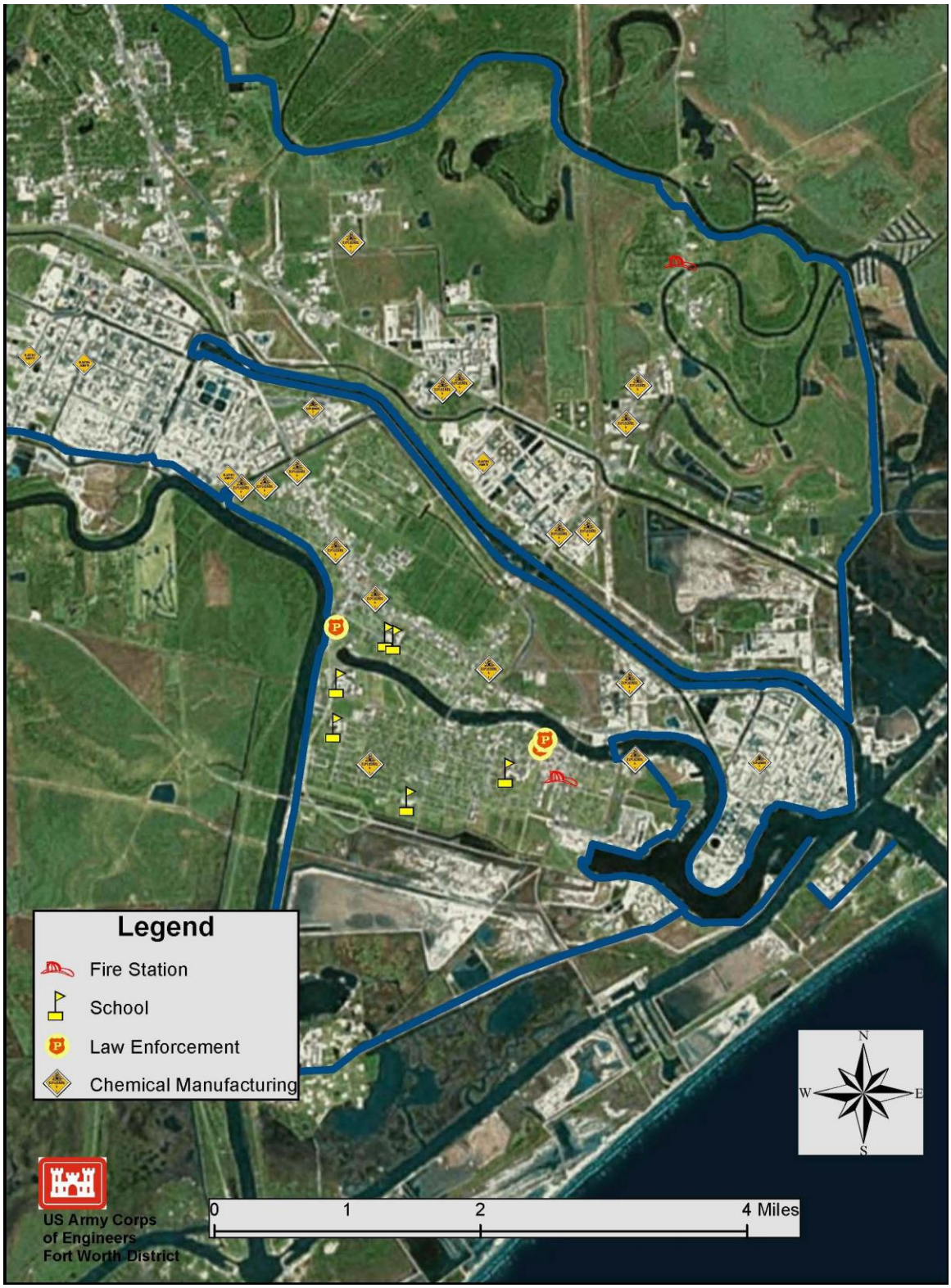


Figure 2-11. Brazoria County Critical Infrastructure

Sabine Pass to Galveston Bay, Texas
Coastal Storm Risk Reduction and Ecosystem Restoration
Draft Integrated Feasibility Report and Environmental Impact Study

Draft Appendix D

Engineering Design, Cost Estimates, and Cost Risk Analysis

September 2015

US Army Corps
of Engineers
Galveston District

Sabine Pass to Galveston Bay, Texas Coastal Storm Risk Management and Ecosystem Restoration

Engineering Appendix

for

Draft Integrated Feasibility Report – Environmental Impact Statement

September 2015

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List of Acronyms

ADCIRC	ADvanced CIRCulation (Model)
ADM	Agency Decision Milestone
AEP	Annual Exceedance Probability
ASTM	American Society for Testing and Materials
ATR	Agency Technical Review
CFR	Code of Federal Regulations
bpd	barrels per day
cfs	cubic feet per second
CPT	cone penetration test
CSRM	Coastal Storm Risk Management
DIFR-EIS	Draft Integrated Feasibility Report and Environmental Impact Statement
DOWSMM	Desktop Off-Channel Wetland Salinity Mitigation Model
EC	Engineering Circular
EM	Engineering Manual
EoC	End of Construction
EPA	U.S. Environmental Protection Agency
ER	Engineering Regulation
ERDC-CHL	Engineer Research and Design Center - Coastal Hydraulics Laboratory
ETL	Engineering Technical Letter
FEMA	Federal Emergency Management Agency
FM	Farm-to-Market Road
FoS	Factor of Safety
FRP	Fiber-Reinforced Polymer
FWOP	Future Without-Project
GIWW	Gulf Intracoastal Waterway
GIS	Geographic Information System
GLO	General Land Office
gpm	gallons per minute
HEC	Hydrological Engineering Center
H&H	Hydraulics and Hydrology
HFPP	Hurricane Flood Protection Project
HH&C	Hydrologic, Hydraulic and Coastal
HPTRM	high performance turf-reinforcement mattress

HQ-USACE	Headquarters - United States Army Corps of Engineers
HSDRRSDG	Hurricane and Storm Damage Risk Reduction System Design Guidelines
IPET	Interagency Performance Evaluation Taskforce
ksf	kips per square foot
ksi	kips per square inch
lf	lineal or linear feet
LiDAR	Light Detection and Ranging
LSAC	Levee Safety Action Classification
MII	Micro-Computer Aided Cost Estimating Software, Second Generation
MLLW	Mean Lower Low Water
MLRA	Major Land Resource Area
NAD	North American Datum
NAVD	North American Vertical Datum
NED	National Economic Development
NFIP	National Flood Insurance Program
NOAA	National Oceanic and Atmospheric Administration
O&M	operations and maintenance
pcf	pounds per cubic foot
PDT	Project Delivery Team
PED	Preconstruction Engineering and Design
PI	Periodic Inspection
PL	Public Law
POR	Period of Record
RMC	Risk Management Center
ROW	Right-of-Way or Rights-of-Way
RP	Rehabilitation Program
RSLC	relative sea-level change
RTK	Real Time Kinematic
SLC	Sea Level Change
SMART	Specific, Measurable, Attainable, Risk-Informed, and Timely
SPF	Standard Project Flood
SQRA	Semi-Quantitative Risk Assessment
SWE	Still Water Elevation
SWG	Southwestern Division, Galveston District
SWIF	system-wide improvement framework
SWL	Still Water Level

TCOON	Texas Coastal Ocean Observation Network
TNRIS	Texas Natural Resources Information System
TRRC	Texas Railroad Commission
TSP	Tentatively Selected Plan
USACE	United States Army Corps of Engineers
USGS	U.S. Geological Survey
UTM	Universal Transverse Mercator
VE	Value Engineering
VT	Vertical Team
WPG	Water at Project Grade

1 GENERAL

1.1 PURPOSE AND CONTEXT

This Engineering Appendix documents the preliminary engineering analyses and concept designs for the coastal storm risk management (CSRM) projects comprising the Tentatively Selected Plan (TSP), specifically for implementation within the Sabine and Brazoria study regions along the upper Texas coast. It supports the viability of the proposed projects, which are developed in the "Sabine Pass to Galveston Bay, Texas Coastal Storm Risk Management and Ecosystem Restoration" Draft Integrated Feasibility Report – Environmental Impact Statement (DIFR-EIS).

The Sabine and Brazoria regions comprise a broader coastal study area in southeast Texas that encompasses six counties. These two sub-regions are the subject of the first interim study where CSRM opportunities were formulated. Additional interim studies are planned for the future to investigate other opportunities where structural alternatives could be implemented to lower the risk of storm surge flooding within the delineated Galveston region and throughout the entire study area. Assessments of the existing and predicted storm surge climate conditions for the Sabine and Brazoria regions, and the concept designs for the proposed project features that came out of these assessments, factor into the economic analyses and are the basis for the costs of the alternatives that were compared during plan formulation. Thus, the preliminary engineering analyses validate the technical and economic viability of the projects from an engineering standpoint.

1.2 SCOPE OF EFFORT

The engineering design work is premised on a feasibility level of detail and analysis, consistent with the SMART planning process that is minimally necessary to substantiate the TSP baseline cost estimate. Thus, an appropriate level of engineering work was done in comparing alternatives during plan formulation. To the maximum extent possible, existing information that could be readily acquired was used to develop the plans and designs for the project features. Sources of available information included maps and imagery from the Federal Emergency Management Agency (FEMA), the U.S. Geological Survey (USGS), and Google; geospatial data; present and historical data from FEMA, the USGS, and the National Oceanic and Atmospheric Administration (NOAA); similar or related area studies; comparative studies; operations and maintenance (O&M) records; and damage risk assessment reports on existing systems. Limited field investigations conducted at a sufficient level of detail to validate the existing data and to provide more localized site-specific data, such as core borings to evaluate existing foundation conditions, complemented this information. Relevant technical references, empirical design guidance, and numerical modeling programs were also used in the engineering analyses.

The processed technical data for the analyses that were done, although adequate to assess project feasibility, are not complete and precise enough in detail to design the project features with the appropriate level of confidence; therefore, it should not to be construed as such. Further engineering analyses and refinements to the feature designs will be made after the Agency Decision Milestone (ADM) to more accurately assess the project's construction cost. The TSP cost presented in this appendix was developed only to the extent needed to equally compare alternatives in deciding the TSP.

1.3 ENGINEERING DOCUMENTATION

Narratives of the engineering analyses are broken out by discipline covering Hydrology and Hydraulics, Surveying and Mapping, Geotechnical engineering, Structural engineering, and Civil Design. The engineering effort level of detail and report content and format are consistent with guidance provided in ER 1110-2-1150. In general, the objective of this appendix is to provide enough supporting documentation to enable reviewers to understand the assumptions and models used to evaluate project benefits and to develop the costs necessary to derive the TSP projects.

The technical sections discuss the development of the preliminary designs for the CSRM features comprising the plans evaluated in the final array of alternatives. They detail the engineering information that was collected, design references and guidance used, computer programs used, the design criteria assumed, design parameters, assumptions made, and methods of analyses.

1.4 PROJECT AREAS

The discrete projects making up the first interim study for the Sabine and Brazoria sub-regions are in, or will be located in Orange, Jefferson, and Brazoria Counties, Texas, along the upper Texas coast (Figure 1-1). These counties are constituent counties of the larger six-county study area between Sabine Pass and the City of Freeport, Texas, that includes Galveston, Harris, and Chambers Counties.

The first interim study specifically looks at CSRM opportunities within the following defined areas:

- Orange-Jefferson County, Texas. Areas within the southern half of Orange County bounded by the Sabine and Neches Rivers and areas along the northeastern boundary of Jefferson County along the Neches River. Specific municipalities, industrial areas, and commercial facilities of interest within Orange County include the cities of Orange, West Orange, Pinehurst, Bridge City, Rose City, and Vidor, as well as surrounding unincorporated areas, an area known as "Chemical Row" along F.M. 1006, and Entergy Texas' Sabine Plant. In Jefferson County, specific areas include the cities of Port Neches and Nederland and industrial complexes along the west bank of

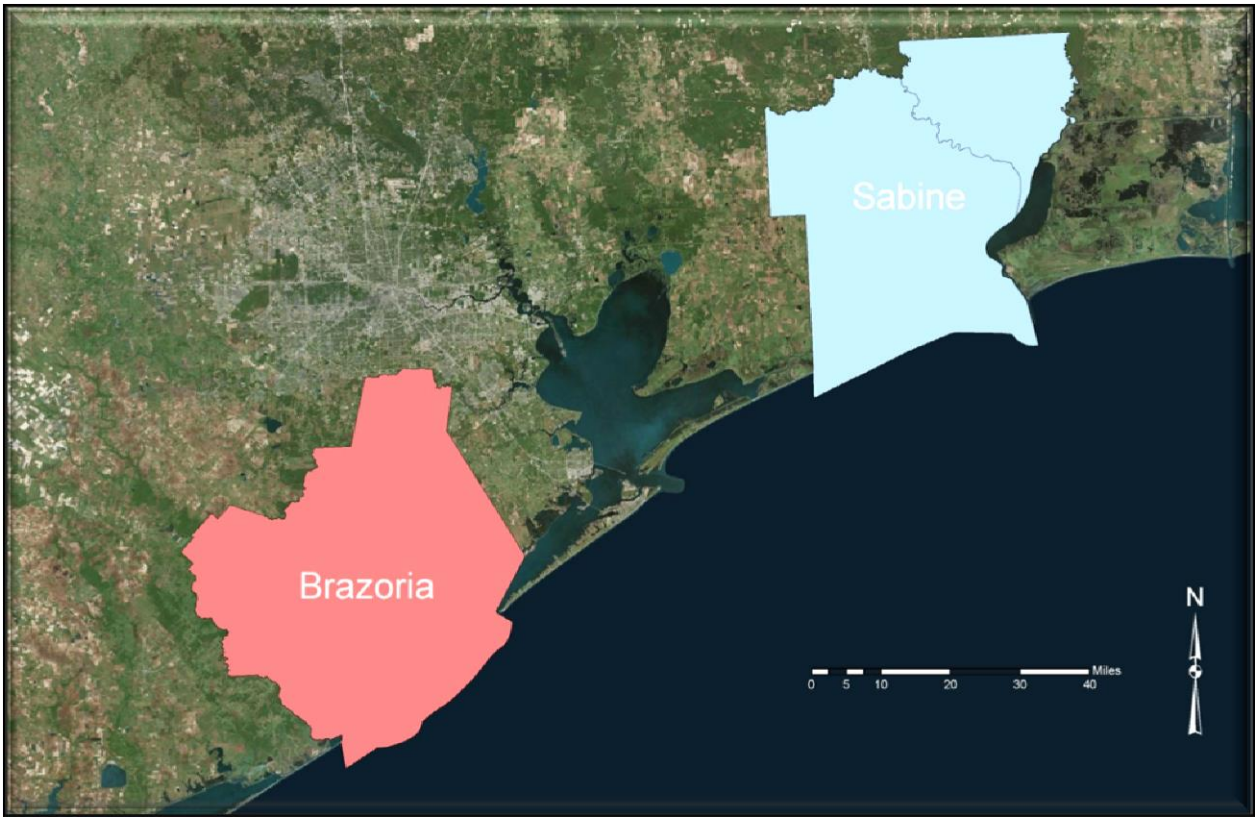

Figure 1-1: Sabine and Brazoria Regions encompassing Orange, Jefferson, and Brazoria Counties

the Neches River, which include the Du Pont Beaumont Works Industrial Park and ExxonMobil's Beaumont Chemical Plant.

- Port Arthur and Vicinity, Jefferson County, Texas. An existing HFPP protects the Port Arthur area from coastal storm surge events coming from the Gulf of Mexico. It also protects against flooding from the Sabine River. The levee system consists of 27.8 miles of earthen embankment and 6.6 miles of floodwall, including 3.5 miles of cantilever wall. There is also a wave barrier on Pleasure Island.

- Freeport and Vicinity, Brazoria County, Texas. An existing HFPP protects the Freeport area from coastal storm surge events coming from the Gulf of Mexico. The line of protection includes multiple structures that also serve as control structures and docks for the Dow Chemical Company, BASF, Conoco Philips, ExxonMobil, and Port Freeport. The system consists of approximately 43 miles of levees and wave barriers, seven pump stations, multiple gates, culverts, and related appurtenances.

1.5 PROJECT OVERVIEW

1.5.1 Project Need

A thorough discussion of the need for the CSRM projects is in Section 4 of the DIFR-EIS – Problems and Opportunities.

Approximately 2.26 million people within the six-county study area reside in areas subject to flooding from storm surge. The population within the study area is currently more than 5 million people and projected to grow to over 9 million people within the next 50 years. Industrially, this area encompasses three of the nine largest oil refineries in the world, 40 percent of the nation's petrochemical industry, 25 percent of the nation's petroleum-refining capacity, and three of the 10 largest U.S. seaports. The damages to the national economy that could be incurred from a one-month closure of the Houston Ship Channel alone are estimated to be upwards of $60 billion. It contains six major rivers and their watersheds, a nationally significant coastal estuary, a commercial fisheries industry, and tourism industry. Given the area's large population, nationally significant industries and facilities, and ecosystems that potentially could be harmed or damaged by storm surge flooding, governmental entities and interests over the years have identified and looked into possible CSRM opportunities in the context of local and regional strategies to address this.

Between 1900 and 2014, more hurricanes struck the upper Texas coast than along any other reach of the Texas coastline, which itself accounts for the second greatest total number of recorded hurricane strikes on the United States coastline, historically, behind only Florida. The probability that a hurricane will strike somewhere along the upper Texas coast in any given year ranges from 31 percent at Sabine Pass to 41 percent around Matagorda Bay. On average, the upper coast will see a major hurricane strike (Category 3 and greater) within a 6-year time frame (*source*: The Formation and Future of the Upper Texas Coast, John B. Anderson, published May 2007).

1.5.2 Project Objective

The tentatively recommended projects (for the Sabine and Brazoria sub-regions) seek to reduce the risk of potential flood damage from coastal storm surge to large at-risk population areas, public and industrial facilities and infrastructure, critical industries in the energy sector having tremendous implications on the economy and national security, and sensitive ecosystems along the Orange, Jefferson, and Brazoria County coastlines. Through the implementation of flood-protection measures, the risks to life safety and property damage associated with coastal storms can be minimized. From a purely economical standpoint, the level of protection sought is that

which optimizes the costs of project construction relative to the potential reduction in economic losses that could be incurred over the 50-year period of economic analysis to derive the greatest net economic benefit. To this end, the economic damage assessments focus only on direct damages to structures. Incidental to reducing the life safety and property damage risks, opportunities were also looked into that preserve and enhance existing environmental habitats or reduce the damage potential to these habitats from storm surge flooding. The project areas covered by this appendix are not inclusive of all the study areas along the upper Texas coast where storm surge flooding is an issue (i.e., areas within Galveston, Harris, and Chambers Counties that are subject to storm surge inundation).

1.5.3 Project Coordination

The engineering assessments, analyses, and preliminary designs for the existing and proposed HFPPs were thoroughly coordinated and vetted with the Engineering Research and Development Center – Coastal Hydraulics Laboratory (ERDC-CHL), the Texas General Land Office (GLO), and other governmental agencies, such as FEMA, the EPA, representatives of Drainage District No. 7 (Port Arthur) and the Velasco Drainage District (Freeport), and county officials. Planning efforts were also coordinated with resource agencies and communities having an interest in the CSRM projects and with the Port of Orange. The interdisciplinary PDT collaborated with subject matter expert colleagues and seamlessly engaged the Vertical Team (VT - USACE District, Division, Headquarters, and Office of Water Project Review) in its efforts throughout the plan formulation process. Agency Technical Reviews (ATRs) and In-Progress Reviews were conducted at key development stages.

1.5.4 Project Background

The USACE, Galveston District, has been aware of the region's need to reduce the risk of flood damage from storm surge and the varied opportunities available in addressing the need given the size of the population at risk, importance of existing public and industrial facilities and infrastructure, and critically important ecosystems that need to be preserved. Consequently, the district, within USACE's Congressional authorization, explored possibilities of building projects that could benefit the region where there might also be a Federal interest in doing so, consistent with an integrated and coordinated approach to locating and implementing opportunities for CSRM and ER. With this as the objective, the district collaborated with the State of Texas and local governmental entities. Through such collaboration and pooling of resources, challenges can be more effectively met. Others have already laid much of the groundwork in evaluating the feasibility of pursuing specific new projects that can reduce flood damage from coastal surge. Considering this, the district leveraged studies, data, and models that have already been produced or are under development.

The DIFR-EIS goes into detail concerning the project's background and describes the focus areas that were advanced from the planning charrettes that were held to scope the feasibility study, along with discussion of the associated non-structural and structural measures that were considered to address CSRM. The focus areas for the Sabine and Brazoria regions and the structural alternatives formulated for these areas by combining selected measures (which are the bases for the TSP projects) are summarized in the paragraph entitled Design Analyses Process, below.

1.5.5 Project Datum

The horizontal and vertical datums used in the engineering analyses and models conform to the current Federal standard. Horizontal coordinates are referenced to North American Datum (NAD) of 1983. Elevations for upland areas and proposed upland features are referenced to the North American Vertical Datum of 1988 (NAVD 88). Water depths are referenced to Mean Lower Low Water (MLLW), unless otherwise stated.

1.6 GENERAL ASSUMPTIONS

1.6.1 Design Considerations

Currently, there is no Federal standard to provide a specified minimum level of flood protection. Historically however, the USACE goal for the design of flood-damage reduction projects protecting major urban areas was to accommodate the Standard Project Flood (SPF) or other "design floods." The SPF is defined as those "discharges that may be expected from the most severe combination of meteorological and hydrologic conditions that are considered reasonably characteristic of the geographical region involved, excluding extremely rare combinations." This goal was rarely achievable though, because the projects had to be economically justified as well and sizing them for SPF protection often was not economical. Although the SPF may have a useful role for application in a risk analysis approach to evaluating flood protection alternatives, it is no longer a valid design target in the context of ER 1105-2-101 (dated 03 January 2006) and risk analysis guidance, having been superseded by guidance that is more current. Instead, a full range of floods, including those that would exceed the SPF, is to be used in the formulation and evaluation of alternatives.

Since the early 1990s, USACE policy has mandated a balanced approach in planning flood-damage reduction projects in which the flood-damage reduction potential (i.e., physical performance), economic success, and residual risks associated with a particular alternative are assessed relative to its implementation cost. Accordingly, the total effect of uncertainty on the project's design and economic viability is examined and conscious decisions can be made that

have taken into account the explicit tradeoff between risks and costs. Alternatives are evaluated and compared based on the scale of the flood damage reduction that reasonably maximizes the expected net benefits (expected benefits less expected costs). Those alternatives accomplishing this objective, with uncertainties in the key variables explicitly included, define the National Economic Development (NED) plans.

Increments in project scale beyond the NED plan can be considered to improve project performance and to manage residual risks to people and property, but existing policy governing such increments must be followed. For example, levee heights are often compared to that which would satisfy the FEMA National Flood Insurance Program (NFIP) base flood level for excluding the floodplain from mandatory flood insurance. In those urban settings where risk-based economics suggest a levee height less than the NFIP base flood protection, the heights are generally increased to that level so that the levees may be certified for NFIP purposes. The resulting project must still be economically justified and the non-Federal sponsor may be required to pay the cost for the increment of levee height between the NED plan project and the NFIP base flood protection project.

The flood-damage reduction potential for the various alternatives evaluated was assessed based on those damages that would be prevented under average still-water conditions only, without provision for relative sea level change (RSLC), wave set-up and run-up, and overtopping. Storm surge modeling results combined with existing information collected was used to determine the areas that would be inundated from storms with return periods varying from 10 to 1,000 years. Therefore, the economic viability of the TSP, to the point that it has been developed, is predicated only on the flood damages that would be prevented from the rise in water elevation due to storm surge. As the project features are further developed, they likely will be raised to accommodate future sea-level rise, wave run-up, and overtopping to the extent practicable. For the existing HFPPs at Port Arthur and Freeport however, the amount of raising that can be done practically is economically constrained by existing structures and facilities (e.g., floodwalls, gate structures, drainage structures, pipelines, utilities, pump stations), whose heights or capacities would have to be increased accordingly. Enlargement of the structures will increase the costs of the affected projects comprising the TSP.

1.6.2 Relative Sea-Level Change

RSLC is an important variable to consider in the design of HFPP structures, so much so that USACE policy requires its consideration in every USACE coastal activity as far inland as the extent of estimated tidal influence. This is because sea-level change (SLC) can potentially affect project and system performance. Therefore, the plans and designs for prospective projects, with

respect to SLC, need to consider how sensitive and adaptable human and engineered systems and natural and managed ecosystems are to climate change and other related global changes. ER 1100-2-8162 requires that planning studies and engineering designs over the project life cycle, for both existing and proposed projects, consider a range of possible future rates of SLC when formulating and evaluating alternatives. This includes both structural and non-structural solutions. For the structural alternative comparisons, it was assumed that the applied range of future SLC would be the same across the system; therefore, there was no need to include or incorporate this criterion in the screening process. The structural alternatives compared are proposed modifications to the existing Port Arthur and Freeport HFPP levees and floodwalls and proposed new levees and floodwalls that would comprise the Orange-Jefferson County HFPP, which includes the Beaumont "A" component. For each system, the principal emphasis regarding the economics of the structural alternatives, for the different still-water levels (SWLs) assumed, was on the reaches and heights of protection that would yield the greatest net excess benefits. To this end, the existing systems and initially laid-out proposed levee system alignments were broken out into segments based on the areas that would be protected and existing topography. These separable elements constituted the structural alternatives that were evaluated to derive the TSP. Including sea-level rise in the alternatives analysis would not have affected the outcome of the plan selection process. SLC is not accommodated in the TSP concept designs as of yet, but is a consideration the PDT recognizes needs to be addressed in the project. This will be done when the TSP is further developed.

Although RSLC was not a determinant factor in deciding TSP, it was investigated nevertheless and is covered in the H&H section of this report. H&H's specific recommendations on how to address future RSLC in the project designs will be considered in developing the feature designs as they evolve. Those recommendations are to consider anticipatory and adaptive strategies to address or accommodate sea level rise. An anticipatory strategy would be to construct project features, including resiliency features, that would be capable of handling the maximum projected seal level rise ("high" scenario) over a given time horizon. An adaptive strategy, on the other hand, would be to construct project features lower than the maximum projected sea level rise at the "low" or "intermediate" scenario for the rate of change and adapting (i.e., raising the structures or building in resiliency) the features accordingly should the projected "low" or "intermediate" rate of change be greater than estimated. When designing the levees, floodwalls, and resiliency elements, both the 50-year and 100-year time horizons will be considered for RSLC. It may be that accommodating for the projected 50-year "high" scenario for sea level rise, for example, could be done at modest extra cost on a comparative basis, which would provide more accommodation than needed for the "low" scenario for the 100-year projected sea level rise. Adaptive strategies could be employed to address higher change potential for sea-level rise over the project's service life, which is assumed to extend well beyond the 50-year

period assumed for the economic analysis. The project features will be optimally designed based on the projected ranges of RSLC combined with CSRM objectives and economic considerations.

1.7 DESIGN ANALYSES PROCESS

The preliminary design process utilizes design parameters and calculation methods described in the respective technical discipline sections of this Appendix. The feature designs presented are schematic in nature and represent systems and components currently in use in the United States and globally. The level of detail of the designs is sufficient to develop order of magnitude cost estimates suitable for the benefit-to-cost analysis in comparing the alternative plans. Primary features considered for the protection systems are:

- Earthen Levees
- Concrete Floodwall (T-Wall)
- Rights-of-Way Acquisitions
- Highway/Roadway Crossings - Non-Gated
- Pipeline and Major Utility Crossings
- Pump Stations
- Closure Gate Structures – Navigation
- Roadway and Railway Crossings – Gated
- Interior Drainage
- Resiliency Features

1.8 DESCRIPTION OF EXISTING PROJECT AREAS

1.8.1 Orange-Jefferson CSRM

The project areas in Orange and Jefferson Counties are characterized by nearly flat terrain that slightly dips towards the Gulf of Mexico, typical of the Gulf Coastal Plain in Texas. The general land slope is 0.05 percent and less with elevations ranging from 0 to 20 feet NAVD 88. Most of the area is less than 10 feet in elevation with a great percentage being less than 5 feet. Much of the areas are fronted by coastal inland marshes. Thus, use of the areas by wildlife is considerable. The major drainage systems in Orange County are the Neches River in the western part and the Sabine River in the eastern part. On the Jefferson County side, the major drainage system in the county is the Neches River. Both rivers, and other minor drainage systems, empty into the Gulf of Mexico at Sabine Lake. Noteworthy of the areas is that they are highly susceptible to rising sea level, with studies suggesting that regional relative sea-level rise rates, inferred from historical tide gauge data, have been significantly higher than presumed eustatic

rise rates. A speculative reason as to why this may be is the down-warping of the earth's crust by sediment loading in the northern Gulf of Mexico.

Most of the areas beyond the coastal marshes and river floodplains are highly developed as evidenced by the several cities, industrial plants, commercial facilities, residential areas, dock facilities, and agricultural-use areas that depict the area. These cities include Orange, West Orange, Pinehurst, Bridge City, and Port Neches. Presently, no flood protection systems of significance are known to exist that would protect even portions of Orange County and the northeastern part of Jefferson County from storm surge inundation. The ExxonMobil Chemical Plant in Beaumont is protected by a barrier that was recently built after Hurricane Ike (2008) to replace a flood protection system that had failed during that storm. Figure 1-2 shows the project areas for the Orange-Jefferson CSRM.

Figure 1-2: Existing Conditions within Orange-Jefferson CSRM Project Area

1.8.2 Port Arthur and Vicinity CSRM

The Port Arthur and Vicinity Hurricane Protection Project (HFPP) protects the Port Arthur region from tropical storm events coming from the Gulf of Mexico. It also protects from riverine loading from the Sabine River. It is operated by Jefferson County Drainage District No. 7. This

project was authorized by Flood Control Act of 1962, Public Law 87-874. Construction began in March 1966 and was completed in April 1982. The levee system consists of 27.8 miles of earthen embankment and 6.6 miles of floodwall. This includes 3.5 miles of coastal cantilever I-wall. The storm of record is Hurricane Ike (2008). This storm produced wave action that overtopped sections of floodwall adjacent to the Sabine-Neches Waterway (a deep-draft navigation channel whose authorized depth is 40 feet) for approximately 30 minutes. Figure 1-3 shows the project area for the Port Arthur and Vicinity CSRM.

Figure 1-3: Existing HFPP within Port Arthur and Vicinity CSRM Project Area

The Port Arthur and Vicinity project area has a preliminary Levee Safety Action Classification (LSAC) that has resulted in the Risk Management Center (RMC) initiating a Semi-Quantitative Risk Assessment (SQRA) to better define the systems risk. This classification was primarily driven by three main risk factors (probability of load, probability of failure, and nature of the consequences). The following paragraphs list the major engineering concerns for the Port Arthur and Vicinity CSRM:

I-wall stability analysis show concerns for performance during events that are at or above the top of the level of protection. These concerns are due to marginal factors of safety for stability and excessive anticipated deflection. Additional I-wall concerns are the lack of resiliency features for overtopping, no design considerations for vessel impact and embankment tie-ins that are susceptible to erosion during an overtopping event. Sections of T-wall type floodwall that were overtopped during Hurricane Ike experienced erosion and loss of supporting fill material due to as little as 30 minutes of overtopping. These T-wall sections are in the vicinity of the I-wall sections that are being evaluated under this study. It is expected that the foundation material at the I-walls will erode in a similar manner.

The Port Arthur system begins to experience overtopping at around a 150-year hydraulic loading event (0.67% ACE). This is a fairly frequent event for still water overtopping, wave overtopping will occur at more frequent events as was observed during Hurricane Ike. The Port Arthur region has a population of around 90,000 in the leveed area along with a large refinery presence (over one million barrels per day (bpd) production). This includes Motiva's 600,000 bpd plant (2012) as well as 60 percent of the nation’s jet-fuel production capacity. High economic consequences along with a large population, together with a high-return frequency for overtopping events that could lead to a catastrophic failure of the system, heavily influenced the LSAC rating.

Currently the system is minimally acceptable in the Rehabilitation Program (RP) under PL 84-99 and certifiable for FEMA accreditation under CFR 65.10, so the local sponsor does not have any plans to address the risk drivers for the LSAC. A Periodic Inspection (PI) was completed for the Port Arthur system in 2012. The Non-Federal Sponsor was provided a list of items to correct and is currently in the process of correcting them. The future without project conditions would result in no action being undertaken to reduce the risk that the system would suffer a catastrophic failure during a future hydraulic loading roughly equivalent or slightly prior to a 150-year event.

Fragility curves were developed for specific locations along the Port Arthur system to account for the anticipated system performance at those locations and were used to scope the reconstruction and resiliency features for the existing system. These curves were developed by the SWG Geotechnical and Structural Engineering section using existing information. Existing data used included performance history based on previous hydraulic loadings for the system, draft findings of the Freeport SQRA, draft findings of the Texas Coastal I-wall study, FY12 periodic inspection and Acradis I-wall analysis, USACE work on erosion for Herbert Hover Dike, Interagency Performance Evaluation Taskforce (IPET) report, ETL 575 criteria, along with influence from the LSAC screenings, the Hydrologic Engineering Center (HEC) Risk Analysis for Flood-Damage Reduction Projects, and RMC Internal Erosion Workshop. The curves

focused on anticipated structural performance of the I-walls along with erosion at tie-in locations and reflect uncertainty in storm duration, size, landfall location, and wind-driven wave height.

The alternative selection process focused on selecting structural features that would significantly reduce the likelihood of a catastrophic failure of the system under extreme hydraulic loading. Features that would allow an increase in the level of protection were also evaluated. These alternatives consisted of overtopping erosion protection along with additional structural features to increase stability along with entire reconstruction/reconfiguration of the I-walls to T-walls. The additional structural features are a system of batter piles and walers along with stiffeners to provide the additional structural capacity to allow the system to be overtopped without catastrophic failure of the wall sections. Erosion control features would be constructed as needed to reduce the likelihood of significant erosion leading to system failure from an overtopping event.

TSP implementation will require additional project scoping to ensure the CSRM project functions as a system. This additional work will include assessing the entire existing system to ensure that the system is able to perform under the anticipated hydraulic event chosen for the TSP. Additionally the system will be evaluated and configured to accommodate relative sea-level rise as needed.

Risks associated with the TSP for the existing system are primarily situated with the use of existing geotechnical and structural information. Given the extensive work for the initial construction, along with additional information obtained by the Non-Federal Sponsor for 65.10 work, this risk should be manageable.

The draft findings of the SQRA for the Freeport system (discussed next in the section on Freeport) were applied to the plan formulation for the Port Arthur because the Port Arthur SQRA has not yet been done. For the Port Arthur system, the detailed description of the needs is similar to what will be presented in the Freeport HFPP section. However, the Port Arthur system is different because there are no known deferred maintenance issues related to this system at this time and general levee and foundation conditions at Port Arthur are less influenced by seepage concerns.

The formulation of alternatives for the Port Arthur and Vicinity CSRM began with defining reaches for the system. These were based on the failure locations identified by the levee safety program in the absence of an SQRA. These locations were included in plan formulation where improvements would positively impact the system's capacity for protection. The following lists the reaches at Port Arthur:

- 8- to 10-foot I-Wall
- Closure Structure
- I-Wall Near Valero
- Tank Farm

8- to 10-foot I-Wall One-Foot Raise

The existing HFPP in this reach was constructed in stages to allow for settlement and consolidation of the soft foundation material. During the second stage of construction, the embankment experienced significant settlement and the final required levee height could not be attained. A decision was made at the time to add an I-wall section on the top of the earthen embankment to obtain the required height. This I-wall section was put in place with excess height to accommodate any future settlement of the foundation or embankment. The additional stick-up height of the I-wall section makes it susceptible to failure for hydraulic loading events that exceed the system's capacity. Top of the I-wall is at elevation 23.5 feet while the top of the embankment is at elevation 16.5 feet. The I-wall does not meet current criteria for embedment.

1) No Fail: 3,500 LF of 15-foot-wide 6-inch scour pad would allow for the existing I-wall to have the excess stick-up height removed and erosion protection installed reducing the likelihood of a brittle failure if the system's capacity is exceeded.
2) One-Foot Raise: 7,500 LF of 15-foot-wide 6-inch scour pad would allow for the existing I-wall to have the excess stick-up height removed and erosion protection installed, reducing the likelihood of a brittle failure if the system's capacity is exceeded. This option would include adding capacity to the system in this reach by addressing low areas of the levee system, raising 2,000 lf of levee one foot and providing overtopping erosion protection.
3) Two-Foot Raise: 7,500 LF of 15-foot-wide 6-inch scour pad would allow for the existing I-wall to have the excess stick-up height removed and erosion protection installed, reducing the likelihood of a brittle failure if the system's capacity is exceeded. Additional 60,000 LF of levee raising 2 feet along with the raising of the State Highway 87 and Highway 73 levee crossings. Floodwalls at two (2) pump stations would be added along with 1,000 LF of floodwall reconstruction at the Taylors Bayou closure. This option would also require the replacement of a gravity drainage structure and vehicle closure structure.

Closure Structure

Top of the closure structure is at elevation 15.5 feet while the top of the embankment is at elevation 17 feet. It was assumed during the fragility curve exercise that a wave action load of 2

feet would occur along with still-water levels. Once the closure structure starts being overtopped, the chances of embankment erosion increase. The closure structure is a steel gate with concrete supports the tie into the adjacent earth embankments with steel sheet pile I-walls. This configuration was shown to have excessive erosion during overtopping during Hurricane Katrina. Similar performance is expected at this structure under the same hydraulic loading conditions.

1) No Fail: Construction of two 300 LF of 100-foot-wide 6-ichn scour pads, one on each side of the structure to provide erosion protection to reduce the likelihood of a brittle failure if the system's capacity is exceeded.
2) One-Foot Raise: Replace closure structure with a gate structure 12-foot height by 30-foot width including two 300 LF of 100-foot-wide 6-inch scour pads, one on each side of the structure to provide erosion protection to reduce the likelihood of a brittle failure if the system's capacity is exceeded. Additional raising of 12,000 LF of levee one foot.
3) Two-Foot Raise: Replace 2 closure structures gate structures are 12-foot height by 30-foot width. Including two (2) 300 LF of 100-foot-wide 6-inch scour pad at each closure structure. Raising 12,000 LF of levee one foot and adding floodwalls at 2 pump stations, 500 LF total (7 feet tall) along with reinforcing pump station walls at four (4) existing pump stations.

<u>I-Wall Near Valero</u>

I-wall near the Valero refinery is a steel sheet pile I-wall that has a stick-up height of 8 to 12+ feet, no scour protection and no protection from debris or vessel impact. Wall has been analyzed for stability and shows significant crack development, marginal FOS for rotational stability and large deflections. Fragility curve exercise was performed assuming a 2-foot wave along with development of still water level (SWL). Hydraulic loading at 15 feet is believed to be enough to cause exceedance in deflection past established thresholds in current criteria.

1) No Fail: Construction of 5,000 LF of 15-foot-wide 6-inch scour pad and batter piling and waler system will provide additional structural integrity and erosion protection to reduce the likelihood of a brittle failure if the system's capacity is exceeded.
2) One-Foot Raise: Construction of 5,000 LF of 15-foot-wide 6-inch scour pad and batter piling and waler system with one-foot rise will provide additional system capacity, increase structural integrity of the I-wall and provide erosion protection to reduce the likelihood of a brittle failure if the system's capacity is exceeded. Additionally, 3,000 LF of levee will need to be raised one foot.
3) Two-Foot Raise: This option will require significant reconstruction of the HFPP in the evaluated area including 5,000 LF of floodwall (15 feet tall), ten (10) closure structures

consisting of a 15-foot height and 20-foot width opening, 3,000 LF of levee raised 2 feet along with the work specified in the I-wall near Tank Farm #3 option and 8- to 10-foot I-wall #3 option.

Tank Farm

I-wall near the Tank Farm is a steel sheet pile I-wall that has a stick up height of 10 to 12+ feet, no scour protection and no protection from debris or vessel impact. Wall has been analyzed for stability and shows significant crack development, marginal FOS for rotational stability and large deflections. Wave action load of 2 feet was assumed during fragility curve exercise.

1) No Fail: Construction of 1,800 LF of 15-foot-wide 6-inch scour pad and batter piling and waler system will provide additional structural integrity and erosion protection to reduce the likelihood of a brittle failure if the system's capacity is exceeded.
2) One-Foot Raise: Construction of 1,800 LF of 15-foot-wide 6-inch scour pad and batter piling and waler system with one foot rise will provide additional system capacity, increase structural integrity of the I-wall and provide erosion protection to reduce the likelihood of a brittle failure if the system's capacity is exceeded. Additionally, 7,000 LF of levee will need to be raised one foot.
3) Two-Foot Raise: Construction of 2,000 LF of floodwall (15 feet tall) along with 9,000 LF of levee raised 2 feet, construct a floodwall at one pump station (200 LF at 7 feet tall) and raise an additional 10,400 LF of levee 2 feet and reconstruct 12,000 LF 15-foot-tall floodwall. Rebuilding four (4) existing pump stations at 1,100 cfs would also be required.

1.8.3 Freeport and Vicinity CSRM

The Freeport and Vicinity HFPP is in the coastal plains in southern Brazoria County, about 48 miles southwest of Galveston, Texas. The overall project for hurricane flood protection for Freeport and Vicinity, Texas, was authorized by the Flood Control Act of 23 October 1962, Public Law 87-874, substantially in accordance with House Document No. 495, 87th Congress, 2nd Session. The authorization provides for construction of improvements at Freeport and Vicinity, Texas, for protection against storm tides caused by tropical cyclones along the Gulf Coast of magnitudes up to and including the standard project hurricane. The existing HFPP at Freeport consists of approximately 43 miles of levees and wave barriers, seven (7) pump stations and multiple gates, culverts, and related appurtenances. Additionally, in the line of protection includes multiple structures that also serve as control structures and docks for the Dow Chemical Co., BASF, Conoco Philips, Exxon and Port Freeport. Figure 1-4 shows the project area for the Freeport and Vicinity CSRM.

The Freeport and vicinity system has a preliminarily LSAC that has resulted in the RMC conducting an SQRA to better define the systems risk. This classification was primarily driven by numerous factors. The primary structural factors that would have federal interest are seepage/slope stability of "sandy" levees, I-wall stability, and a "low" level of protection. These performance factors in an area that has very high consequences drove the LSAC.

Currently the system is unacceptable in the RP under PL 84-99 and not certifiable for FEMA accreditation under CFR 65.10, so the Non-Federal Sponsor has a SWIF plan in place to address the deferred maintenance issues and issues impeding 65.10 accreditation. The Sponsor does not plan on addressing the structural risk drivers for the LSAC due to the performance concerns coming at a more significant hydraulic loading event than the requirements under 65.10. The FWOP conditions would result in no action being undertaken to reduce the risk that the system would suffer a catastrophic failure during a future hydraulic loading roughly equivalent to or slightly before the 130-year event.

Figure 1-4: Existing HFPP within Freeport and Vicinity CSRM Project Area

Fragility curves were developed for specific locations along the existing systems in order to account for the anticipated system performance at those locations and were used to scope the reconstruction and resiliency features for the existing systems. These curves were developed by

the SWG Geotechnical and Structural Engineering Section using existing information. Existing data used included performance history based on previous hydraulic loadings at each system, draft findings of the Freeport SQRA, draft findings of the Texas Coastal I-wall study, USACE work on erosion for Herbert Hover Dike, IPET report, ETL 575 criteria, along with influence from the LSAC screenings and the HEC Risk Analysis for Flood Damage Reduction Projects and RMC Internal Erosion Workshop. The curves were focused on erodeability of "sandy" levees, steady state seepage concerns, saturated levee stability concerns, anticipated structural performance of the I-walls, and erosion at tie-in locations. These curves reflect uncertainty in storm duration, size, landfall location, and wind driven wave height.

The alternative selection process focused on selecting structural features that would significantly reduce the likelihood of a catastrophic failure of the system under extreme hydraulic loading. Features that would allow an increase in the level of protection were also evaluated. These alternatives consisted of overtopping erosion protection along with additional structural features to increase stability along with entire reconstruction/reconfiguration of the I-walls to T-walls. The additional structural features are a replacement of a wall/drop in panel system at the Port Freeport and a closure of the Dow Barge Canal. Erosion control features would be constructed as needed to reduce the likelihood of significant erosion leading to system failure from an overtopping event.

TSP implementation will require additional project scoping to ensure the CSRM project functions as a system. This additional work will include assessing the entire existing system to ensure that the system is able to perform under the anticipated hydraulic event chosen for the TSP. Additionally the system will be evaluated and configured to accommodate relative sea-level rise as needed.

Risks associated with the TSP for the existing system are primarily situated with the use of existing geotechnical and structural information. Given the extensive work for the initial construction, along with additional information obtained by the sponsor for 65.10 work, this risk should be manageable.

The draft findings of the SQRA for the Freeport system show vulnerabilities primarily associated with steady-state seepage issues and floodwall and levee overtopping. Other performance issues identified during the SQRA were the result of deferred Sponsor maintenance, or alterations that local industrial stakeholders have constructed over time, these are not being evaluated under this project. Floodwall performance issues, at locations where the originally constructed floodwall is still in place and has been operated and maintained in an acceptable manner, are being evaluated to include stability and resiliency. Levee reaches that are non-uniform in height or otherwise

susceptible to concentrated overtopping erosion during an event are being evaluated for raising or armoring to reduce the likelihood of breach.

The formulation of alternatives for the Freeport and Vicinity CSRM began with defining reaches for the system. These locations were then narrowed during formulation to those locations where improvements would positively impact the system's capacity for protection and to reduce any redundancies. For example, improvements to the Dow Barge Canal would negate any failures at the Dow Turning Basin. The following is the resulting list of reaches at the Freeport and Vicinity CSRM:

- South Storm Levee
- Freeport Dock
- Tide Gate I-Wall
- Old River at Dow Thumb
- Dow Barge Canal
- East Storm Levee
- Oyster Creek Levee

South Storm Levee Raise

The South Storm Levee is a frontal levee that has potential for direct wave impact from the Gulf of Mexico during storm loading. When this levee was originally constructed, the area south of the levee was very low in elevation and allowed surge and waves to reach it. Over the last 40 years, USACE has constructed dredge disposal areas for the deep-draft navigation channel in this low area. Continued use of the disposal areas has increased the elevation of the low area to a point that it is now higher than the South Storm Levee.

1) One-Foot Raise: Construction would include earth placement on top of the existing earth embankment for a 1-foot raise.
2) Two-Foot Raise: Construction would include earth placement on top of the existing earth embankment for a 2-foot raise.

Freeport Dock Floodwall Raise

The Freeport Dock floodwall is a 3-foot floodwall that was added to the dock face at the Port Freeport docks after Hurricane Ike under PL 84-99. This floodwall has drop-in panels that are removable to allow for "roll on - roll off" cargo loading. During evaluation of the HFPP for 65.10 the Non-Federal Sponsor noted that the wall/panels were structurally deficient. This deficiency was confirmed during the RMC-led Freeport SQRA.

1) Partial Fail: Construction includes replacing the drop-in panels and anchor system.
2) No Fail: Construction of 3,000 LF of floodwall to meet all USACE requirements for a wall/drop-in panel system located at a port facility.
3) One-Foot Raise: Construction would require complete reconstruction of the dock and floodwall assembly.

Tide Gate One-Foot Raise

The I-wall located at the Tide Gate was constructed as part of the original HFPP construction when the earth embankment section could not reach the design elevation. The very soft foundation materials present in the old river channel would not support the additional weight of the initially proposed embankment section. The original sheet pile/concrete cap I-wall in an embankment over very soft foundation material is of similar design to the poor performing I-wall sections in New Orleans, Louisiana. The stability concerns for this section of I-wall are at design exceedance events with water levels near or at the top of wall. The proposed construction will be to reconstruct the I-wall as a pile founded T-wall. The construction process will include demolishing the existing concrete monoliths and exposing the existing PZ27 sheet piles, driving concrete foundation piling, placing a concrete piling cap, placing scour protection, and placing the concrete stem of the T-wall. The overall length of the T-wall is approximately 362 feet.

1) No Fail: Construction of 362 LF of floodwall 10 feet tall.
2) One-Foot Raise: Construction of 700 LF of floodwall 11 feet tall along with 2,000 LF of levee raised one foot.
3) Two-Foot Raise: Construction of 700 LF of floodwall (12 feet tall) and 3,500 LF of levee raised 2 feet along with adding a floodwall at one pump station (200 LF at 7 feet tall). The Tide Gate structure adjacent to the I-wall will require significant modification or complete reconstruction to accommodate the 2-foot raise.

Old River at Dow Thumb

This reach of levee is an earth embankment that would be susceptible to erosion during an overtopping event. Updated modeling shows an area of this reach that has significant risk to large wave attack and overtopping from wave propagation along the adjacent deep draft navigation channel. This area has a very low FOS for global stability and is currently being evaluated under the General Re-evaluation Report for the navigation project. Any action taken under this planning study will not reduce the current FOS for global stability.

1) No Fail: Construction of 14,500 LF of high performance turf-reinforcement mattress (HPTRM) and 4,000 LF of 15-foot-wide 6-inch scour pad to provide erosion protection to reduce the likelihood of a brittle failure if the systems' capacity is exceeded.

2) One-foot Raise: Construction of 4,000 LF of 15-foot-wide 6-inch scour pad along with 3,000 LF of levee raised 1foot and 14,500 LF of HPTRM to "level up" the low spots and provide erosion protection to reduce the likelihood of a brittle failure if the systems' capacity is exceeded.
3) Two-Foot Raise: Due to extremely low FOS for global stability raising the levee over existing heights by adding additional earth fill is not an option so for the 2-foot raise scenario the existing embankment would be removed and 12,000 LF of 10-foot-tall floodwall would be constructed. In areas that do not have stability issues 6,500 LF of levee would be raised 2 feet, one drainage structure would be replaced, and the saltwater intake at Dow A801 would be replaced.

Dow Barge Canal

The Dow Barge Canal levees are approximately 8.0 miles long and represent a significant risk to the HFPP performance at and above the design event. This risk is primarily from seepage and instability caused by seepage through the "sandy" levee and foundation material. Significant risk also exists with numerous pipeline penetrations, I-wall instability, and non-uniform levee heights. Taking into account the significant existing infrastructure within the existing embankment and the uncertainty in the performance of seepage control measures installed in such a complex environment, the PDT chose to utilize a closure structure and pump station constructed at the junction of the North Barge Canal and East Storm Levee. This structure will allow barge traffic to pass during routine operations and will have a pumping capacity of 2,000,000 gpm. The structure length will be approximately 500 feet long with two (2) sector gates totaling approximately 80 feet wide for vessel traffic. Additional tidal circulation will be provided by two (2) sluice gates approximately 15 feet wide each. The final configuration of this structure will match the proposed level of protection for the system.

East Storm Levee Raise

The East Storm Levee is a large earth embankment that faces the Gulf of Mexico and has direct wave and surge impacts from the gulf. The proposed construction procedure will include stripping topsoil, removal of a two lane asphalt road, placement of fill, replacement of a two-lane road, placement of a HPRTM, and turfing.

1) No Fail: Construction of 13,115 LF of HPTRM.
2) One-Foot Raise: Construction includes 13,115 LF of levee raised 1foot with HPTRM
3) Two-Foot Raise: Construction includes 19,115 LF of levee raised 2 feet with HPTRM and a floodwall at one pump station, 800 LF total (5 feet tall). Reinforcement of the pump station walls and raising FM 332 at the levee crossing would also be required.

Oyster Creek Levee Raise

The Oyster Creek Levee was constructed at varying elevations to account for changes in flood elevation as noted in the hydraulic modeling. The updated ADCIRC modeling showed a height deficiency over 3,500 LF where the updated modeling shows an elevated surge.

1) No Fail: The Oyster Creek Levee will be raised 2 feet over 3,500 LF in order to correct the height deficiency. The construction procedure will include stripping topsoil, removal of a 12-foot-wide asphalt road, placement of fill, replacement of a 12-foot-wide road, and turfing.
2) One-Foot Raise: Construction will include 3,500 LF of 3-foot levee raise and 10,000 LF of 1-foot levee raise for a total distance of 13,500 LF. The construction procedure will include stripping topsoil, removal of a 12-foot-wide asphalt road, placement of fill, replacement of a 12-foot-wide road and turfing.
3) Two-Foot Raise: Construction will include 3,500 LF of 4-foot levee raise and 1,000 LF of floodwall reconstruction along with raising FM 523 at the levee crossing. Additionally, 33,000 LF of levee raised 2 feet, reconstruction of one pump station, 1,100 cfs, and replacement of six (6) gravity structures would also be required.

1.9 PLAN EVALUATION, COMPARISON, AND SELECTION

The evaluation and comparison of the various alternative plans considered is described in the DIFR-EIS. The actual plan selection process is undertaken as one of the final steps in the planning process and is performed in conjunction with sponsor input and HQ-USACE reviews and approval. The selected plan is held to stringent standards. Consequently, it must be technically viable, economically feasible, and environmentally acceptable, all in accordance with governing agency regulations and associated Federal statutes.

A preliminary array of conceptual structural alternatives was compiled by combining planning measures. Through the plan formulation process, this array was culled to an evaluation array of four (4) concept structural alternatives that were carried forward for further development. These generalized alternatives were evaluated and refined accordingly to come up with the final array of structural alternatives summarized in Table 1-1 and shown on maps on Plates 1-1 through 1-6. These structural alternatives were then further evaluated at a preliminary level of design to determine the projects that would comprise the TSP. Incidental to this evaluation, alternative levels of protection were economically assessed to optimize the plans. Other alternatives screened in the early study phases are discussed in Appendix B. This appendix focuses on the final array evaluation.

Table 1-1: Structural Coastal Storm Risk Management Alternatives Evaluated

Project Area	Final Array - Alt. Name	Description of CSRM Alternative	Optimization Alternatives
Orange-Jefferson CSRM	**Orange 1 New Levee**	Orange 1 begins at its north terminus in the City of Vidor north of U.S. Interstate 10 across from Church Street (which is south of the freeway). From there, the alignment runs southwesterly parallel to the freeway and nearly coincident with Rose City's north boundary line. Because of the limited availability of land area and considerable real estate hurdles that would have to be overcome, concrete floodwall is proposed for this leg. The alignment continues a little to the south across the freeway along Rose City's westernmost boundary, after having made a short jog to the north, and back east-northeasterly south of and parallel to an existing railway. After following most of the incorporated city boundaries, the alignment takes a sharp turn to the south-southeast, where it ends at an existing pipeline corridor about 1.5 miles away. The length of the entire reach is 8.2 miles. A levee system consisting of earthen levee and concrete floodwall was evaluated at four (4) incremental heights, in one-foot increments, that were correlated to corresponding reductions in the interior flood depths. As conceived, the system would consist of approximately 3.1 miles of concrete floodwall. Regardless of the structure heights assumed, Interstate 10 and the railroad would have to be accommodated by closure structures, or the freeway would have to be elevated, which is the more plausible alternative. Orange 1 reduces the surge flood-damage risk for Rose City and west Vidor.	All Alternatives Total new Levee length: 5.1 miles Total new Floodwall length: 3.1 miles Total new Reach length: 8.2 miles Incremental Levee Heights • New levee/floodwall, 11 feet high (not economically feasible) • New levee/floodwall, 12 feet high (not economically feasible) • New levee/floodwall, 13 feet high (not economically feasible) • New levee/floodwall, 14 feet high (not economically feasible)
	Orange 2 New Levee	Orange 2 generally runs east and south from the south end of the Orange 1 reach to an arbitrary high ground tie-in point at its southeast end less than a mile southwest of FM 1135, where it intersects FM 105 (Orangefield Road), midway between Rose City and Bridge City to the southeast. A levee system consisting of earthen levee was evaluated at four (4) incremental heights, in one-foot increments, that were correlated to corresponding reductions in the interior flood depths. No floodwalls are proposed. Orange 2 is approximately 6.6 miles long and protects incorporated areas within the City of Vidor and unincorporated areas of Vidor.	All Alternatives Total new Levee length: 6.6 miles Total new Reach length: 6.6 miles Incremental Levee Heights • New levee, 11 feet high (not economically feasible) • New levee, 12 feet high (not economically feasible) • New levee, 13 feet high (not economically feasible) • New levee, 14 feet high (not economically feasible)

Project Area	Final Array - Alt. Name	Description of CSRM Alternative	Optimization Alternatives
Orange-Jefferson CSRM	**Orange 3 New Levee**	Orange 3 runs southeasterly from the end of the Orange 2 reach to Bridge City. The alignment goes around the south side of the city and continues east-northeasterly to the Port of Orange. Along this segment, the alignment crosses Cow and Adams Bayous, both of which are used for navigation. From the port, the alignment runs northwesterly along the port's west property line (along Alabama Street) and to the north along much of the length of the Sabine River's west bank. The northeast terminus of the Orange 3 reach, and entire Orange County system reach, is at U.S. Interstate 10, on its south side, about 2/10ths of a mile east of the U.S. Highway 90 Business (Simmons Drive) intersection. (Continuation of the levee system beyond I-10 was considered, but eventually ruled out because of the associated environmental impacts, construction costs, and deduction that only modest damages would be incurred based on the assumed still-water elevations.) In total, the longest reach of the three (3) Orange reaches is 27.2 miles long. A levee system consisting of earthen levee and floodwall was evaluated at four (4) incremental heights, in one-foot increments, that were correlated to corresponding reductions in the interior flood depths. Because the levee system alignment traverses several industrial areas, sensitive environmental habitat areas, places where the land area is insufficient for levee construction, or there are other real estate constraints, and wide floodplains subject to constant inundation (where the foundation conditions are likely to be poor), the system assumes 6.1 miles of concrete floodwall. The alignment crosses many pipelines and utilities, several roadways, including State Highway 87, and two (2) navigation channels, all of which will have to be accommodated accordingly, relocated, or modified. Orange 3 provides the greatest amount of protection as it reduces the surge flood-damage risk to the Cities of Orangefield, Bridge City, Pinehurst, West Orange, and Orange, which together represent a large population area and heavily industrialized area. It also protects Entergy Texas Inc.'s Sabine (Power) Plant, Bridge City.	All Alternatives Total new Levee length: 21.1 miles Total new Floodwall length: 6.1 miles Total new Reach length: 27.2 miles Incremental Levee Heights • New levee/floodwall, 11 feet high (TSP) • New levee/floodwall, 12 feet high (NED Plan) • New levee/floodwall, 13 feet high (not economically feasible) • New levee/floodwall, 14 feet high (not economically feasible)
	Jefferson Main New Levee	This component of the Orange-Jefferson CSRM in Jefferson County begins near the northeastern terminus of the existing Port Arthur and Vicinity HFPP where it will tie into high ground. The alignment runs west-northwest nearly 11.0 miles, generally along the west bank of the Neches River to a point on the north side of the Du Pont Beaumont Works Industrial Park in Nederland. A levee system consisting of earthen levee and floodwall was evaluated at four (4) incremental heights, in one-foot increments, that were correlated to corresponding reductions in the interior flood depths. Because industrial facilities to be protected front the river, floodwall will have to be constructed along these reaches. As conceived, floodwall will comprise 3.1 miles of the system.	All Alternatives Total new Levee length: 7.6 miles Total new Floodwall length: 3.1 miles Total new Reach length: 10.7 miles Incremental Levee Heights • New levee/floodwall, 11 feet high (TSP) • New levee/floodwall, 12 feet high (NED Plan) • New levee/floodwall, 13 feet high (not economically feasible) • New levee/floodwall, 14 feet high (not economically feasible)

Project Area	Final Array - Alt. Name	Description of CSRM Alternative	Optimization Alternatives
Orange-Jefferson CSRM	**Beaumont A New Levee**	This reach provides protection exclusively for the ExxonMobil Beaumont Chemical Plant, which is among the top ten domestic producers of refined products. A 3.6-mile-long system is proposed that consists of 1.1 miles of earthen levee and 2.5 miles of concrete floodwall. The same four (4) one-foot increment heights assumed for all the Orange-Jefferson CSRM reaches were assumed for this reach.	All Alternatives Total new Levee length: 1.1 miles Total new Floodwall length: 2.5 miles Total new Reach length: 3.6 miles Incremental Levee Heights • New levee/floodwall, 11 feet high • New levee/floodwall, 12 feet high (TSP) • New levee/floodwall, 13 feet high (NED Plan) • New levee/floodwall, 14 feet high
	Beaumont B New Levee	This reach was intended to provide isolated protection for an electrical power distribution station initially thought to be actively operating. This station is no longer being used for that purpose. It is now only of historical significance.	Screened Out
	Beaumont C New Levee	This reach provides isolated protection for a sulfur terminal on the Neches River owned by Martin Midstream Partners. The proposed earthen ring levee is 1.3 miles long. Four (4) levee heights were evaluated at one-foot increments.	All Alternatives Total new Levee length: 1.3 miles Total new Reach length: 1.3 miles Incremental Levee Heights • New levee/floodwall, 11 feet high (not economically feasible) • New levee/floodwall, 12 feet high (not economically feasible) • New levee/floodwall, 13 feet high (not economically feasible) • New levee/floodwall, 14 feet high (not economically feasible)

Project Area	Final Array - Alt. Name	Description of CSRM Alternative	Optimization Alternatives
Port Arthur and Vicinity CSRM	**8-10 Feet I-Wall Raise**	The "8-10 ft I-Wall" is a section floodwall located along the southernmost corner of the existing Port Arthur and Vicinity Hurricane Flood Protection Project. This legacy wall does not meet the current criterion for embedment. Therefore, structural resiliency is proposed to protect the base of the wall from being scoured on the protected side from overtopping. The feature proposed to address this is a 15-foot-wide by 6-inch thick concrete scour pad along the protected side of the wall. Raising of the adjoining levee embankments is also proposed in combination with the floodwall scour protection because they are not high enough to accommodate the economically derived still-water level with a 2-foot wave applied. Future relative sea level rise will only compound this problem. Overtopping would effectively reduce the level of protection afforded for the local area and could severely erode the levee embankment. Adding more height to this reach of the system, beyond that premised on just the still-water level and assumed 2-foot wave alone, to account for future sea-level rise and wave run-up, as the TSP is further developed, will have impacts on other elements comprising the system. If these structures were raised, the structures near the Valero Refinery and the Tank Farm would have to be raised as well. Consequently, the incorporation of sea level rise and wave run-up into the project will substantially increase the lengths of levee requiring raising, the heights of raising necessary, and the lengths of floodwall requiring resiliency measures, reinforcement, or replacement, system-wide, which would expand the scope of the TSP as contemplated at this time.	• "No Fail" – Construct 3,500 LF of 15-foot-wide by 6-inch thick scour pad to protect I-wall against structural failure. • Construct 7,500 LF of 15-foot-wide by 6-inch scour pad and raise levee embankment one foot over a distance of 2,000 LF. (NED Plan/TSP) • Construct 7,500 LF of 15-foot-wide by 6-inch scour pad and raise levee embankment 2 feet over a distance of 60,000 LF. In addition, - replace 1,000 LF of steel I-wall (Taylors Bayou closure structure, 20 feet high); - elevate State Highways 87 (2,500 LF) and 73 (5,000 LF) at levee crossings; - construct 500 LF of new floodwall, 7 feet high, at two (2) pump stations; - replace a gravity drainage structure; and - replace a 30 feet wide by7 12 feet high vehicle closure structure.
	I-Wall Raise near Valero	This section of I-wall is at the south corner of the system near the Valero Refinery plant. The wall has been documented to not meet deflection criterion. Therefore, structural resiliency is proposed for this steel wall in which a 5,000-foot-long by 15-foot-wide by 6-inch thick concrete scour pad along the protected side of the floodwall would be constructed to prevent scouring at the base of the wall, which in turn will prevent the wall from over-deflecting when subjected to full loading. (The fragility-curve exercise for this section assumed a 2-foot wave on top of the still-water levels.) Levee raising in this area is also proposed because the existing levees are not high enough to accommodate the assumed water level with a 2-foot wave applied. Overtopping would effectively reduce the level of protection afforded for the local area and could severely erode the levee embankment. Adding more height to this reach of the system, beyond that premised on just the still-water level and assumed 2-foot wave alone, to account for future sea level rise and wave run-up, as the TSP is further developed, will have impacts on other elements comprising the system. The incorporation of these considerations into the project will substantially increase the lengths of levee requiring raising, the heights of raising necessary, and the lengths of floodwall requiring resiliency measures, reinforcement, or replacement, system-wide, which would expand the scope of the TSP as contemplated at this time.	• "No Fail" – Construct 5,000 LF of 15-foot-wide by 6-inch thick scour pad to protect I-wall against structural failure. • Construct 5,000 LF of 15-foot-wide by6-inch thick scour pad and raise levee embankment 1 foot over a distance of 3,000 LF. In addition, structurally reinforce the I-wall with batter piles and walers. (NED Plan/TSP) • Replace the I-wall with new concrete T-wall, 15 feet high; raise 3,000 LF of levee 2 feet; and replace ten (10) 20-foot-wide closure structures. Additionally, construct the work associated with raising the "8- to 10-foot I-Wall" and the I-wall near the Tank Farm 2 feet.

Project Area	Final Array - Alt. Name	Description of CSRM Alternative	Optimization Alternatives
Port Arthur and Vicinity CSRM	**I-Wall Raise near Tank Farm**	This section of I-wall is at the south corner of the system near an oil tank farm. The wall is documented to have global stability issues because of insufficient embedment. Therefore, structural resiliency is proposed for this wall in which a 1,800-foot-long by 15-foot-wide by 6-inch thick concrete scour pad along the protected side of the floodwall would be constructed to prevent scouring at the base of the wall. The wall would also be structurally reinforced with batter piling and a waler system. Levee raising in this area is also proposed due to the possibility of overtopping from the assumed still-water level with a 2-foot wave applied. Sheet flow over the top of the levee effectively compromises the level of protection afforded for the local area and could severely erode the embankment, which would further reduce the level of protection provided. Adding more height to this reach of the system, beyond that premised on just the still-water level and assumed 2-foot wave alone, to account for future sea level rise and wave run-up, as the TSP is further developed, will have impacts on other elements comprising the system. The incorporation of these considerations into the project will substantially increase the lengths of levee requiring raising, the heights of raising necessary, and the lengths of floodwall requiring resiliency measures, reinforcement, or replacement, system-wide, which would expand the scope of the TSP as contemplated at this time.	• "No Fail" – Construct 1,800 LF of 15-foot-wide by 6-inch thick scour pad and structurally reinforce the I-wall with batter piles and a waler system to protect against wall failure. • Construct 1,800 LF of 15-foot-wide by 6-inch thick scour pad, structurally reinforce the I-wall with batter piling and walers, and raise the levee embankment one foot over a distance of 7,000 LF. (NED Plan/TSP) • Replace the I-wall with 2,000 LF of new concrete T-wall, 15 feet high, and raise 19,400 LF of levee 2 feet. In addition, - install 200 LF of 7-foot-high floodwall at an existing pump station; - replace an additional 12,000 LF of floodwall with new concrete T-wall, 15 feet high; and - rebuild four (4) pump stations, each with capacity of 1,100 cfs.
	Closure Structure Raise	The Port Arthur closure structure, which consists of two (2) gated structures, is near the easternmost corner of the system. The top of the structure is at Elev. 15.5 feet, while the top of the adjacent levee embankment is at Elev. 17.0 feet. It was assumed during the fragility-curve exercise that a wave action load of 2 feet would occur along with still-water levels. Once the closure structure starts being overtopped, the chances of embankment erosion increase. To reduce the likelihood of a brittle failure due to erosion if the system's capacity is exceeded, 100-foot-wide by 6-inch concrete scour pads are proposed along both sides of the structure. The length of this protection would be about 300 LF. In conjunction with the scour protection, the adjoining levees would be raised to prevent localized overtopping. The length of levee requiring raising is approximately 12,000 LF.	• "No Fail" – Construct 300 LF of 100-foot-wide by 6-inch thick scour pad along both sides of two (2) closure structures to reduce the likelihood of a brittle failure due to erosion if the system's capacity is exceeded. • Construct 300 LF of 100-foot-wide by 6-inch thick scour pad along both sides of two (2) closure structures and raise levee embankment one foot over a distance of 12,000 LF. Additionally, replace a 30 feet wide by 12 feet high vehicle closure structure. (NED Plan/TSP) • Construct 300 LF of 100-foot-wide by 6-inch thick scour pad along both sides of two (2) closure structures and raise the levee embankment 2 feet over a distance of 12,000 LF. Additionally, replace two (2) 30 feet wide by 12 feet high vehicle closure structures, construct 500 LF of 7-foot floodwall at two (2) pump stations, and reinforce the existing pump station walls.

Project Area	Final Array - Alt. Name	Description of CSRM Alternative	Optimization Alternatives
Freeport and Vicinity CSRM	**South Storm Levee**	The South Storm Levee reach is on the south side of the Freeport and Vicinity Hurricane Flood Protection Project paralleling the Gulf Intracoastal Waterway. Because the levee embankment is not uniform in height and is therefore susceptible to concentrated overtopping erosion for the assumed design storm event, the reach was considered a candidate for levee raising. Levee raising was dropped from further consideration however because it was demonstrated not to be economically feasible.	• Raise levee embankment one foot (not economically feasible) • Raise levee embankment 2 feet (not economically feasible)
	Freeport Dock Floodwall	The existing floodwall along the Port of Freeport dock is not structurally competent to handle the additional hydrostatic loading and overtopping from the assumed design storm event. Consequently, structural reinforcement measures were considered that included replacing panels and anchor system, at a minimum, and structurally reinforcing the wall. The other alternative considered was to entirely reconstruct the dock and floodwall to a higher elevation.	• "Partial Fail" - Replace panels and anchor system. • "No Fail" - Reinforce 3,000 LF of floodwall. (NED Plan/TSP) • Reconstruct dock and floodwall (3,000 LF), raising by one foot. (not economically feasible)
	Tide Gate I-Wall	Because of floodwall performance issues related to stability and resiliency, the I-wall at the Tide Gate is proposed to be reconstructed as a pile-founded T-wall. The construction process will involve demolishing the existing concrete monoliths and exposing the existing PZ27 sheet piling, driving concrete piling for the foundation, constructing a concrete pile cap, constructing scour protection, and placing concrete for the T-wall stem. The overall length of the replaced wall would be 700 feet. Two thousand (2,000) LF of the adjacent levee embankment would also be raised one foot.	• "No Fail" – Replace 362 lf of I-wall with concrete T-wall, 10 feet high. • Replace 700 LF of I-wall with new concrete T-wall, 10 feet high, and raise levee embankment one foot over a distance of 2,000 LF. (NED Plan/TSP) • Replace 700 LF of I-wall with new concrete T-wall, 11 feet high, and raise levee embankment 2 feet over a distance of 3,500 LF. In addition, construct 200 LF of floodwall at one pump station, 7 feet high, and rebuild the Tide Gate structure.
	Old River Levee at Dow Thumb	The Old River North Levee at Dow Thumb is not high enough to prevent overtopping by waves during extreme surge events. Consequently, structural resiliency measures and/or structure height raises are proposed to prevent erosion of the levee embankment and scouring behind the existing floodwall. Construction activities to raise the existing earthen levee embankment will involve stripping the embankment side slopes, removing and replacing a 12-foot-wide asphalt road on the crown, placing and compacting fill atop the crown and along the interior slope, installing high-performance turf reinforcement mattress (HPTRM) on the slopes, and turfing the slopes.	• "No Fail" – Reinforce 14,500 LF of the levee embankment with HPTRM and construct 4,000 LF of 15-foot-wide by 6-inch thick concrete scour pad behind the I-wall - 3,000 LF feet along the "thumb" and 1,000 LF near the entrance of the Dow Barge Canal to provide structural resiliency. • Reinforce 14,500 LF of the levee embankment with HPTRM and construct 4,000 LF of 15-foot-wide by 6-inch thick concrete scour pad behind the I-wall to provide structural resiliency, and raise levee embankment one foot over a distance of 3,000 LF. (NED Plan/TSP) • Raise levee embankment 2 feet over a distance of 6,500 LF, replace 12,000 LF of floodwall, making it 10 feet high, replace one drainage structure, and construct a new saltwater intake structure. (not economically feasible)

Project Area	Final Array - Alt. Name	Description of CSRM Alternative	Optimization Alternatives
Freeport and Vicinity CSRM	**Dow Barge Canal**	A closure structure with a navigable opening and pump station is proposed at the junction of the North Barge Canal and East Storm Levee to obviate the need to resolve the seepage problem with the existing "sandy" levees when steady-state seepage is assumed (which is the condition required to be assumed versus transient seepage). It is not technically feasible to fix the underseepage problem given the existing infrastructure along the length of the levee. The closure structure will allow barge traffic to pass during routine operations. As conceived, the pump station would be capable of pumping of 2,000,000 gallons per minute. The structure will be approximately 500 feet long with two (2) sector gates to provide an 80-foot-wide opening for vessel traffic. Tidal circulation would be maintained with two (2) sluice gates, each approximately 15 feet wide.	• Rehabilitate levee along barge canal (~13 miles), including the installation of a seepage cut-off wall. (not technically feasible) • Construct a new gate structure with a navigable opening across the barge canal. The structure will be approximately 500 feet long with two (2) sector gates to provide an 80-foot-wide opening for vessel traffic, have two (2) sluice gates to maintain tidal circulation, and have an auxiliary pump station with a 2,000,000 gallons per minute pumping capacity. (NED Plan/TSP)
	East Storm Levee	The reach of levee along the system's east side is not high enough to prevent wave overtopping from the design surge event. Construction activities to raise the existing earthen levee embankment will involve stripping the embankment side slopes, removing and replacing a two-lane asphalt road on the crown, placing and compacting fill atop the crown and along the interior slope, installing HPTRM on the slopes, and turfing the slopes.	• "No Fail" – Install HPTRM on levee embankment slopes along a distance of 13,115 LF • Raise levee embankment one foot over a distance of 13,115 LF and install HPTRM on slopes. (NED Plan/TSP) • Raise levee embankment 2 feet over a distance of 19,115 lf and install HPTRM on slopes. In addition, construct 800 lf of new floodwall at one pump station, 5 feet high, reinforce the pump station walls, and raise FM 332 at levee crossing (2,500 lf).
	Oyster Creek Levee	The reach of levee flanking the south bank of Oyster Creek Levee is not high enough to prevent wave overtopping from the design surge event. Construction activities to raise the existing earthen levee embankment will involve stripping the embankment side slopes, removing and replacing a 12-foot wide asphalt road on the crown, placing and compacting fill atop the crown and along the interior slope, installing HPTRM on the slopes, and turfing the slopes.	• "No Fail" – Raise levee embankment two (2) feet over a distance of 3,500 LF. • Raise levee embankment one foot over a distance of 10,000 LF and 3 feet over a distance of 3,500 LF. (NED Plan/TSP) • Raise levee embankment 2 feet over a distance of 33,000 LF and 4 feet over a distance of 3,500 LF. In addition, - replace 1,000 LF of floodwall, making it 8 feet high; - build new pump station with 1,100 cfs pumping capacity; - replace six (6) gravity structures; - and raise FM 523 at levee crossing (2,500 LF).

1.10 DESCRIPTION OF TSP PROJECTS

1.10.1 Orange-Jefferson CSRM Project (reference Plate G-1)

1.10.1.1 Orange 3 Reach

The proposed Orange 3 reach is a levee/floodwall flood protection system that will serve to reduce the flood-damage potential from storm surge to much of the southern half of Orange County along the Sabine River and Bessie Heights Marsh (see Plate G-1). As conceived, the structures comprising the system will be built to an elevation capable of handling an 11-foot storm surge. At this time, there is no provision in the concept features assumed in developing the TSP project costs that accounts for future relative sea level rise, waves on top of the surge level, and additional minimum freeboard for wave overtopping. Therefore, the structure heights to accommodate this surge likely will end up being designed several feet higher than the heights assumed for the optimization analysis. (For the optimization analysis, it was assumed that sea-level rise, wave run-up, and overtopping could be uniformly applied across the system without affecting the TSP outcome.)

Orange 3 begins at I-10 at its northeast end, about 1.75 miles west of where the highway crosses the Sabine River. From there, the alignment roughly parallels the Sabine River to the south and then to the southwest to an industrial canal 1.65 miles northeast of the mouth of Cow Bayou. Along this reach, the alignment crosses Adams Bayou, which is used for navigation. There, the alignment turns sharply to the northwest, going up to a point near the south corner of the Du Pont Sabine River Works plant. From this point, the alignment runs southwesterly to Bridge City, crossing Cow Bayou along the way, which is also used for navigation. The alignment then wraps around Bridge City to the south, turning northwesterly along the north side of the Bessie Heights Marsh to an end point less than a mile southwest of FM 1135, where it intersects FM 105 (Orangefield Road). Along this reach, the system will protect an electrical power-generating plant. In total, the length of the system will be approximately 27.1 miles, 21.1 miles of which will consist of earthen levee and 6.1 miles of concrete floodwall. The proposed alignment crosses several secondary roads, State Highway 87, Adams and Cow Bayous, an industrial canal, power plant intake canal, and floodplains where the foundation conditions are poor. It also crosses numerous pipelines and utilities, industrial facilities, commercial properties, residential areas, and sensitive environmental habitats. Consequently, there are going to be several challenges in implementing this reach of the project that will add considerably to its construction cost.

Orange 3 reduces the flood-damage potential from storm surge within the Cities of Orange, West Orange, Pinehurst, Bridge City, and Orangefield. It also protects petrochemical plants and Entergy Texas Inc. Sabine (Power) Plant, Bridge City.

1.10.1.2 Jefferson Main Reach

The proposed Jefferson Main reach is an earthen levee/concrete floodwall protection system that will serve to reduce the flood-damage potential from storm surge along the northeastern boundary of Jefferson County defined by the Neches River (see Plate G-1). As conceived, the structures comprising the system will be built to an elevation capable of handling an 11-foot storm surge. At this time, there is no provision in the concept features assumed in developing the TSP project costs that accounts for future relative sea level rise, waves on top of the surge level, and additional minimum freeboard for wave overtopping. Therefore, the structure heights to accommodate this surge likely will end up being designed several feet higher that the heights assumed for the optimization analysis.

The alignment begins near the northeastern terminus of the existing Port Arthur and Vicinity HFPP where it will tie into high ground. It runs west-northwest generally along the west bank of the Neches River, nearly 11.0 miles, to a point on the north side of the Du Pont Beaumont Works Industrial Park in Nederland. Because industrial facilities to be protected front the river, approximately 3.1 miles of the system will consist of floodwall. The alignment crosses industrial plants and must provide for access to several docking facilities along the river. It circumvents a large upland wetland area, thereby avoiding adverse impacts to the wetland.

1.10.1.3 Beaumont "A" Reach

The proposed Beaumont "A" reach is an earthen levee/concrete floodwall protection system that will serve to protect ExxonMobil's Beaumont Chemical Plant (see Plate G-1). This 3.6-mile-long system, consisting of 1.1 miles of levee and 2.5 miles of floodwall, was envisioned to supplant the existing flood-protection system surrounding the plant to provide a level of protection that reduces the flood-damage risk against a 12-foot surge. It has been discovered since this alternative was forwarded to be included in the TSP as a project reach however that the recently industry-built barrier is approximately 3 to 4 feet higher than that being proposed based on the SWL alone. The proposed alignment generally follows the existing barrier alignment. When storm surge from Hurricane Ike inundated the plant in 2008, the plant was 6 to 10 feet under water. This resulted in a shutdown of the plant for more than a month. To prevent future damages from storm surge, ExxonMobil Corporation replaced its former levee system, making the barrier more robust and providing a higher level of protection.

1.10.2 Port Arthur and Vicinity CSRM Project (reference Plate G-2)

1.10.2.1 Port Arthur 8- to 10-foot I-Wall One-Foot Raise

The TSP for reconstruction and resiliency features for the existing HFPP in this reach was selected to be the one-foot raise plan. A one-foot raise will require 7,500 LF of 15-foot-wide by 6-inch thick concrete scour pad along with removing the excess stick-up height from the existing I-wall and adding erosion protection to reduce the likelihood of a brittle failure if the system's capacity is exceeded. This plan includes adding capacity to the system in this reach by addressing low areas of the levee system, raising 2,000 LF of levee one foot, and providing overtopping erosion protection at areas subject to excessive erosion.

1.10.2.2 Port Arthur Closure Structure

The TSP for reconstruction and resiliency features for the existing HFPP at the closure structure is the one-foot raise plan. The replaced closure structure gate structure is proposed to be 12 feet high by 30 feet wide. In addition to replacing the structure, 2,300 LF of 100-foot-wide by 6-inch thick concrete scour pad will be constructed, one on each side of the structure, to provide erosion protection to reduce the likelihood of a brittle failure if the system's capacity is exceeded and 12,000 LF of levee will be raised one foot.

1.10.2.3 I-Wall near Valero

The TSP for reconstruction and resiliency features for the existing HFPP at the I-wall near the Valero refinery is additional structural support and a one-foot raise. Construction of 5,000 LF of 15-foot-wide by 6-inch thick concrete scour pad and a batter piling and waler system with a one-foot raise will provide additional system capacity, assure the wall's structural integrity, and provide erosion protection to reduce the likelihood of a brittle failure if the system's capacity is exceeded. In conjunction with these reinforcement and resiliency measures, an additional 3,000 LF of adjacent levee will be raised one foot.

1.10.2.4 Port Arthur Tank Farm

The TSP for reconstruction and resiliency features for the existing HFPP at the I-wall near the Tank Farm is additional structural support and a one-foot raise. Construction of 1,800 LF of 15-foot-wide by 6-inch thick concrete scour pad and a batter piling and waler system with a one-foot raise will provide additional system capacity, assure the wall's structural integrity, and provide erosion protection to reduce the likelihood of a brittle failure if the system's capacity is exceeded. In conjunction with these reinforcement and resiliency measures, an additional 7,000 LF of adjacent levee will be raised one foot.

1.10.3 Freeport and Vicinity CSRM Project (reference Plate G-3)

1.10.3.1 South Storm Levee Raise

The South Storm Levee was determined not to be an economically viable option.

1.10.3.2 Freeport Dock Floodwall Raise

The TSP for reconstruction and resiliency features for the existing HFPP at the Freeport Dock floodwall is a reconstruction of the existing wall/drop in panel system. The construction will include 3,000 LF of floodwall to meet all USACE requirements for a wall/drop-in panel system for a port facility.

1.10.3.3 Tide Gate One-Foot Raise

The TSP for reconstruction and resiliency features for the existing HFPP at the I-wall located at the Tide Gate is a complete reconstruction of the I-wall and extension of the reconstructed floodwall to replace two (2) additional sections of floodwall at a one-foot raise in system capacity. Construction will consist of 700 LF of floodwall, 11 feet high, along with 2,000 LF of levee raised one foot.

1.10.3.4 Old River at Dow Thumb

The TSP for reconstruction and resiliency features for the existing HFPP along the Dow thumb levee reach is a one-foot raise in system capacity. Construction will include 4,000 LF of 15-foot-wide by 6-inch thick concrete scour pad along with 3,000 LF of levee raised one foot and 14,500 LF of high performance turf reinforcement mattress (HPTRM). Additional material will be added in order to “level up” the low spots of this reach of levee, which, in conjunction with the erosion protection, will to reduce the likelihood of a brittle failure if the system’s capacity is exceeded.

1.10.3.5 Dow Barge Canal Protection

The TSP for reconstruction and resiliency features for the existing HFPP at the Dow Barge Canal levee is a closure structure and pump station constructed at the junction of the North Barge Canal and East Storm Levee across the barge canal to the South Barge Canal Levee. This structure will allow barge traffic to pass during routine operations and will have a pumping capacity of 2,000,000 gpm. The structure will be approximately 500 feet in length with two (2) sector gates to provide for an 80-foot-wide navigable opening. Tidal circulation will be maintained by two (2) sluice gates, each approximately 15 feet wide. The structure’s final configuration will match the proposed level of protection for the system.

1.10.3.6 East Storm Levee Raise

The TSP for reconstruction and resiliency features for the existing HFPP at the East Storm Levee is a one-foot raise in system capacity. Construction includes 13,115 LF of levee raised one foot along with HPTRM installation for erosion protection.

1.10.3.7 Oyster Creek Levee Raise

The TSP for reconstruction and resiliency features for the existing HFPP at the Oyster Creek Levee reach is a one-foot raise in system capacity along with extending an elevation to account for changes in surge loading. Construction will include 3,500 LF of a 3-foot levee raise and 10,000 LF of a one-foot levee raise for a total raised distance of 13,500 LF. The construction procedure will include stripping, removal and replacement of a 12-foot-wide asphalt road, placement of compacted fill, and turfing.

2 HYDROLOGY AND HYDRAULICS

2.1 INTRODUCTION

This section discusses the Hydrologic and Hydraulic (H&H) data gathering efforts and engineering analyses for the Sabine to Galveston DIFR-EIS. The H&H analysis was included as part of the information used to select the NED plans and TSP.

The focus areas of the study, the Brazoria and Sabine Regions, contain a complex system of floodwalls, earthen levees, pump stations, culverts, sluice gates, flap gates, sector gates, hazardous material sites, small local levees, large adjacent rivers and vertical lift gates. Two large sector gates are recommended as part of the tentatively selected plan on Cow and Adams Bayous in Orange County. A complete SMART planning feasibility level of analysis of the storm surge, waves, run-up, and interior drainage features including culverts and pumps was performed. Additionally, RSLC and climate change were estimated and the impacts assessed in accordance with Engineering Regulation (ER) 1100-2-8162 and Engineering Technical Letter (ETL) 111-2-1. Levee height analyses were performed and overtopping rates calculated for all levee systems in the two study regions following guidance in planning guidance documents (as of 2015), Engineering Circular (EC) 1110-2-6067, ETL 1110-2-299, and Code of Federal Regulations (CFR) 44 and 45. The Brazoria Region contains Brazoria County and the Sabine Region contains Jefferson and Orange Counties. Some surrounding areas such as Southern Louisiana near the Sabine Region were also included in the current study to determine, assess, and minimize adjacent impacts.

An overall view showing the locations of the Brazoria and Sabine Regions is presented in Figures 2-1, 2-2, and 2-3. Three major rivers flow through these regions. The Neches River and Sabine River flow through the Sabine Region, with the Neches River delineating the county line between Jefferson and Orange Counties, and the Sabine River which marks the state line between Texas and Louisiana. In the Brazoria Region, the Brazos River flows along the west side of the existing Freeport and Vicinity HFPP. Additional important and also navigable waterways in the project study areas are discussed in further detail later in this section of the appendix.

2.1.1 Brazoria Region

The H&H analysis of Brazoria Region focused on detailed analysis of the existing Freeport levee system and its components, and how the existing system should be modified to prevent failure and increase the level of protection where needed. The Freeport levee footprint will change minimally or not at all, with some exceptions, between the with-project and without-project

conditions with the exception of the proposed DOW barge canal gate. The system is being evaluated for an array of possible improvements and modifications. Improvements considered include raising the levees, changing the levee embankment geometry and height, acquiring rights-of-way (ROW), and constructing resiliency features (e.g., concrete scour pads on the interior side of the levee/floodwall and drainage features to manage overtopping flows). Additionally constructing a large closure structure with a navigable opening to block one of the longest and weakest sections of the system along a barge canal from being impacted by surge. Areas where these changes are recommended will have corresponding change in footpring and possibly change in the levee alignment. Detailed analysis of the Freeport levee system was performed is discussed in Section 2.9. Improvements to or replacement of existing drainage features, such as pumping stations, to accommodate changes in flows due to improvements/modifications were preliminarily evaluated. Features needed to create a resilient and robust levee system were identified. An aerial view of the existing Freeport and Vicinity HFPP is shown in Figure 2-1.

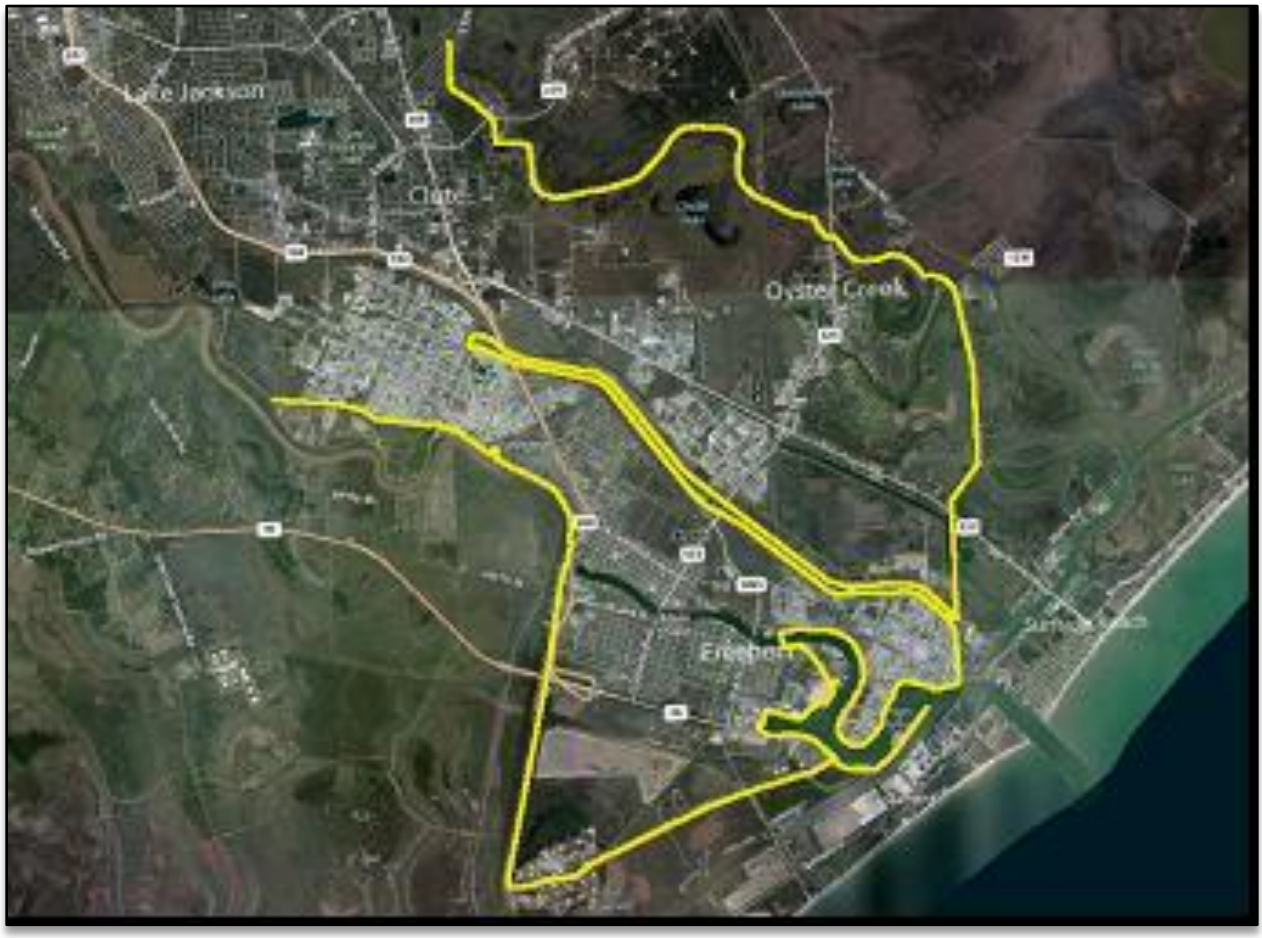

Figure 2-1: Existing Freeport and Vicinity HFPP

2.1.2 Sabine Region

The Sabine Region contains an existing levee system – the Port Arthur and Vicinity HFPP (Figure 2-2), which was evaluated from an H&H perspective using the same procedures and methodology as the existing Freeport levee system. The City of Port Arthur is in Jefferson County on the west bank of Sabine Lake. A deep-draft navigation channel is immediately in front of the Port Arthur levee frontal wall facing Sabine Lake (mostly reinforced-concrete floodwall, 15+ feet high). The Sabine Region study area also contains proposed new levee systems in Orange and Jefferson Counties (Figure 2-3). The new levee systems studied included levees protecting the majority of Orange County south of Interstate 10, as well as additional components in Jefferson County along the west bank of the Neches River. An analysis was performed on the proposed Orange system to determine levee heights, required drainage features, and adjacent impacts. This included new storm surge and wave modeling. A preliminary analysis and design of an interior drainage system and levee components for the proposed Orange County system was completed, including drainage structures such as culverts, gates, and pump structures for Adams and Cow Bayous.

Figure 2-2: Existing Port Arthur and Vicinity HFPP

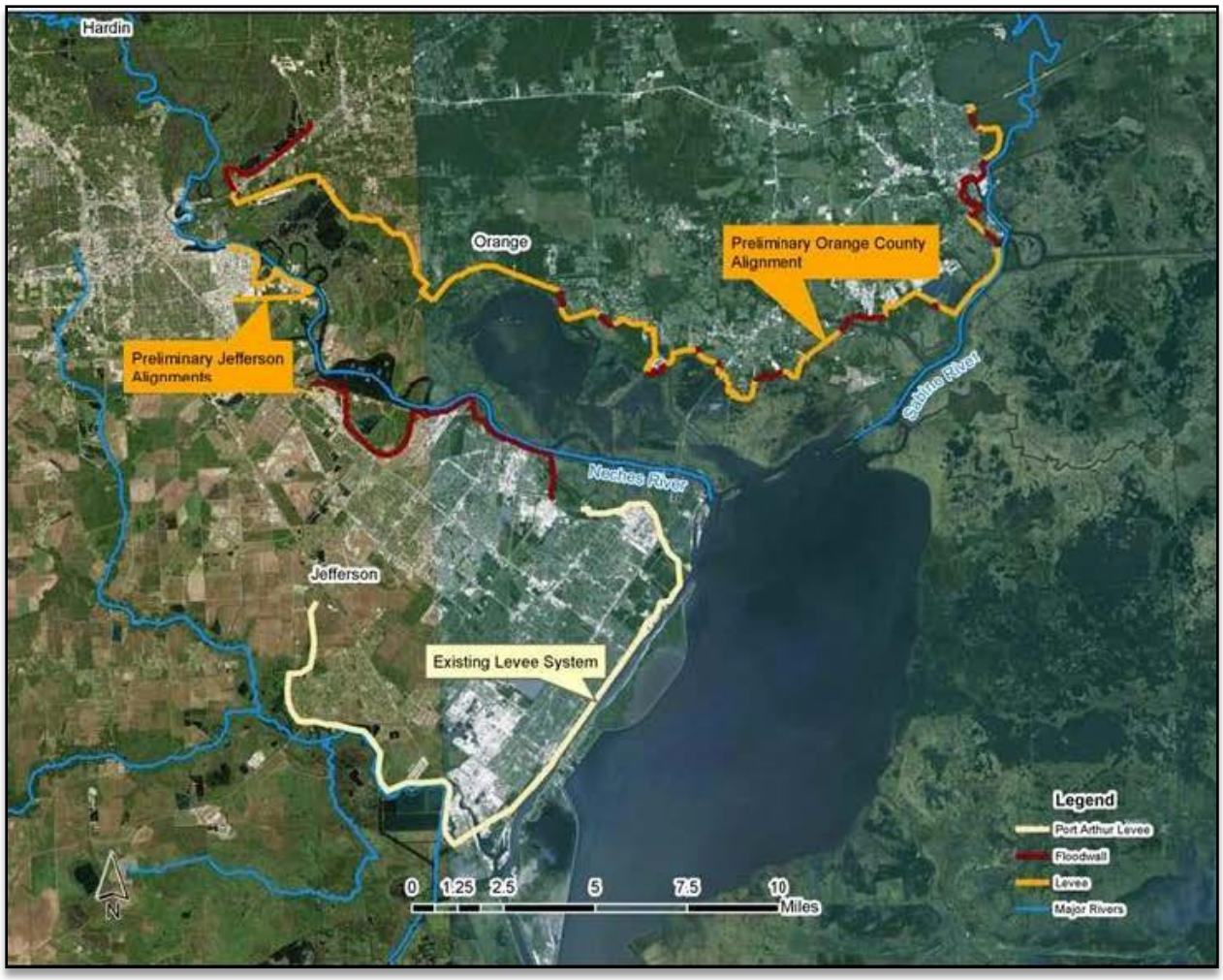

Figure 2-3: Maximum Extents of Proposed New Orange and Jefferson Counties Levee Systems Considered

New levee systems were also proposed and evaluated in Jefferson County across the Neches River from Orange County. Impacts from the proposed levee were assessed and levee heights were recommended accordingly. The locations and configurations of interior drainage features such as culverts and pumps were identified using existing plans and aerial photography. Deficient pumps or pump station requiring modification were identified with the help of levee periodic inspection reports and Jefferson Drainage District #7. The storm surge modeling is discussed in detail in Section 2.9. Interior drainage is discussed in Section 2.14.

2.2 REGIONAL DATA

2.2.1 Units and Coordinate System

All units are in International System (SI) of units unless stated otherwise. Vertical and elevation data is in feet, referenced to NAVD 88 datum unless noted otherwise. Horizontal coordinates shown are in Universal Transverse Mercator (UTM) Zone 15. The project horizontal datum is NAD 83.

2.2.2 Gage Data

Measured age data including water levels, flows, and velocities in the study area was obtained from NOAA. Local gages used to gather data include Gage 8772440 in the Brazoria Region and Gages 8770520 and 8770570 in the Sabine Region. Gage Locations are shown in Figures 2-4 and 2-5. Additionally Discharge data is available from the Neches River gage was utilized.

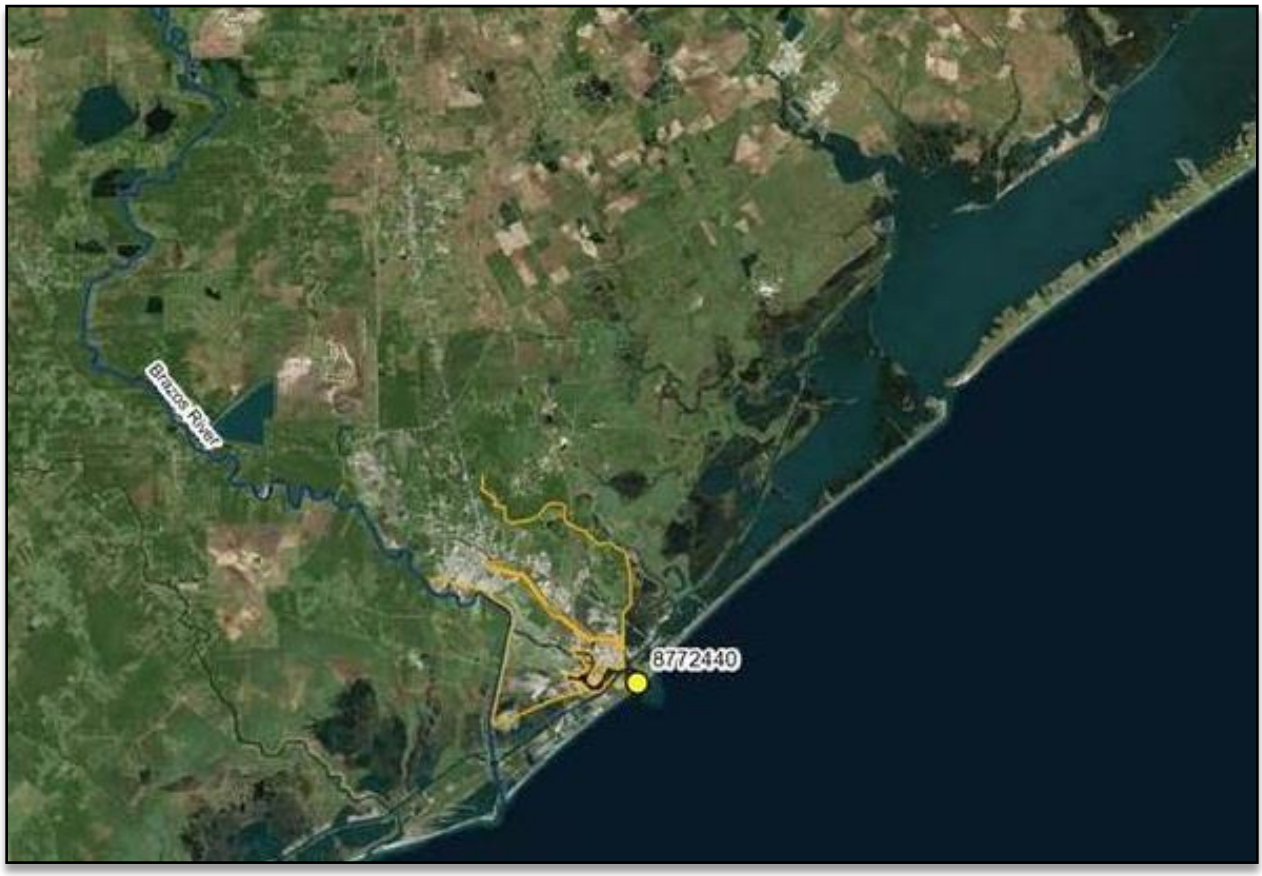

Figure 2-4: NOAA Gage 8772440 in Brazoria Region

Figure 2-5: NOAA Gages 8770570 and 8770520, Sabine Region

2.2.3 Datum and Tidal Information

Elevations in this report are referenced to NAVD 88 unless noted otherwise. Much of the data gathered used datums such as Mean Sea Level, Mean Low Tide, Mean Low Water, and Mean Lower Low Water. For easy reference, the conversion between datums for each region is presented in the Table 2-1 on the next page. For additional information on datum conversion, reference EM 1110-2-6056.

Tides in the Brazoria Region of the study area range from a low ebb tide of -0.28 feet (MLLW) to a high flood tide of 1.78 feet (MLLW). (NOAA Gage 8772440)

Tides in the Sabine Region of the study area range from a low ebb tide of 0.62 feet (MLLW) to a high flood tide of 1.22 feet (MLLW). (NOAA Gage 8770520)

Table 2-1: Datum Conversion Summary Table for Brazoria and Sabine Region

Datum	Freeport Region	Sabine Region
	Gage 8772440	Gage 8770520 (Rainbow Bridge)
	Value (feet)	Value (feet)
MHHW*	5.61	4.96
MHW*	5.67	4.89
MTL*	5.00	4.45
MSL*	5.00	4.48
MLW*	4.32	4.00
MLLW*	4.05	3.90
NGVD29**	6.43	5.23
NAVD88**	3.41	3.72
Source - http://tidesandcurrents.noaa.gov/stations.html?type=Datums		
Conversion Source -USACE Survey, OPUS Control Monuments_Rizzo		

*Asterisk indicates water-based datum, **Asterisk indicates land-based datum

2.3 EXISTING DATA COLLECTION

2.3.1 Data Collection Summary

An extensive amount of existing data was gathered for both regions for use in this study. A wide variety of reports, models, design plans/as-built plans, feasibility studies, historical studies, watershed master plan studies, and multiple other various studies. The reference section of this document contains a list of data used for the HH&C analysis. Additionally, the latest available tools including the Coastal Hazard System, IWR Suite, the latest ERDC storm modeling capabilities, and ERDC environmental modeling capabilities, among others, were used in this study to the extent possible. It is recommended that some of the modeling be revisited when the project features are designed for construction as the models will be improved and site conditions could change.

2.3.2 Topographic, Bathymetric, and Survey Data

Detailed terrain data were obtained for the study area in the form of LiDAR data obtained from the Texas Natural Resources Information System (TNRIS). LiDAR data for Brazoria/Orange/Jefferson County, dated 2010, were at a 1-meter resolution. Additional terrain data were taken from existing surveys, USGS contour maps, and aerial photography. Historical reports, historical photography, and historical terrain maps were used where applicable. Bathymetry data for the study regions was obtained from the NOAA Geophysics Bathymetry and Global Relief World Data Services. Survey data in USACE's possession and ADCIRC mesh elevation data were also used. Recent survey data from other projects and construction plans were used to cross-reference the elevations in the data USACE is using. These data were compared to the latest ADCIRC mesh data. In areas where the gathered topography, survey and

bathymetry data contained more recent and/or more accurate data, the ADCIRC mesh data were updated. Some previously used data, prior to USACE analysis, were found to be incorrect and those errors were fixed before modeling began.

2.3.3 FEMA Data

The FEMA Coastal Counties Report (2011) and associated electronic files were obtained and used in this study. The Coastal Counties Study covered the entire Texas coast. USACE obtained flood inundation maps from FEMA for the 10-, 50-, 100-, and 500-year still-water levels (SWL). These data were used in the screening for the Alternative Milestone Meeting (AMM) and Workshop (Reference Appendix B For information on screening). The data were later refined and stage-frequency data for the 10-, 20-, 50-, 100-, 200-, 500- and 1,000-year events were obtained utilizing ADCIRC modeling capabilities to determine the surge elevations for a range of different storms at points blanketing the area. ADCIRC coupled with STWAVE for the Brazoria Region was rerun. Statistical analysis of the data generated was conducted using StormSim, a computer program recently developed by ERDC to produce results that are more accurate. ADCIRC was coupled with STWAVE for the Sabine Region for the without-project and with-project conditions. The statistical analysis, again, was performed using StormSim. The ADCIRC runs for the Sabine Region contained additional storms not modeled in the 2011 FEMA study. The surge modeling and data were provided to assist in selecting the TSP. Additional discussion regarding the use of the FEMA data and storm surge modeling and accompanying analysis is discussed in Section 2.5.

2.3.4 Tropical Cyclones and Floods of Record

Both regions have a long history of being subjected to large topical events, including major hurricanes. The earliest documented hurricane in Texas made landfall at Matagorda Bay in 1527. For a complete list of documented hurricanes in Texas reference “Texas Hurricane History” authored by David Roth of the National Weather Service, last updated in 2010. The hurricane with the greatest known loss of life is the 1900 Galveston Storm with deaths estimated at between 6,000 and 12,000 people. The hurricane striking the Texas Gulf Coast with the greatest economic damages is Hurricane Ike, in 2008. A list of major tropical events that have impacted Texas since the 1850s is given in Table 2-2 (Reference: David Roth, NWS, 2010).

Table 2-2: Tropical Cyclone Strikes by Decade since 1850

Tropical Cyclone Strikes By The Decade			
Decade	**Hurricanes**	**Tropical Storms**	**Total**
1850's	3	1	4
1860's	4	1	5
1870's	2	4	6
1880's	8	3	11
1890's	3	3	6
1900's	4	2	6
1910's	7	1	8
1920's	2	3	5
1930's	5	4	9
1940's	8	6	14
1950's	2	5	7
1960's	3	3	6
1970's	2	7	9
1980's	5	4	9
1990's	1	4	5
2000's	5	5	10
Total	64	56	120
Avg Per Decade	4	3.5	7.5

Tropical cyclones impacting the study area have included major hurricanes such as the Galveston storms of 1900 and 1915, the unnamed hurricane in 1943, Hurricane Carla in 1962, Hurricane Rita in 2005, and Hurricane Ike 2008. These storms have caused considerable loss of life and extensive economic damages. As evident in Table 2-2, tropical cyclones along the Texas Gulf Coast occur frequently, averaging 7.5 per decade. This includes an average of four (4) hurricanes per decade over the last 150+ years. It is important to note that these are storms which made landfall in Texas. They do not include storms that made landfall in Louisiana or Mexico, but had significant impacts of surge and/or wind to the Texas coast, such as Hurricane Katrina in 2006.

2.4 SUMMARY OF PROJECT AREAS AND H&H OBJECTIVE

The coastal areas of Texas are low-lying and highly populated areas, and include a vast variety of recreation, population centers, residential areas, businesses, and industrial infrastructure. The area is subject to frequent tropical cyclones, which historically have caused great loss of life and high economic losses.

The objective of the CSRM study is to evaluate alternatives that would reduce coastal storm damages in the Brazoria and Sabine Regions. H&H analyses are key components in determining a plan to reduce damages from storm surge. This section of the engineering appendix presents an overview of the H&H efforts performed to inform, evaluate, and provide support to USACE efforts in determining the TSP to reduce damages from storms along the Texas coast.

2.5 ANALYSIS OF HYDRAULIC LOADING FOR FLOOD PROTECTION SYSTEMS

The following documents the analyses that were done to support the design of the proposed hurricane-flood protection systems. Hydraulic analyses were conducted to inform flood-protection system design. Analyses were conducted to support design of the levees and floodwalls. The following parameters were evaluated for design:

- Levees
  - Crest elevation
  - Side slopes
  - Overtopping rate

- Flood walls
  - Crest elevation
  - Side slopes
  - Overtopping rate

In order to calculate design parameters, the following general process was applied:

Gather existing data

1) Analyze storm surge and waves
   a. ADCIRC/STWAVE for large-scale storm surge and waves
   b. Output statistics for various return periods for waves and water levels along with quantification of uncertainty for surge and wave modeling results
2) Local wave transformations using CMS-Wave, where required
3) Overtopping analysis
   a. Existing structures: run-up and overtopping were calculated for the 1 % ACE
   b. Proposed structures: acceptable overtopping limits were specified to calculate freeboard
4) Recommend levee crest elevation based on hydraulic analyses presented

5) Assess any adjacent impacts due to new levee construction or modification to existing levees

2.6 EXISTING DATA SUMMARY

Existing data gathered and reviewed for each study region included:

- Previous surge and wave models and results
- Topographic and bathymetric data, aerial imagery, USGS maps
- Historical data including plans, modification studies, O&M manuals, and design memorandums, local hurricane flood protection plans, FEMA and other Texas coastal surge models and documentation
- Ongoing analysis and reports (for example, the Risk Management Center (RMC) draft report on the Freeport levee system)
- Existing levee alignment data and proposed modification from ports, districts, and cities

Data gathered were summarized using ArcMAP and Excel to simplify comparison and analysis.

2.6.1 Brazoria Region

Existing data were gathered for the Brazoria Region, focusing on data related to the existing Freeport and Vicinity HFPP, to enable hydraulic analyses. Figure 2-6 shows a map of some of the available data including LiDAR data. Readily available data gathered included:

- FEMA DEM of LIDAR data collected in 2007
- Existing levee alignment and elevation data collected for the National Levee Database
- 10-, 50-, 100-, and 500-year return period water levels calculated for the FEMA (2011) study
- STWAVE results from the FEMA (2011) study
- COULWAVE results from Lynett (2012)
- USACE channel survey data
- NOAA bathymetry surveys
- USGS, TCOON, and NOAA water data
- Aerial imagery from various sources
- USACE RMC Freeport Semi-Quantitative Risk Assessment (SQRA)
- Various other reports as referenced in this document

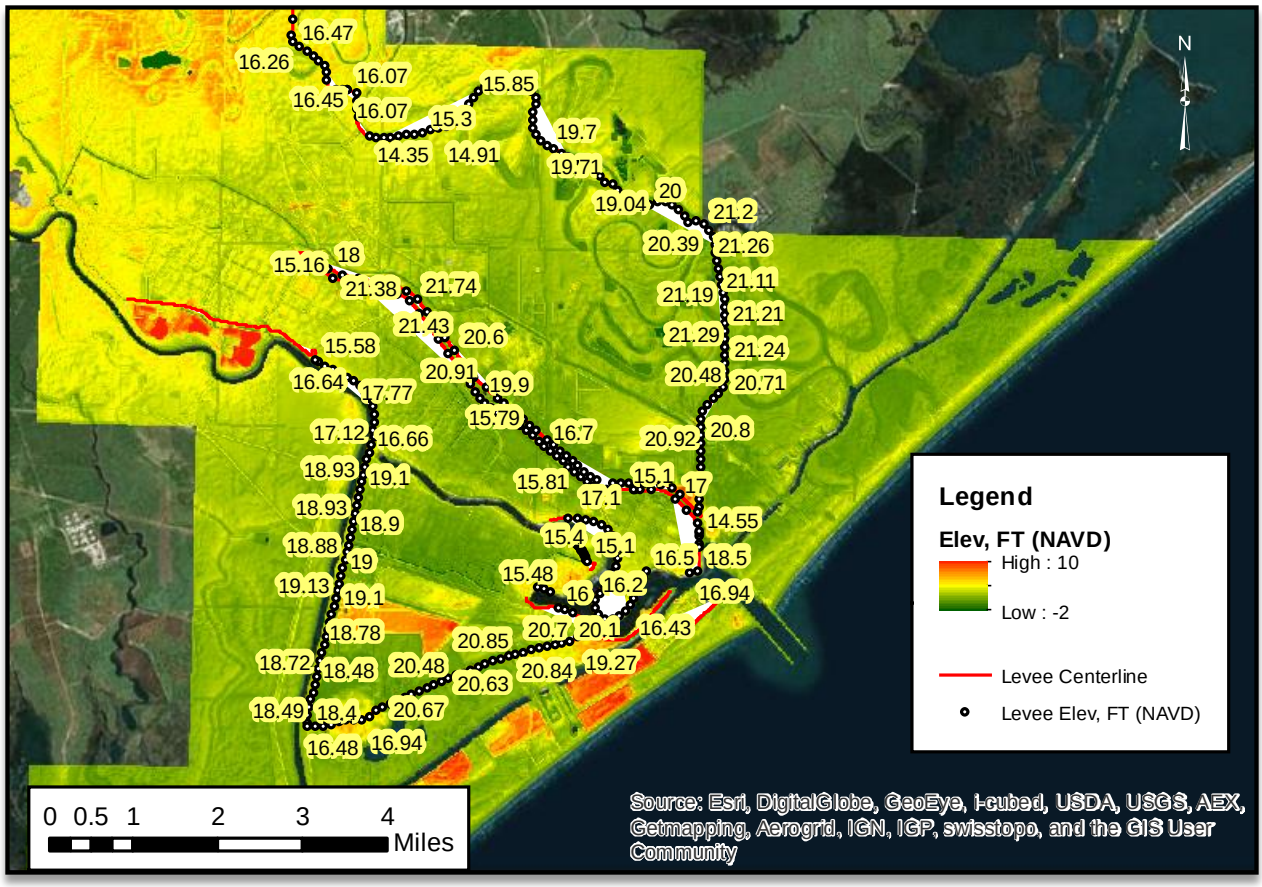

Figure 2-6: Map of Freeport Area with Select Data Gathered

2.6.2 Sabine Region

Existing data were gathered for the Sabine Region related to the storm-protection system to enable hydraulic analyses. Figure 2-7 shows a map of some of the available data including LiDAR data. Readily available data included:

- FEMA Digital Elevation Model (DEM) of LiDAR data collected in 2007
- Existing levee alignment and elevation data collected for the National Levee Database
- 10-, 50-, 100-, and 500-year return period water levels calculated for the FEMA (2011) study
- STWAVE results from the FEMA (2011) study
- Flood Protection Planning Study, Hurricane Flood Protection System, Orange County, Texas report (Carroll & Blackman, Inc. 2012)
- Neches River Corps Water Management System (CWMS) and Modeling, Mapping, and Consequences (MMC) hydraulic models
- Adams Bayou Hydraulic Modeling and Drainage Area Delineation for Cow and Adams Bayou (Carroll & Blackman, 2015)

- USGS, TCOON, and NOAA water level data
- USACE channel survey data
- NOAA bathymetric surveys
- Aerial imagery from various sources
- Various other reports as referenced in this document

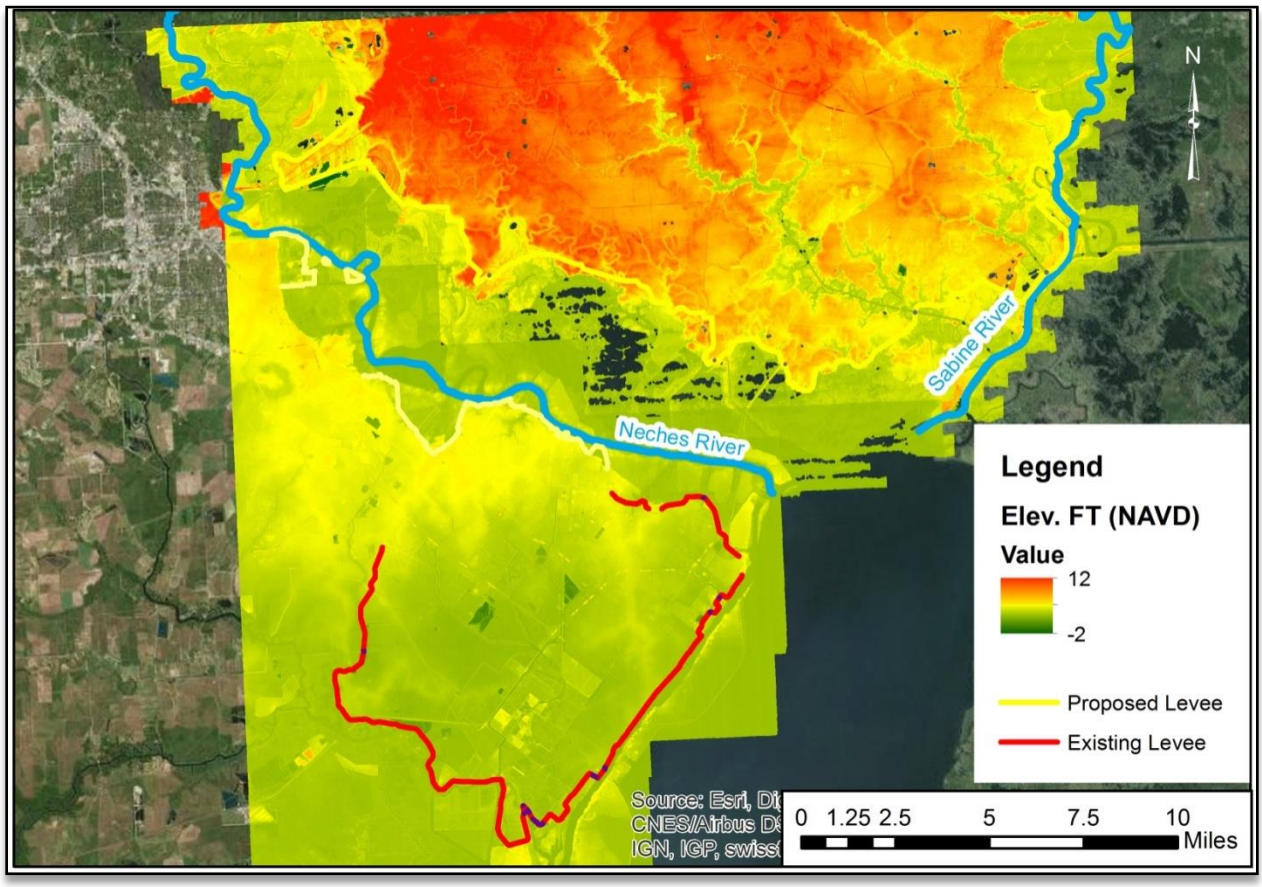

Figure 2-7: Map of Sabine Region with Select Data Gathered

2.7 ANALYSIS OF STORM WATER LEVEL AND WAVES

This section summarizes the modeling of storm surge and correlated waves for the with-project and without-project conditions.

2.7.1 Storm Modeling Approach

ERDC-CHL completed a storm modeling study of the Brazoria and Sabine Regions. The process applied and details of the model setup and accuracy are discussed in the ERDC report (Melby, et al 2015). The study took advantage of previous modeling efforts conducted for the FEMA Region VI NFIP Risk Mapping, Assessment and Planning (MAP) study reported in

FEMA (2011). In general, hydrodynamic modeling of the offshore waves and coupled surge and nearshore waves that was conducted for the FEMA study was used for the current study. However, all storm statistics as well as response statistics were recomputed using new software developed at ERDC called StormSim. In addition to improved statistical analysis, new modeling was conducted to improve some of the prior modeling and to model the with-project alternatives for the Sabine Region (including the proposed new levee systems in Jefferson and Orange Counties). A joint probability model of tropical storm parameters was developed specifically for this study. Storm recurrence rates for the coastline were defined. Previously-defined synthetic tropical storms, as summarized in FEMA (2011), were mapped onto the new joint probability model. These storms had a frequency range of roughly 1 in 10 years to 1 in 1,000 years. For the FEMA study, 446 synthetic tropical storms were defined and modeled for the Texas coast. These included 152 low-frequency storms and 71 high-frequency storms for both the north and south Texas regions. In addition, 152 Louisiana west low-frequency and 71 high-frequency storms defined in FEMA (2008) were used for the FEMA study.

2.7.1.1 Brazoria Region

For the Brazoria Region, nearshore waves and water levels modeled during the FEMA (2011) study were used to compute statistics for the Freeport area. There was no change in levee alignment for the with-project condition, so no additional with-project modeling was conducted for this area.

Extremal statistics for waves and water levels were computed using StormSim and the joint probability method. In addition, confidence levels were computed. Mean water level, wave height, and wave period responses were defined for return periods of 10, 20, 50, 100, 200, 500, and 1,000 years at save points in the Freeport area, including points surrounding and within the Freeport levee system. The average, standard deviation and 90, 95, and 98 percent levels of assurance were also calculated. Finally, the integrated uncertainty as used in the FEMA study was computed for comparison to the FEMA (2011) results to help verify quality. Figure 2-8 shows the 1 % ACE average water level at Freeport. Figure 2-9 shows the 1 % ACE upper 90 percent level of assurance at Freeport. Figure 2-10 shows plots of the return period of water level for some key locations around Freeport.

Inundation maps comparing the with-project and without-project conditions based on the FEMA (2011) 100-year storm level are presented in the Plate H-01 as part of this Engineering Appendix - H&H Support Documentation.

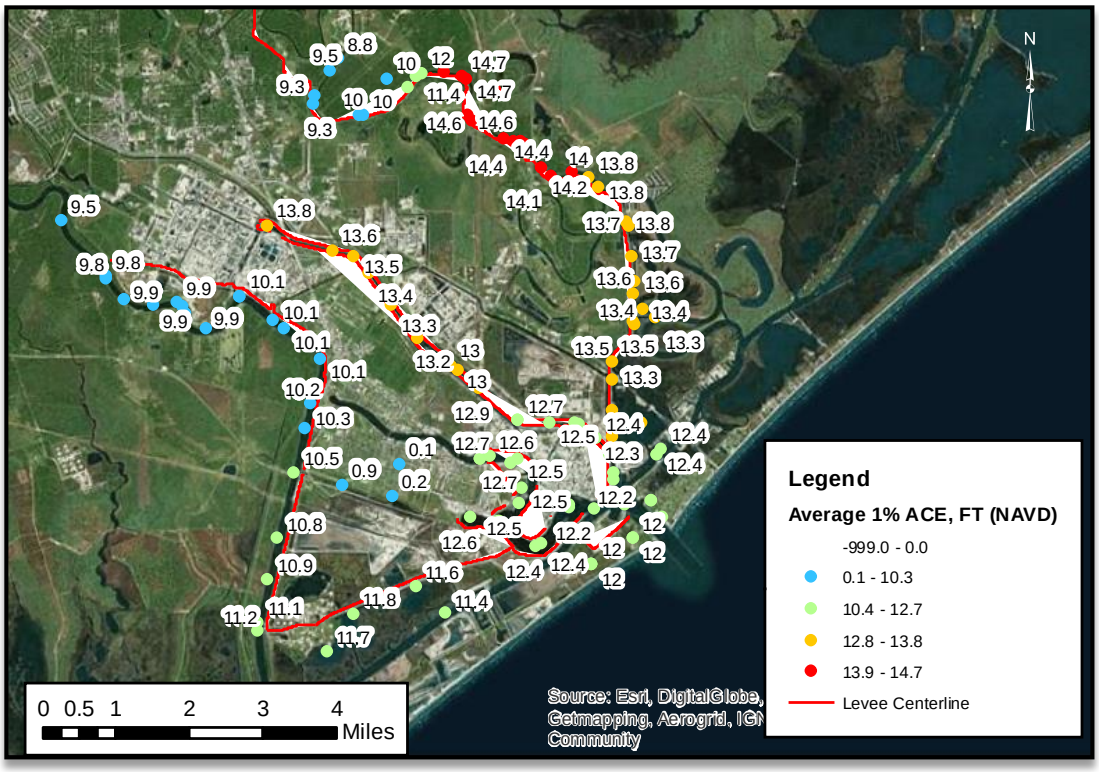

Figure 2-8: Average 1.0% ACE Still-Water Level at Freeport

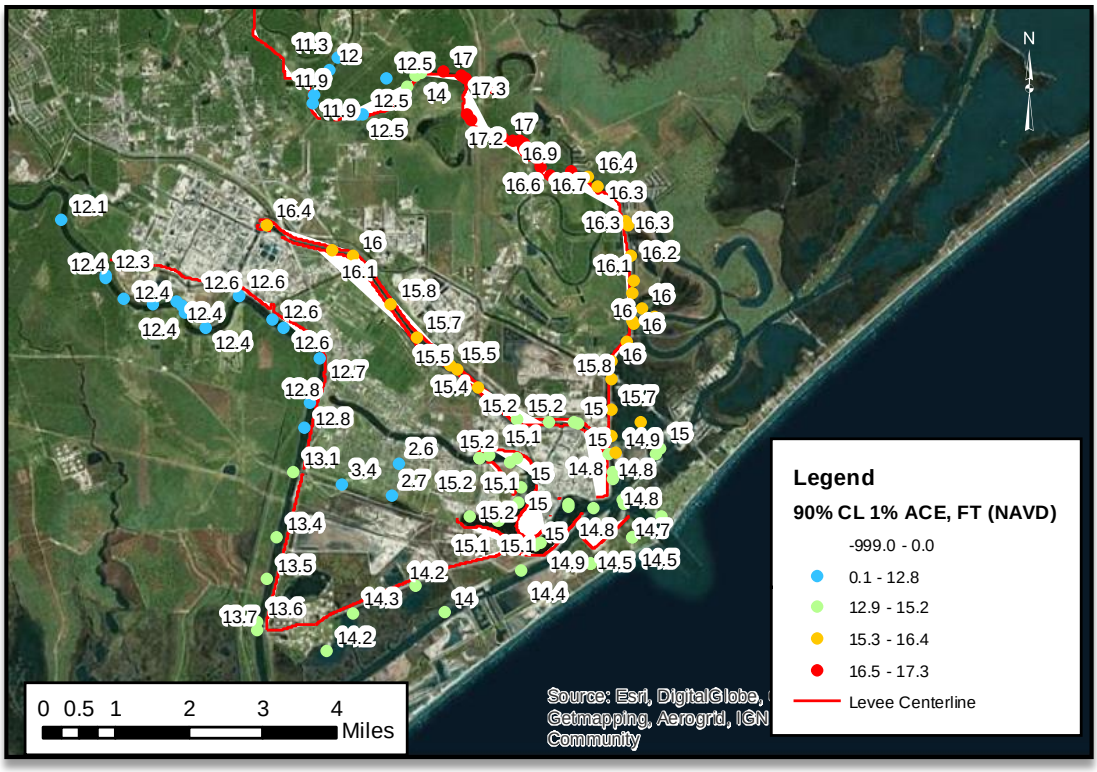

Figure 2-9: 90% Confidence Level for the 1.0% ACE Still-Water Level at Freeport

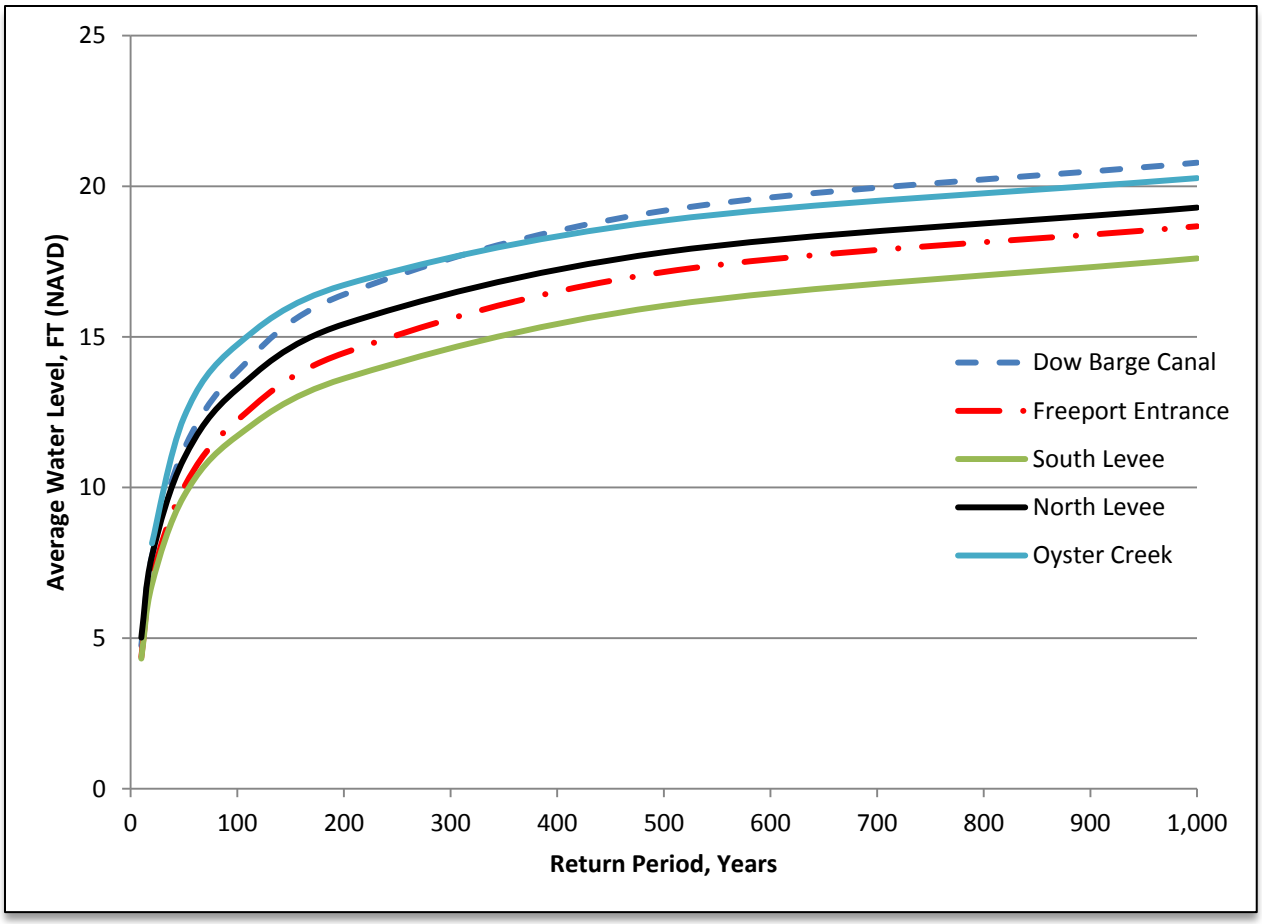

Figure 2-10: Example of Average Water-Level Return Periods at Freeport

2.7.1.2 Sabine Region

Nearshore waves and water levels modeled during the FEMA study were used to compute initial statistics. Comparison of the initial statistics with previous analyses indicated that some of the storms were previously run on the Louisiana grids only. Thus, there was concern that including these storms might dramatically increase the water levels for the Sabine Region projects. Additional model runs were conducted to include these storms and test this assumption. The results indicated that the additional storms did not increase the water levels.

New model grids were developed to include the proposed levee alignments. The same suite of storms was run on both grids and the same statistical analysis was run on both sets of results. Extremal statistics for waves and water levels were computed using StormSim and the joint probability method. Confidence levels were also computed. Mean water level, wave height, and wave period responses were defined for return periods of 10, 20, 50, 100, 200, 500, and 1,000 years for save points in the Sabine Region, including points surrounding and within the Port Arthur levee system. The standard deviation and 90 and 95 percent levels of assurance were also

calculated. Finally, the integrated uncertainty as used in the FEMA study was computed for comparison to the FEMA (2011) results to help verify results. Figure 2-11 shows the 1 % ACE average water level in the Sabine Region. Figure 2-12 shows the 1 % ACE upper 90 percent level of assurance in the Sabine Region. Figure 2-13 shows plots of the return period of water level for some key locations around the Sabine Region.

Inundation maps comparing the with-project and without-project conditions based on the FEMA (2011) 100-year storm level are presented in Exhibit 2-11.

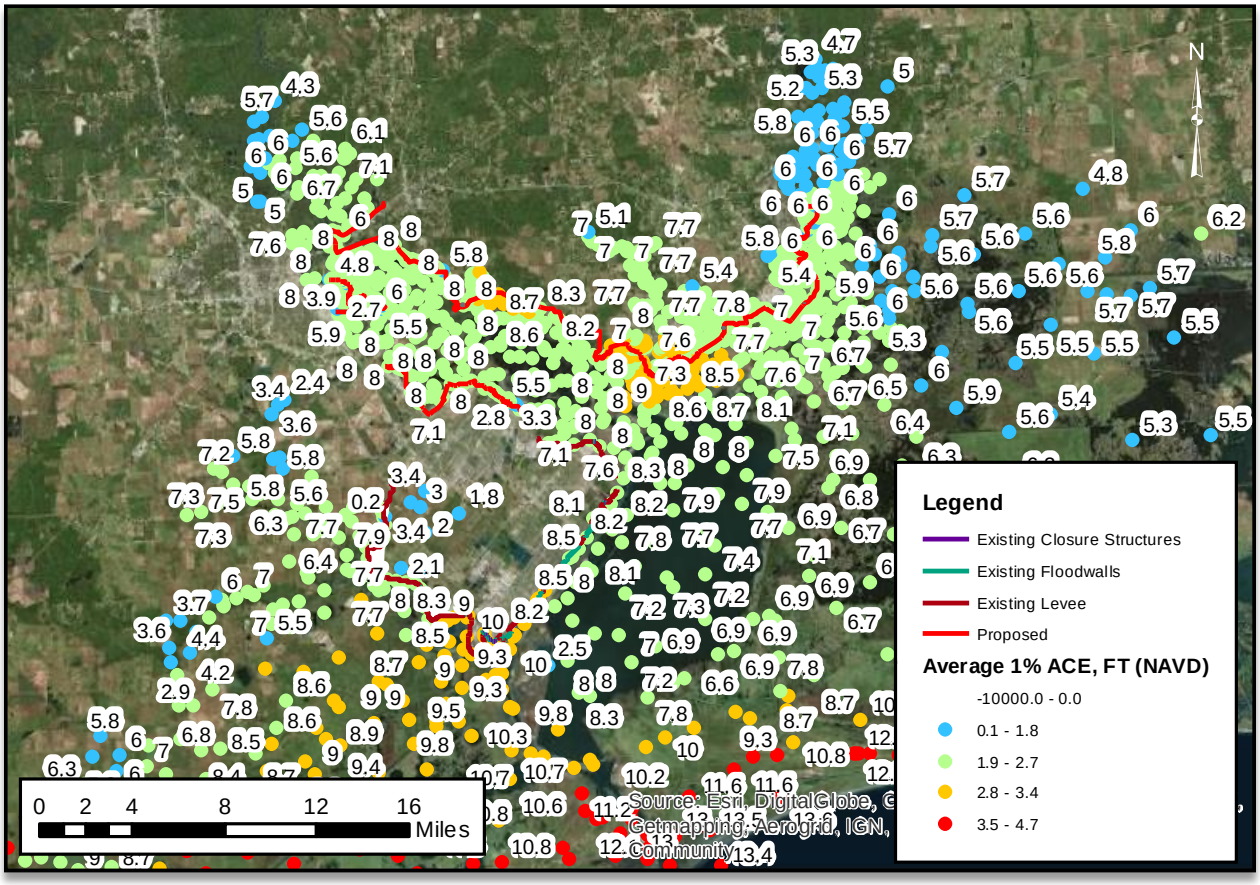

Figure 2-11: Average 1 % ACE Still-Water Level in Sabine Region

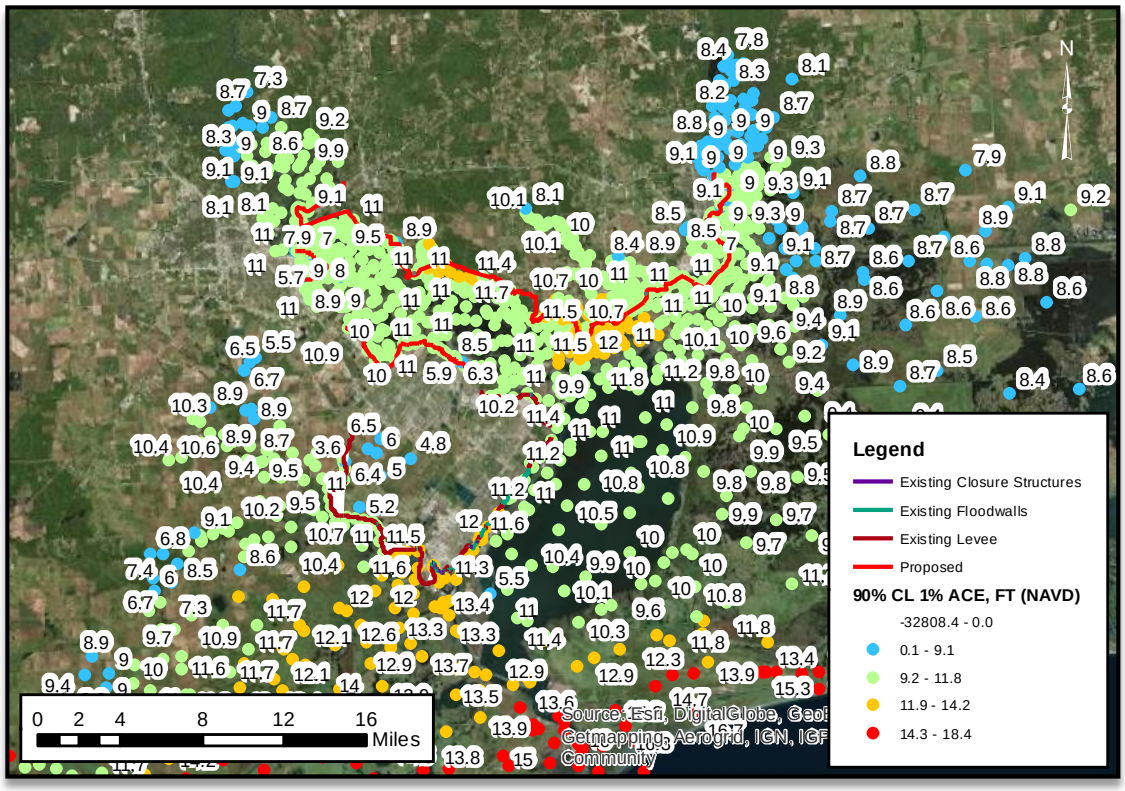

Figure 2-12: 90 percent Confidence Level for the 1 % ACE Still-Water Levels in Sabine Region

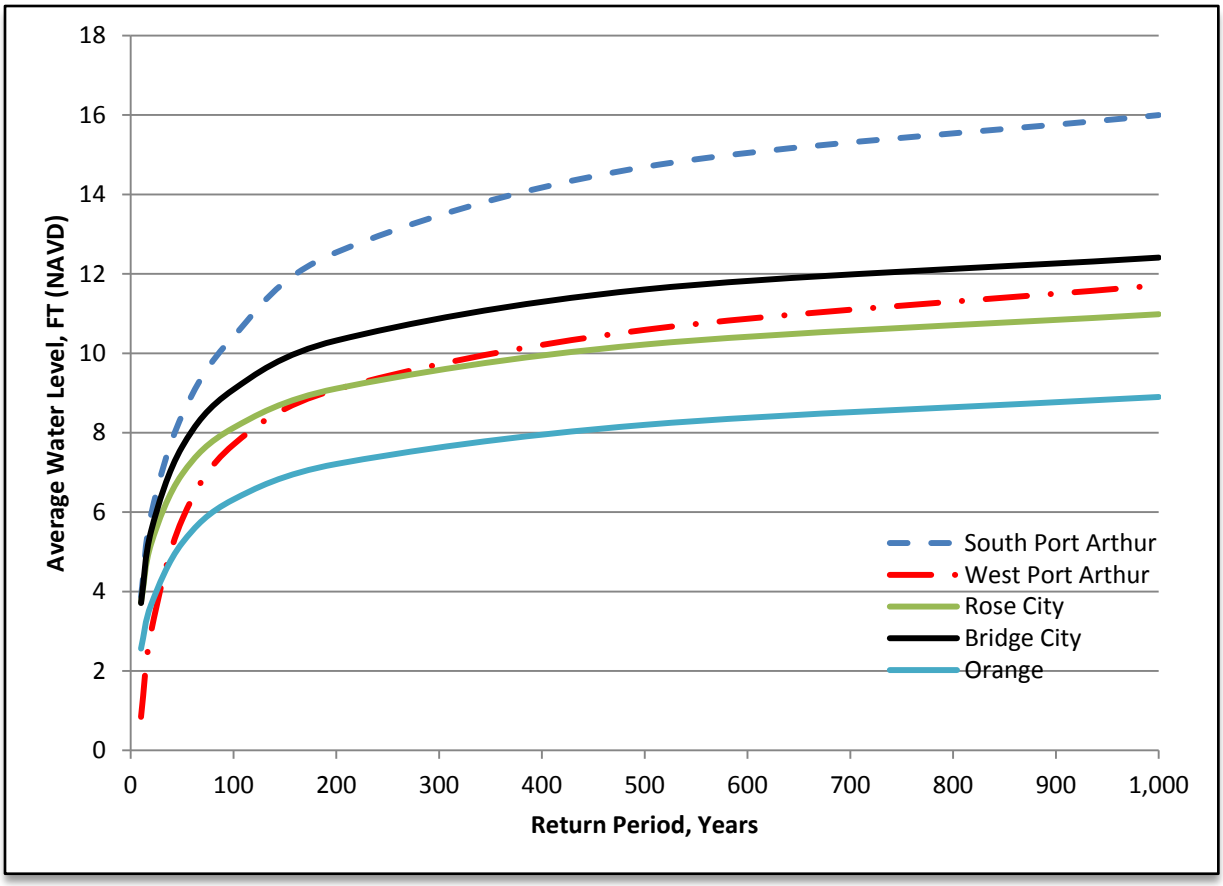

Figure 2-13. Example of Average Water-Level Return Periods in Sabine Region

2.8 LOCAL WAVE TRANSFORMATION AND CALCULATIONS

Local scale wave modeling was required to augment the WAM and STWAVE models run by ERDC. This section describes the local scale wave modeling.

2.8.1 Software Description

- STWAVE (STeady state spectral WAVE)
- STWAVE was applied to simulate wave propagation and generation from the larger scale STWAVE grid to the structure toe. STWAVE is a spectral wind-wave model capable of simulating growth, decay and transformation of wind generated waves, and swell in offshore and coastal areas (Massey, et al, 2011).
- Coastal Modeling System - Wave (CMS-Wave)
- CMS-Wave is a two-dimensional (2D) spectral wave model with energy dissipation and diffraction terms (Lin, et al 2011). The model was applied to help evaluate STWAVE results since no measured wave data were available.

2.8.2 Model Approach and Conventions

Numerical models were developed to simulate wave propagation and generation from the larger scale STWAVE grid to the structure toe.

2.8.3 Direction Convention

Wind and wave direction follow the meteorological convention for input and output, indicating direction of origin (direction from which it travels).

2.8.4 Model Parameters

The following model parameters were specified in the STWAVE model (CMS-Wave setup was similar):

- Depth type: Nontransient
- Source terms and propagation
- No current interaction
- Bottom friction: Manning's estimated and set at 0.03 based on known data
- Constant surge applied
  - Average 1 % ACE applied when waves on the boundary were known
  - 95 percent CL 1 % ACE applied when waves are generated by local winds only
- Winds
  - Based on ASCE (2010)
- 100-year return period
- 20-minute average
- Winds were applied in the worst-case direction to determine the worst-case waves using CMS-Wave and STWAVE.

2.8.5 Calibration and Verification

Measured or observed wave data at the project site were not available for calibration or verification. Since appropriate data for calibration and verification were not available, the solution from STWAVE was compared to results from CMS-Wave and the Automated Coastal Engineering System (ACES).

2.9 MODEL RESULTS

2.9.1 Brazoria Region (Freeport)

Large-scale STWAVE models run as part of the storm simulations for FEMA (2011) were not well resolved near the Freeport levees, requiring transformation of waves from nearshore to the levee toe. Waves inside the Freeport channels were also not resolved by the FEMA (2011) model runs, requiring calculation. Five (5) local grids were modeled with rectangular cells ranging in size from 2 to 20 meters (Figure 2-13). The figure shows the local model domains and the location of waves output from the large-scale storm model suite.

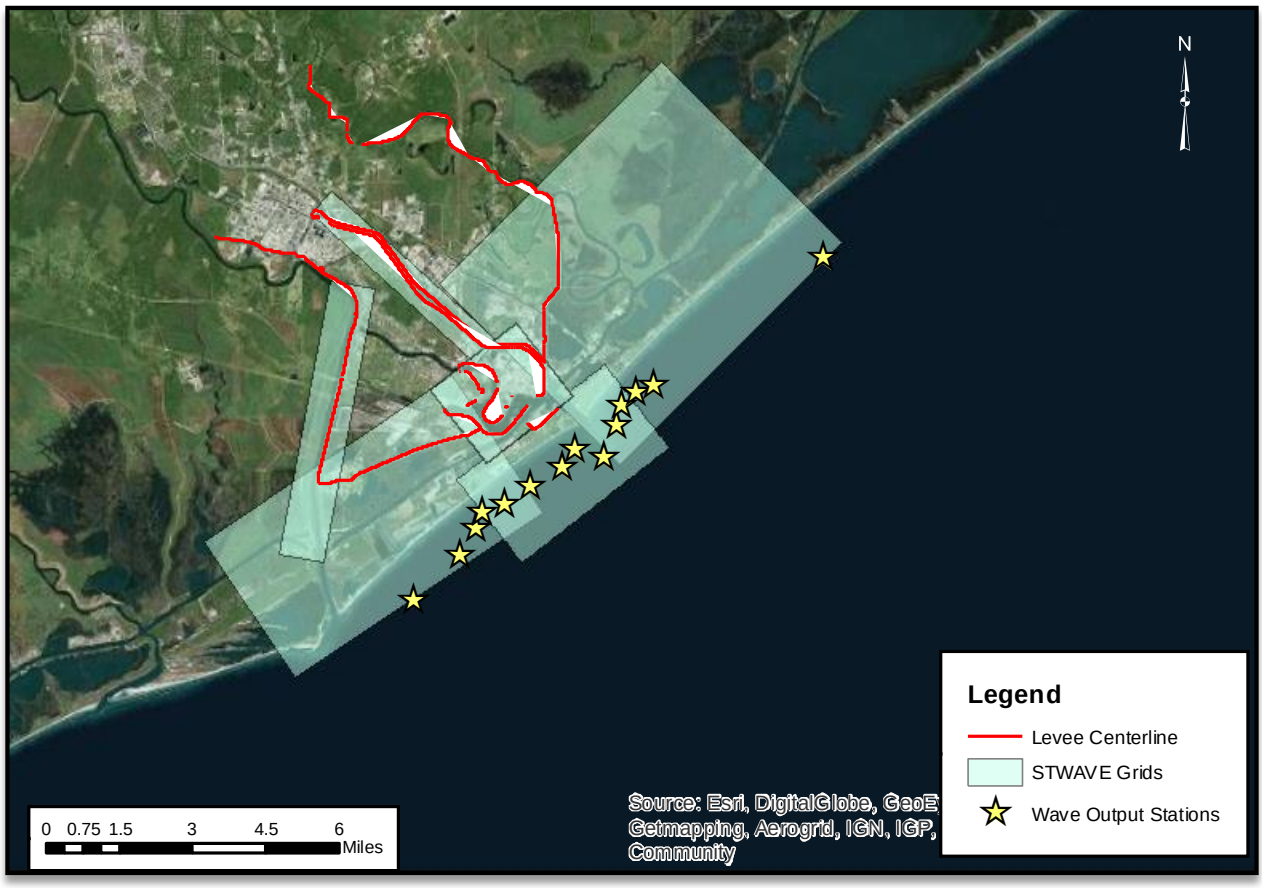

Figure 2-13: STWAVE Model Domains at Freeport

Each domain was forced with winds and offshore waves. The largest waves along each levee reach were summarized from all available runs. Figure 2-14 shows plots of the approximate locations of wave output used to inform the levee design. Table 2-3 lists the zero-moment spectral wave height (Hm0) and peak spectral wave period at each location (Figure 2-14).

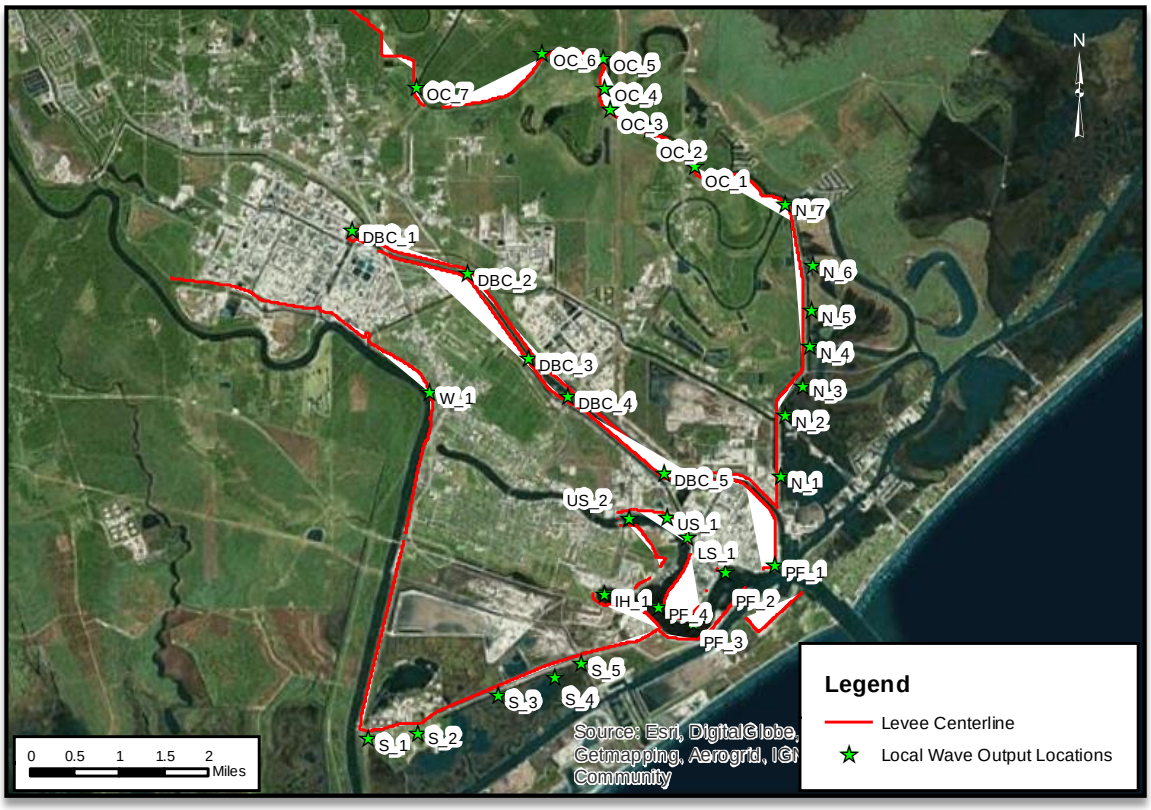

Figure 2-14: Freeport Local Wave Output Locations

Table 2-3: Summary of Local Wave Output for Freeport

Wave Output Station Name	H_{m0}, ft	T_p, s	Wave Output Station Name	H_{m0}, ft	T_p, s
DBC_1	1.28	2.8	PF_4 Phillips	2.23	2.80
DBC_2	1.38	2.8	PF_2	2.23	2.80
DBC_3	1.76	2.8	PF_1	2.53	8.57
DBC_3v2*	1.64	2.8	US_2	2.13	2.80
DBC_4	1.35	2.8	US_2v2*	0.69	2.80
DBC_4v2*	2.23	2.8	IH_1*	1.15	2.80
DBC_5	0.72	2.8	IH_1	2.36	2.80
DBC_5v2*	1.67	2.8	N_1	1.77	8.12
W_1	1.84	4.2	N_2	1.84	9.40
S_1	2.07	3.4	N_3	2.89	9.40
S_2	0.00		N_4	2.46	9.10
S_3	1.25	5.8	N_6	1.87	9.10
S_4	1.35	4.3	N_5	2.13	9.12
S_5	0.52	7	N_7	2.13	8.70
PF_3-wave barrier	2.79	3	LS_1	1.61	3.30
PF_3-thumb	1.51	2.8	US_1	2.33	2.80
PF_4 thumb*	2.00	2.8			

2.9.2 Sabine Region

Large-scale STWAVE models run as part of the storm simulations conducted in this study were not well resolved along all of the proposed and existing systems, requiring wave generation and transformation of waves from nearshore to the levee toe in some locations. Five (5) local grids were modeled with rectangular cells ranging in size from 2 to 20 meters (Figure 2-15). The figure shows the local model domains and the location of waves output from the large-scale storm model suite.

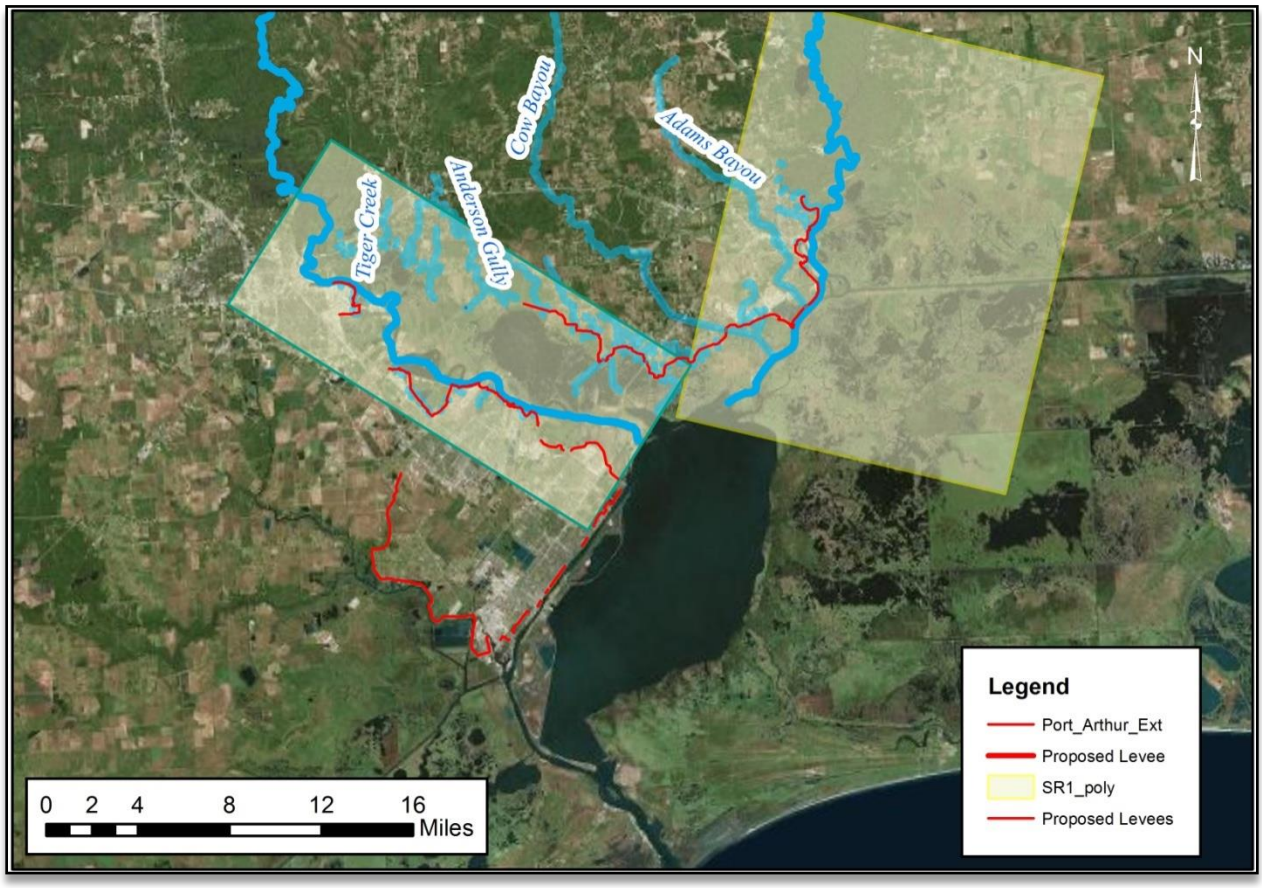

Figure 2-15: STWAVE Model Domains in Sabine Region

Each domain was forced with winds and offshore waves. The largest waves along each levee reach were summarized from all available runs. Figure 2-16 shows plots of the approximate locations of wave output used to inform the levee design. Wave output at the stations shown in the figure are included in Table 2-4. The values in the table are a combination of local wave model results and results from the storm simulation STWAVE models, where appropriate.

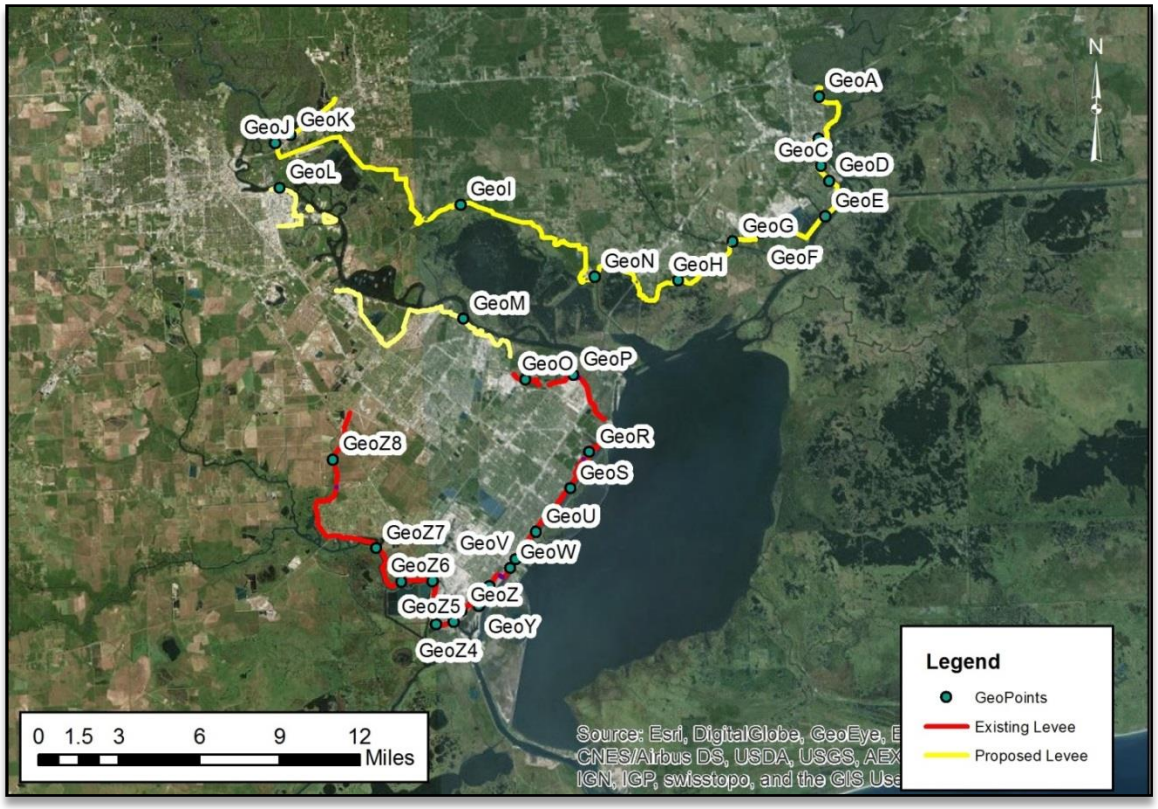

Figure 2-16: Sabine Local Wave Output Locations

Table 2-4: Summary of Wave Output for Sabine Region

Wave Output Station Name	Hm0, ft	Tm0, s	Wave Output Station Name	Hm0, ft	Tm0, s
GeoA	3.9	4.5	GeoR	2.1	5.0
GeoB	2.6	2.9	GeoS	2.3	4.3
GeoC	3.7	4.5	GeoT	2.3	4.9
GeoD	2.0	3.0	GeoU	2.3	4.9
GeoE	2.0	2.9	GeoV	2.3	5.0
GeoF	2.4	4.0	GeoW	2.3	5.0
GeoG	1.0	2.9	GeoX	2.1	4.6
GeoH	1.3	4.5	GeoY	2.3	2.9
GeoI	1.0	3.4	GeoZ	2.1	3.2
GeoJ	2.8	3.8	GeoZ1	2.9	2.9
GeoK	2.4	4.0	GeoZ2	2.9	2.9
GeoL	2.3	2.8	GeoZ3	2.2	3.2
GeoM	2.4	3.2	GeoZ4	1.4	3.0
GeoN	1.3	3.4	GeoZ5	2.0	3.4
GeoO	2.2	4.7	GeoZ6	1.9	3.4
GeoP	2.5	4.5	GeoZ7	2.1	3.4
GeoQ	2.1	4.9	GeoZ8	0.9	3.4

2.9.3 Wave Overtopping Analysis Methods

Wave overtopping calculations were conducted following the EurOtop Manual (Pullen, et al 2007). Both deterministic and probabilistic overtopping equations were calculated. In-house calculations were compared to the online overtopping calculator to verify results (http://www.overtopping-manual.com/). In addition to overtopping, 2.0 percent and maximum run-up values were calculated to inform comparison to typical FEMA requirements. Sensitivity analysis showed that various methods for calculating overtopping are not consistently conservative, meaning that selecting one method over another does not necessarily guarantee lower or higher values. For consistency, the EurOtop deterministic equations were applied to estimate overtopping rates for each reach. The locations shown for wave model output are used to summarize overtopping conditions.

The Hurricane and Storm Damage Risk Reduction System (HSDRRS) design guidelines (USACE 2012) criteria were applied to estimate required freeboard and determine levee crest elevation. The following criteria were applied:

- For the 1.0 percent exceedance still water, wave height, and wave period, the maximum allowable average wave overtopping of 0.01 cfs/ft at 50 percent level of assurance for grass-covered levees.
- For the 1.0 percent exceedance still water, wave height, and wave period, the maximum allowable average wave overtopping of 0.03 cfs/ft at 50 percent level of assurance for floodwalls with erosion-appropriate protection on the back side.

The HSDRRS criteria also include design guidance for the 90 percent level of assurance of no more than 0.1 cfs/ft for both floodwalls and earthen levees. The level of detail in the analysis conducted for this study does not allow for accurate estimation of the 90 percent level of assurance for overtopping. Therefore, the 50 percent level of assurance will be applied for this feasibility study and the 90 percent level of assurance will be checked during the project engineering and design (PED) phase.

2.10 LEVEE ANALYSIS

2.10.1 General Process

Waves and water levels from the ERDC-CHL storm surge and local wave modeling results were combined with the existing data gathered and analyzed to determine required levee heights based on EC 1110-2-6067 and CFR 2000 Title 44, and additional ERs, EMs, and ECs referenced below. The processes used for determining the required levee crest elevations were:

1. In areas subject to waves, levee crest elevation was calculated based on the maximum of:

    a. Freeboard associated with average overtopping rate plus the average 1 % ACE SWL
    b. 90 percent assurance level for the 1 % ACE SWL
    c. Freeboard associated with average overtopping rate plus FEMA required freeboard plus average 1 % ACE SWL (For coastal levees subject to overtopping, minimum required freeboard is 1 foot.)

2. In areas not subject to waves, levee crest elevation was calculated based on the maximum of:

    a. 90 percent Assurance Level for the 1 % ACE SWL
    b. FEMA required freeboard plus average 1 % ACE SWL (For levees subject to SWL overtopping only, required freeboard is 3 feet.)

After the required levee height was determined as described above, RSLC was added to determine the final recommended height. Recommendation is to add 50 years of projected RSLC at the low rate to earthen levees and the intermediate rate to floodwalls. RSLC is added linearly in this analysis. As discussed in Section 2.13, this is recommended because it is much easier to adapt the earthen crest elevation than the floodwall elevation. Recommended levee crest elevations based on other RSLC rates were also calculated to support planning scenario analysis for climate change.

2.10.2 Recommended Elevations for Brazoria Region (Freeport)

Based on the analyses, crest elevations are recommended. Tables 2-5 and 2-6 summarize recommended elevations for earthen levees subject to waves and water-level overtopping only, respectively.

Table 2-5: Recommended Earthen Levee Elevations Subject to Waves for Freeport as a Function of RSLC

Wave Output Station Name	Recommended Elevation in feet, NAVD without RSLC	Recommended Elevation in feet, NAVD with Low RSLC	Recommended Elevation in feet, NAVD with Intermediate RSLC	Recommended Elevation in feet, NAVD with High RSLC
DBC_1	16.6	17.3	17.9	19.6
DBC_2	16.2	16.9	17.5	19.2
DBC_3	15.9	16.6	17.2	19.0
DBC_3v2*	15.9	16.6	17.2	19.0
DBC_4	15.7	16.5	17.0	18.8
DBC_4v2*	15.7	16.5	17.0	18.8
DBC_5	15.4	16.1	16.7	18.5
DBC_5v2*	15.4	16.1	16.7	18.5
W_1	12.9	13.6	14.2	15.9
S_1	13.9	14.6	15.1	16.9
S_2	14.5	15.2	15.7	17.5
S_3	14.5	15.2	15.8	17.6
S_4	14.4	15.1	15.7	17.4
S_5	14.4	15.1	15.7	17.4
PF_3 - wave barrier	16.5	17.3	17.8	19.6
PF_3 - thumb	15.2	15.9	16.4	18.2
PF_4 - thumb*	15.6	16.3	16.8	18.6
PF_2	15.6	16.3	16.9	18.7
PF_1	19.1	19.8	20.3	22.1
US_2	15.4	16.1	16.6	18.4
US_2v2*	15.4	16.1	16.6	18.4
IH_1*	15.4	16.1	16.6	18.4
IH_1	15.4	16.1	16.6	18.4
N_1	17.9	18.7	19.2	21.0
N_2	18.4	19.1	19.7	21.5
N_3	21.3	22.0	22.5	24.3
N_4	20.1	20.8	21.4	23.2
N_6	18.7	19.4	20.0	21.7
N_5	19.3	20.0	20.6	22.4
N_7	19.5	20.2	20.7	22.5
LS_1	15.3	16.0	16.5	18.3
US_1	15.3	16.0	16.5	18.3

Table 2-6: Recommended Earthen Levee Elevations Subject to Water Level Overtopping Only (Oyster Creek Section of Freeport Levee) as a Function of RSLC

Wave Output Station Name	Recommended Elevation in feet, NAVD without RSLC	Recommended Elevation in feet, NAVD with Low RSLC	Recommended Elevation in feet, NAVD with Intermediate RSLC	Recommended Elevation in feet, NAVD with High RSLC
OC_1	17.2	17.2	17.2	17.2
OC_2	17.4	17.4	17.4	17.4
OC_3	17.6	17.6	17.6	17.6
OC_4	17.7	17.7	17.7	17.7
OC_5	17.7	17.7	17.7	17.7
OC_6	15.0	15.0	15.0	15.0
OC_7	12.3	12.3	12.3	12.3

2.10.3 Recommended Elevations for Sabine Region

Based on the analyses, crest elevations are recommended. Tables 2-7 and 2-8 summarize recommended elevations for earthen levees and floodwalls, respectively.

Table 2-7: Recommended Earthen Levee Elevations for Sabine as a Function of RSLC

Wave Output Station Name	Recommended Elevation in feet, NAVD without RSLC	Recommended Elevation in feet, NAVD with Low RSLC	Recommended Elevation in feet, NAVD with Intermediate RSLC	Recommended Elevation in feet, NAVD with High RSLC
GeoA	16.6	17.5	18.1	19.9
GeoB	9.5	10.4	11.0	12.8
GeoC	12.7	13.7	14.2	16.0
GeoD	11.2	12.1	12.7	14.5
GeoE	11.3	12.2	12.8	14.6
GeoF	11.7	12.6	13.2	14.9
GeoG	10.9	11.8	12.4	14.2
GeoH	13.5	14.4	15.0	16.7
GeoI	11.9	12.8	13.4	15.2
GeoJ	12.6	13.5	14.1	15.9
GeoK	14.2	15.1	15.7	17.4
GeoL	12.8	13.7	14.3	16.1
GeoM	13.2	14.1	14.7	16.4
GeoN	12.2	13.1	13.6	15.4
GeoO	10.7	11.6	12.2	13.9

Wave Output Station Name	Recommended Elevation in feet, NAVD without RSLC	Recommended Elevation in feet, NAVD with Low RSLC	Recommended Elevation in feet, NAVD with Intermediate RSLC	Recommended Elevation in feet, NAVD with High RSLC
GeoP	10.7	11.6	12.2	14.0
GeoQ	11.2	12.2	12.7	14.5
GeoR	11.3	12.2	12.8	14.5
GeoS	15.4	16.4	16.9	18.7
GeoT	15.6	16.5	17.0	18.8
GeoU	12.2	13.1	13.7	15.5
GeoV	16.2	17.2	17.7	19.5
GeoW	16.0	16.9	17.5	19.3
GeoX	12.8	13.8	14.3	16.1
GeoY	13.1	14.0	14.6	16.3
GeoZ	Floodwall Only			
GeoZ1	Floodwall Only			
GeoZ2	Floodwall Only			
GeoZ3	13.5	14.4	15.0	16.7
GeoZ4	12.3	13.2	13.7	15.5
GeoZ5	12.2	13.1	13.7	15.5
GeoZ6	12.0	12.9	13.5	15.2
GeoZ7	11.5	12.4	13.0	14.8
GeoZ8	11.0	11.9	12.5	14.3

Table 2-8: Recommended Floodwall Elevations for Sabine as a Function of RSLC

Wave Output Station Name	Recommended Elevation in feet, NAVD without RSLC	Recommended Elevation in feet, NAVD with Low RSLC	Recommended Elevation in feet, NAVD with Intermediate RSLC	Recommended Elevation in feet, NAVD with High RSLC
GeoA	16.4	17.3	17.9	19.6
GeoB	11.6	12.6	13.1	14.9
GeoC	13.5	14.4	15.0	16.8
GeoD	10.5	11.4	11.9	13.7

2.11 ADJACENT IMPACTS

This section discusses impacts to areas adjacent to the proposed new levees, including changes in surge water surface elevations, run-up, and waves. The ERDC surge model was run with the full "maximum" footprint for the Freeport, Port Arthur, Jefferson, and Orange levees being considered (see Figure 2-3). The model results showed induced impacts could reach levels of

nearly 1 foot for the full configuration along the Neches River and the Orange County levee. The existing systems of Port Arthur and Freeport showed negligible impacts during a 100-year event.

In the area up the Neches and Sabine, some induced flooding was determined, particularly along the Neches River. The TSP removed a large part of the original levee system causing adjacent impacts due to lack of economic justification. This drastically reduced induced impacts along the Neches River from 1-foot levels to an insignificant impact on the order of 0.5 foot. Most areas impacted are vacant areas of grasslands with some trees and wetlands. It is recommended that some minor surge protection features be created to block induced damages in developed or sensitive areas. These would be small features with a height of approximately 6 inches. These could be small earthen berms, small I-walls, small rock walls, or other features. During design, the TSP configuration should be modeled in ADCIRC/STWAVE.

2.12 TSP/NED PLANS COMPARED TO RECOMMENDED FEMA CERTIFICATION AND USACE ACCREDITATION HEIGHTS

It is important to note that a planning study recommends the project that provides the most net excess benefits. That is what is being done at this level of the study to determine the limits of what items and percentages the Government would cost share. Reference the Main Report for cost share information. The NED plans use the average SWL and wave information without any application of statistics for the HH&C inputs (confidence levels, etc.). Additional consideration includes whether the system will meet FEMA CFR requirements and USACE Accreditation requirements.

Elevations required to meet FEMA CFR 65.10, as well as USACE Accreditation elevation requirements, are included in this Section. In many cases, the elevation recommended by the NED plan is in fact the highest recommended elevation. Many are also equal. For areas where the NED plan recommends a top levee elevation lower than FEMA or USACE required elevation for that location it is recommended that USACE move forward with the NED plan, and take the information the Non-Federal Sponsors to see if they desire or can pay the cost to add the extra elevation to the top of levee. This is a considerable benefit to them, and with the wall already close to the required height they would have to pay relatively little (example: many areas would just require a raise of a foot or two, which compared to a 12-foot pile-founded T-Wall is a rather small cost.

The level of detail in the analysis conducted for this study does not allow for accurate estimation of the 90 percent level of assurance for overtopping. The 50 percent level of assurance will be applied for this feasibility study as required by planning studies, and the 90 percent level of

assurance will be checked during the Preliminary Engineering and Design (PED) phase. For additional information on the topics in this section, reference the DIFR-EIS and Geotechnical Engineering section of this appendix.

2.13 CLIMATE CHANGE

2.13.1 Relative Sea-Level Change

This document uses current USACE guidance to assess relative sea level change (RSLC). Current USACE guidance - ER 1100-2-8162, December 2013, and ETL 1100-2-1, June 2014, specifies the procedures for incorporating climate change and RSLC into planning studies and engineering design projects. Projects must consider alternatives that are formulated and evaluated for the entire range of possible future rates of RSLC for both existing and proposed projects. USACE guidance specifies evaluating alternatives using "low," "intermediate," and "high" rates of future sea level change.

- Low - Use the historic rate of local mean sea-level change as the "low" rate. The guidance further states that historic rates of sea level change are best determined by local tide records (preferably with at least a 40-year data record).
- Intermediate - Estimate the "intermediate" rate of local mean sea-level change using the modified NRC Curve I. It is corrected for the local rate of vertical land movement.
- High - Estimate the "high" rate of local mean sea-level change using the modified NRC Curve III. It is corrected for the local rate of vertical land movement.

USACE (ETL 1100-2-1, 2014) recommends an expansive approach to considering and incorporating RSLC into civil works projects. It is important to understand the difference between the period of analysis (POA) and planning horizon. Initially, USACE projects are justified over a period of analysis, typically 50 years. However, USACE projects can remain in service much longer than the POA. The climate for which the project was designed can change over the full lifetime of a project to the extent that stability, maintenance, and operations may be impacted, possibly with serious consequences, but also potentially with beneficial consequences. Given these factors, the project planning horizon (not to be confused with the economic period of analysis) should be 100 years, consistent with ER 1110-2-8159. Current guidance considers both short- and long-term planning horizons and helps to better quantify RSLC. RSLC must be included in plan formulation and the economic analysis, along with USACE expectations of climate change and RSLC, and their impacts. Some key expectations include:

- At minimum 20-, 50-, and 100-year planning horizons should be considered in the analysis.

- Reinforces the concept that a thorough physical understanding of the project area and purpose is required to effectively assess the projects sensitivity to RSLC.
- Sea level changes should be incorporated into models at the mean and extreme events.
- Identification of thresholds by the project delivery team and tipping points within the impacted project area will inform both the selection of anticipatory, adaptive, and reactive options selected and the decision/timing strategies.

2.13.2 Historical RSLC

Historical rates are taken from the Center for Operational Oceanographic Products and Services (CO-OPS) at NOAA, which has been measuring sea level for over 150 years. Changes in MSL have been computed using a minimum 30-year span of observations at each location. These measurements have been averaged by month to eliminate the effect of higher frequency phenomena such as storm surge, in order to compute an accurate linear sea-level trend.

The MSL trends presented are local relative trends as opposed to the global (eustatic) sea-level trend. Tide gauge measurements are made with respect to a local fixed reference level on land; therefore, if there is some long-term vertical land motion occurring at that location, the relative MSL trend measured there is a combination of the global sea-level rate and the local vertical land motion, also known as RSLC.

Historical rates of local RSLC can be obtained from local tide records. The tide gage nearest to the Sabine Lake system, with over 40 years of record, is at Sabine Pass (NOAA Gage 8770570). The NOAA MSL trend at this site (from 1958 to 2008) is equal to 5.66 mm/yr with a 95 percent confidence interval of +/- ± 0.98 mm/yr. Using the estimated historic eustatic rate equals that given for the modified NRC curves (1.70 mm/yr). This results in an observed subsidence rate of 3.96 mm/yr (5.66 mm/yr - 1.70 mm/yr). A vicinity map for NOAA Gage 8770570 is shown in Figure 2-17 on the next page.

The tide gage nearest to the Galveston coast region, with over 40 years of record, is at the Galveston Pleasure Pier, which is on the Gulf of Mexico coast side of Galveston Island (NOAA Gage 8771510). The NOAA MSL trend at this site (from 1957 to 2008) is equal to 6.84 mm/yr with a 95 percent confidence interval of ± 0.74 mm/yr. If the estimated historic eustatic rate equals that given for the modified NRC curves, the observed subsidence rate would be 5.14 mm/yr (6.84 mm/yr - 1.70 mm/yr). A vicinity map for NOAA Gage 871510 is shown in Figure 2-18.

Figure 2-17: NOAA Gage 8770570 Vicinity Map

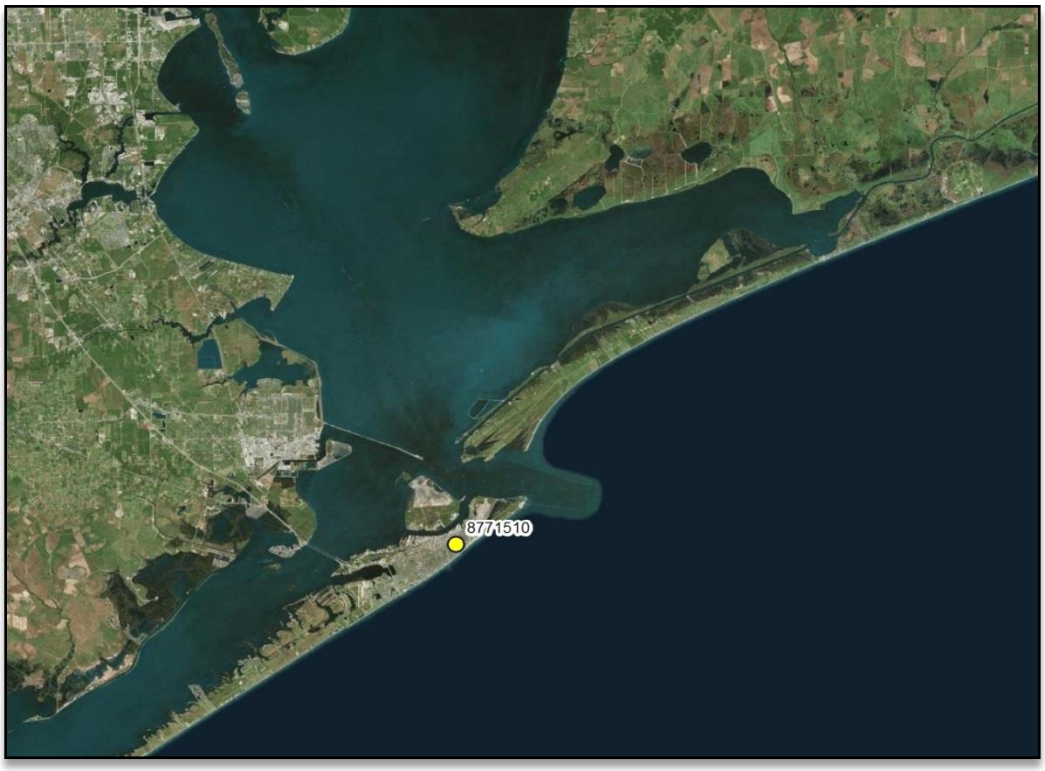

Figure 2-18: NOAA Gage 877150 Vicinity Map

The tide gage nearest to the Brazos River system, with over 40 years of record, is located at Freeport, TX Island (NOAA Gage 8772440). The NOAA MSL trend at this site (from 1954 to 2006) is equal to 4.35 mm/yr with a 95 percent confidence interval of ± 1.12 mm/yr. If the estimated historic eustatic rate equals that given for the modified NRC curves, the observed subsidence rate would be 2.65 mm/yr (4.35 mm/yr - 1.70 mm/yr). A vicinity map for NOAA gage 8772440 is shown in Figure 2-19.

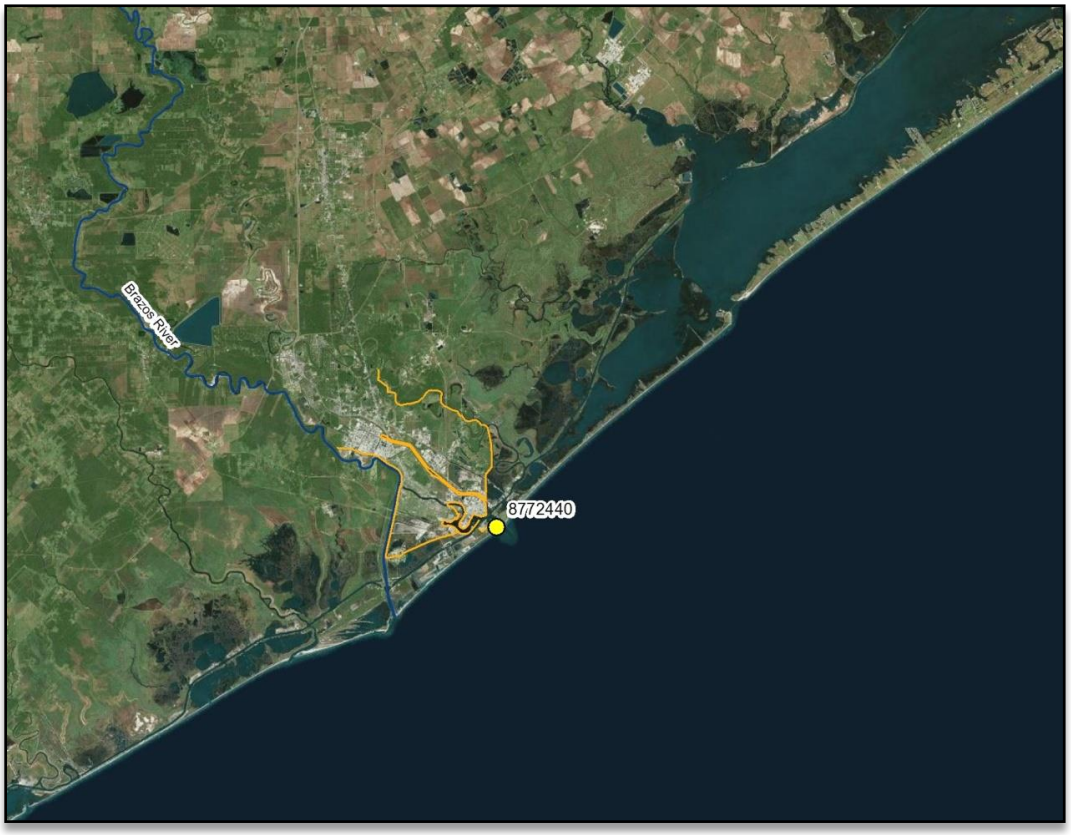

Figure 2-19: NOAA Gage 8772440 Vicinity Map

2.13.3 Predicted Future Rates of RSLC for 20-Year Period of Analysis

The computed future rates of RSLC in this section give the predicted change between the years 2030 and 2050 for the Sabine Lake, Galveston Bay, and Brazos River systems. RSLC values for this 20-year period are summarized in Table 2-9 and plotted for each of the systems in Figures 2-20, 2-21, and 2-22.

Table 2-9: Estimated RSLC over the First 20 Years of the Project Life (2030 - 2050)

Tide Gage	Measured Relative SLR Rate (NOAA)	Low (ft)	Intermediate (ft)	High (ft)
Sabine Pass, TX	5.66 mm/yr	0.37	0.54	1.08
Galveston Pleasure Pier, TX	6.84 mm/yr	0.45	0.62	1.16
Freeport, TX	4.35 mm/yr	0.29	0.46	1.00

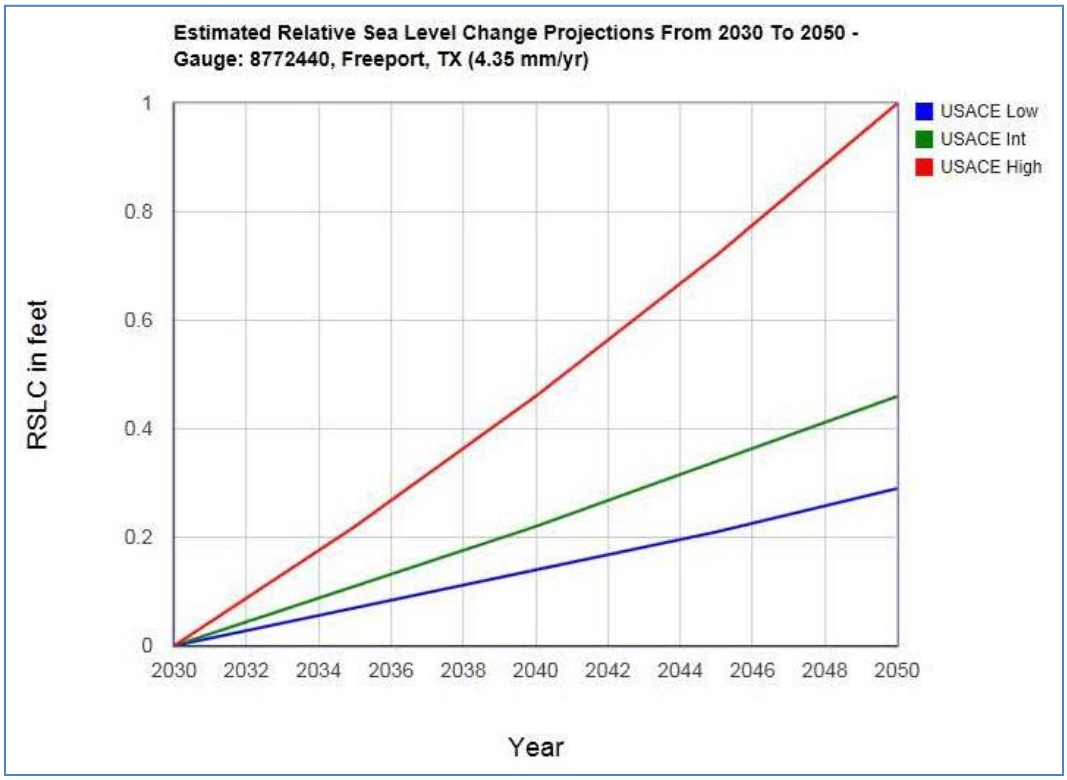

Figure 2-20: RSLC at Sabine, Texas over 20-Year Period of Analysis

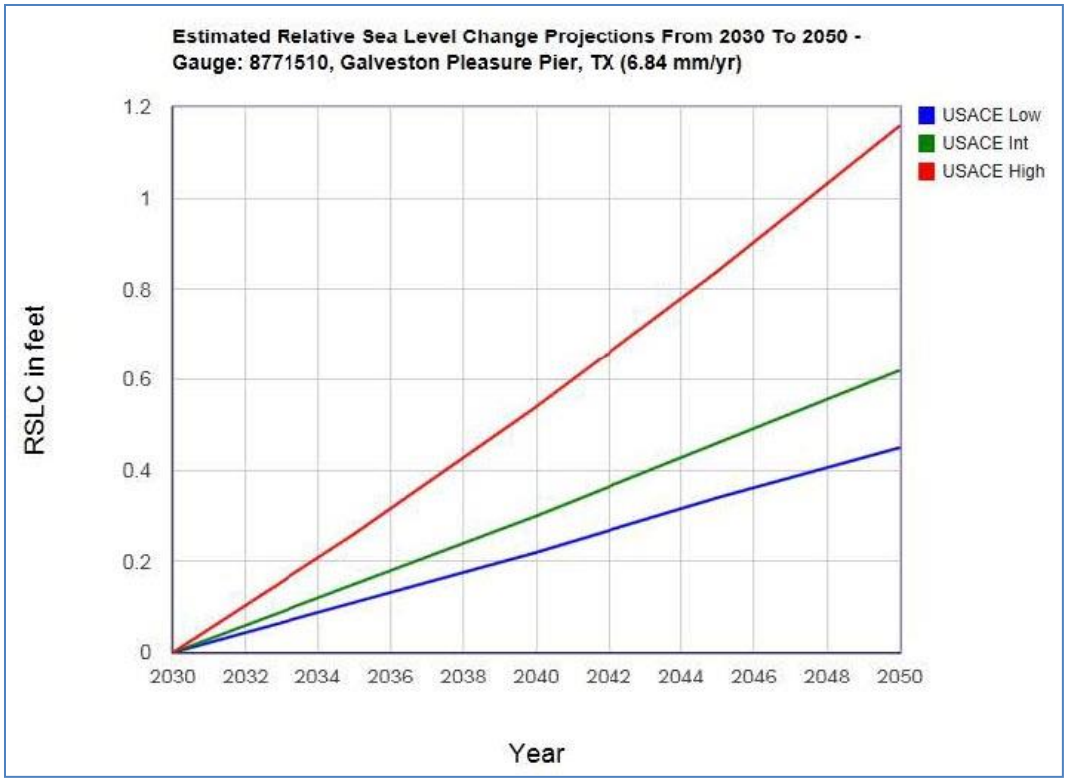

Figure 2-21: RSLC at Galveston, Texas over 20-Year Period of Analysis

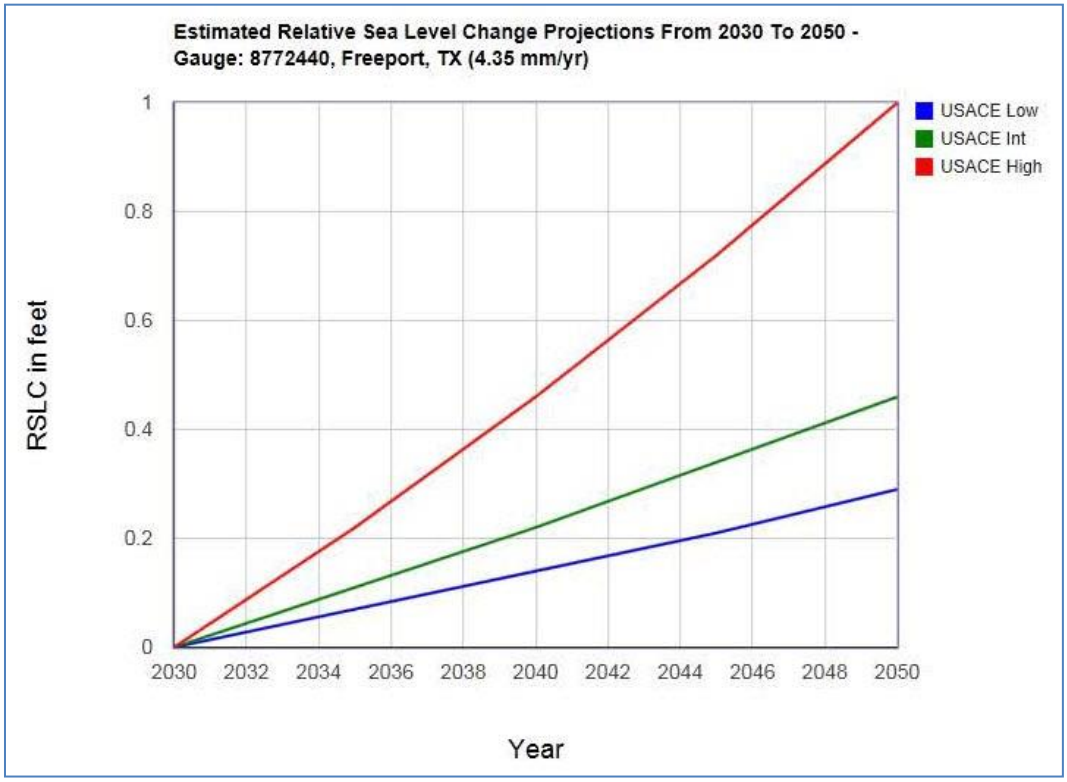

Figure 2-22: RSLC at Freeport, Texas over 20-Year Period of Analysis

2.13.4 Predicted Future Rates of RSLC for 50-Year Period of Analysis

The computed future rates of RSLC given here assume a 50-year period of analysis, and give the predicted change between the years 2030 and 2080 for the Sabine Lake, Galveston Bay, and Brazos River systems. Relative sea level change values for the 50-year period of analysis are summarized in the table below.

Table 2-10: Estimated RSLC over the First 50 Years of the Project Life (2030 - 2080)

Tide Gage	Measured Relative SLR Rate (NOAA)	Low (ft)	Intermediate (ft)	High (ft)
Sabine Pass, TX	5.66 mm/yr	0.93	1.49	3.26
Galveston Pleasure Pier, TX	6.84 mm/yr	1.12	1.68	3.46
Freeport, TX	4.35 mm/yr	0.72	1.27	3.05

Figure 2-23 shows in graphical form the computed sea level change for the Sabine Lake system based on the latest guidance for the "low," "intermediate," and "high" rates of change.

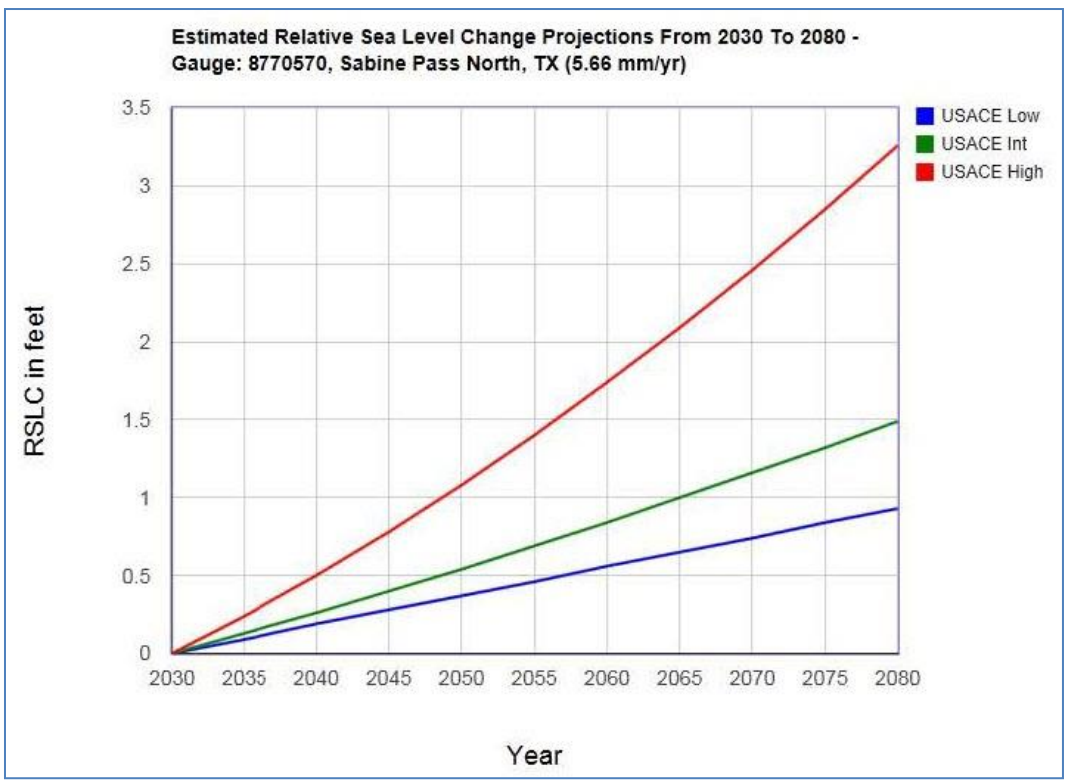

Figure 2-23: RSLC at Sabine Pass, Texas over 50-Year Period of Analysis

Using NOAA's Sea Level Rise and Coastal Flooding Impacts Viewer, it is apparent that much of the land around Sabine Pass in Jefferson County is low-lying. With just 1 foot of sea level rise, much of the coastline from Sabine Pass west to the Chambers County line is inundated during high tide. Areas as far as 10 miles inland experience increased inundation under this sea level rise scenario. There is substantial risk for lowland flooding without consideration of storm surge and waves. Adding surge and wave attack from a large hurricane to even the lowest SLR estimate yields substantial additional flooding. At 2 feet of sea level rise, the coastline west of Sabine Pass in Jefferson County becomes inundated without consideration of storm surge and waves, as does much of Port Arthur. Beaumont experiences more widespread flooding as well (Figure 2-24).

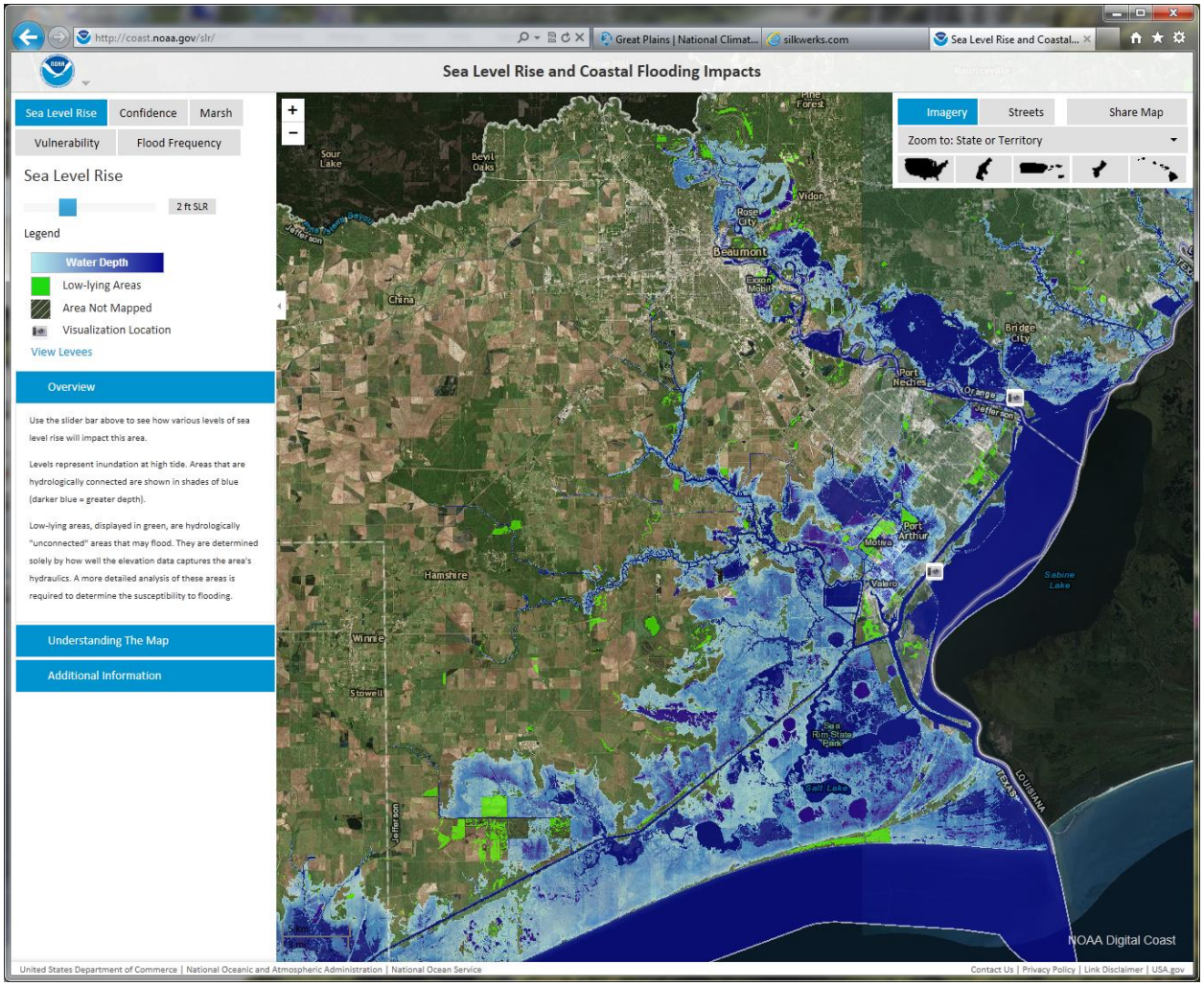

Figure 2-24: Extent of inundation at Sabine Pass, Texas with 2-foot sea level rise

Figure 2-25 shows the computed sea level change for the Galveston Bay system based on the current USACE guidance for “low,” “intermediate,” and “high” rates of change.

The Galveston County coastline is elevated higher than Jefferson County’s coastline. At a 2-foot rise in sea level, the centerline of Bolivar Peninsula west of Rollover Bay remains above water. Chambers County, on the other hand, experiences significant flooding around Galveston Bay. However, the majority of Galveston County is mostly unaffected (Figure 2-26).

Figure 2-27 shows the computed sea level change for the Brazos River system based on the current USACE guidance for “low,” “intermediate,” and “high” rates of change.

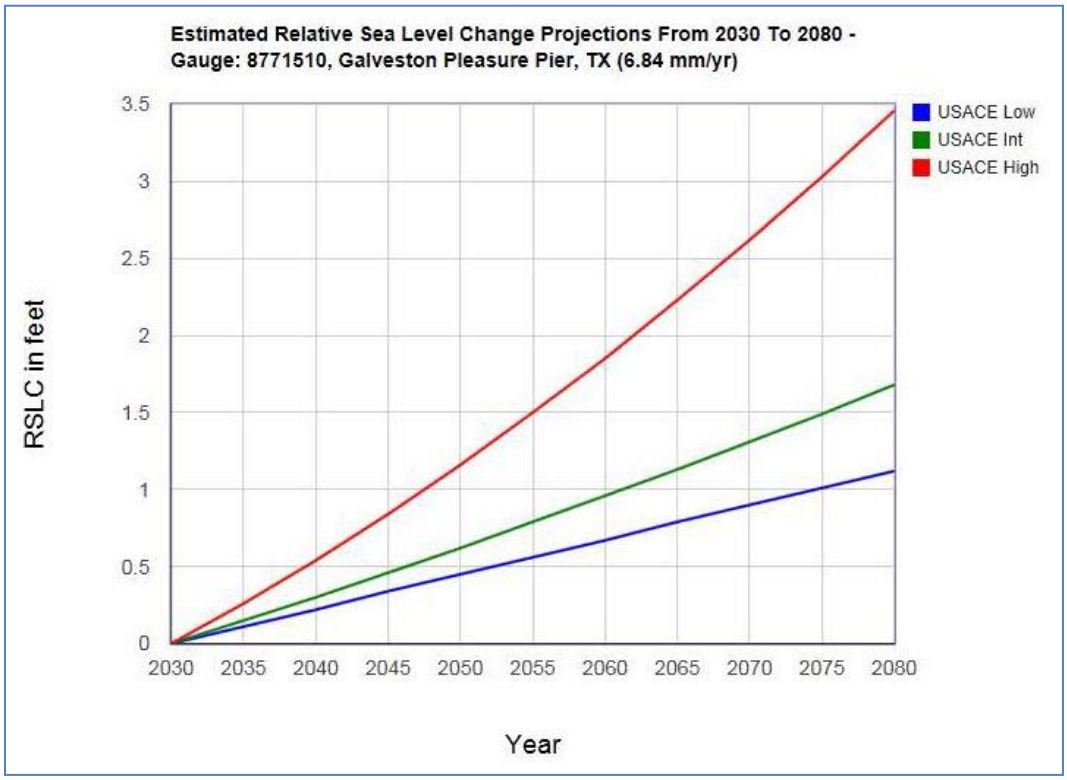

Figure 2-25: RSLC at Galveston Bay, Texas over 50-Year Period of Analysis

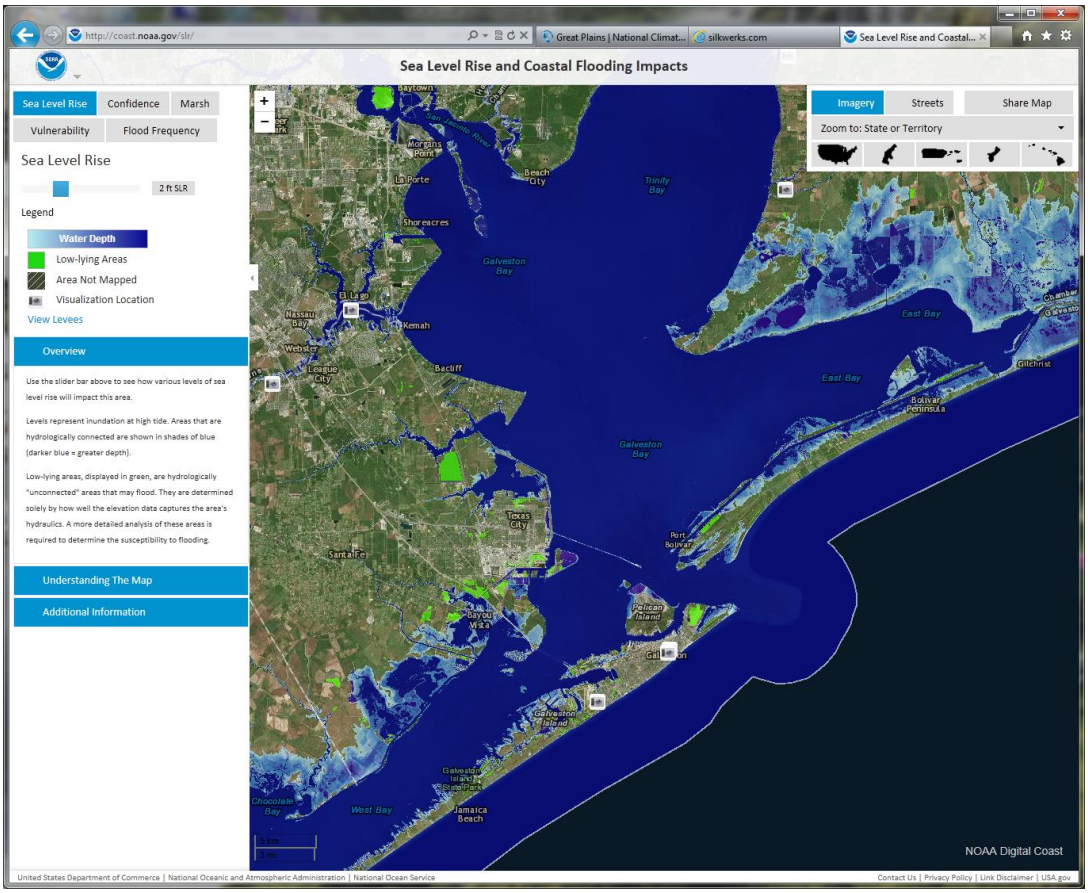

Figure 2-26: Extent of inundation at Galveston, Texas with 2-foot sea level rise

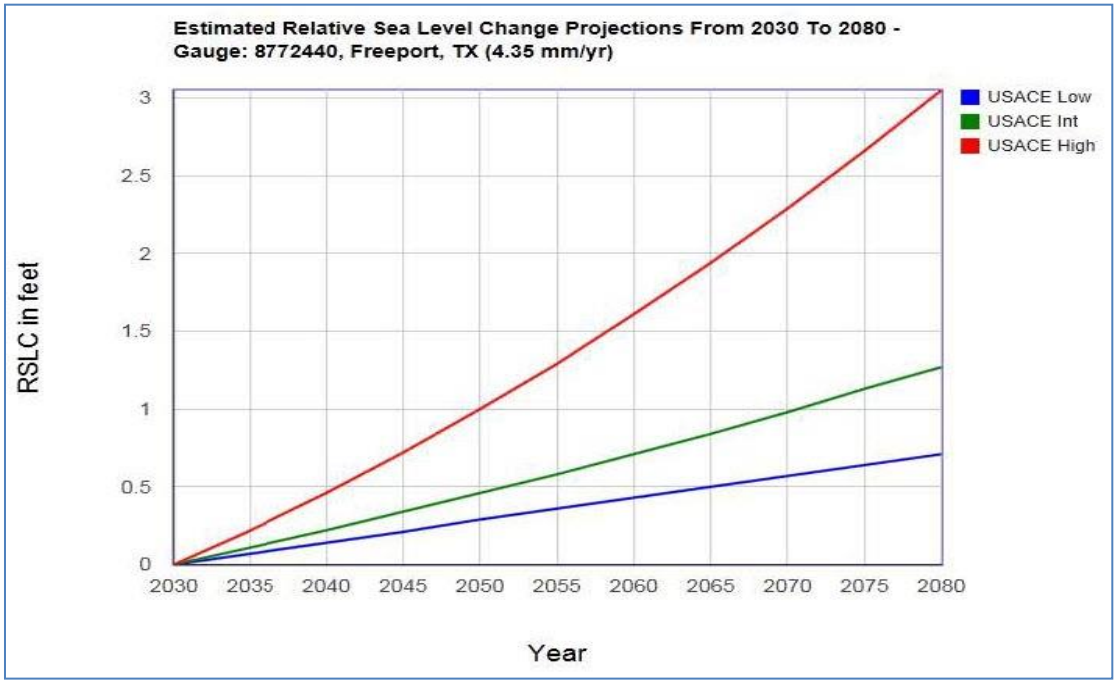

Figure 2-27: RSLC at Freeport, Texas over 50-Year Period of Analysis

Much of the area in the Freeport vicinity is low-lying. The majority of these low-lying areas are undeveloped, consisting of empty plots of land, some including marshes and wetlands. At 1 foot of sea level rise, several of these plots are inundated. It is important to note that water has begun to impact the Surfside Beach community just east of the Freeport Entrance Channel under this sea level rise scenario. At 2 feet, water begins to flood some central parts of Surfside Beach, inundating dozens of homes. For all considered sea level rise scenarios, safety from storm surge and wave attack for low-lying areas consistently decreases (Figure 2-28).

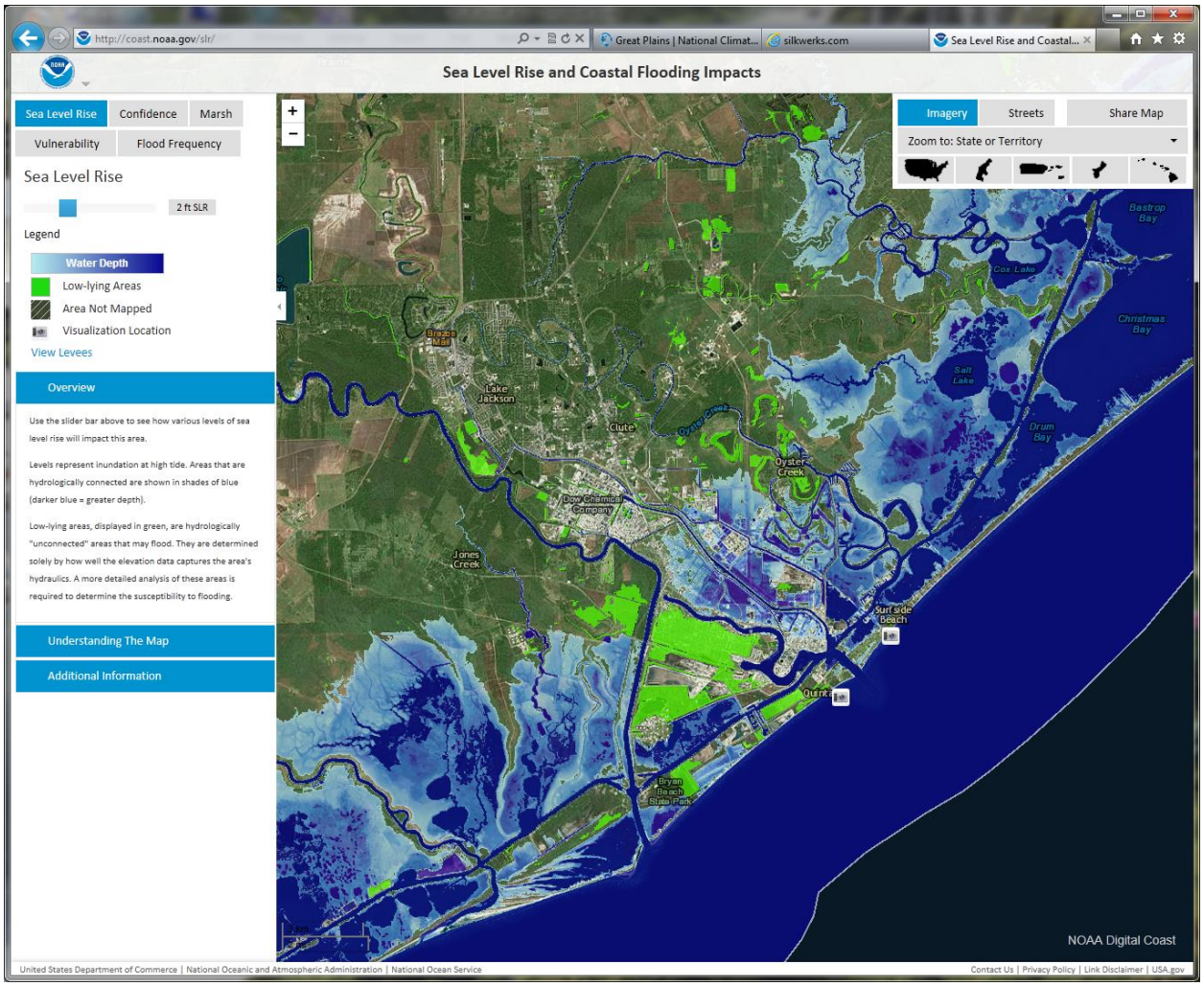

Figure 2-28: Extent of inundation at Freeport, Texas with 2-foot sea level rise

2.13.5 Predicted Future Rates of RSLC – 100-year Sea-Level Change

The planning, design, and construction of a large water resources infrastructure project can take decades. Though initially justified over a 50-year economic period of analysis, USACE projects often remain in service much longer. The climate for which the project was designed can change over the full lifetime of the project to the extent that stability, maintenance, and operations may

be affected. These changes can cause detrimental or beneficial consequences. Given these factors, the project planning horizon (not to be confused with the economic period of analysis) should be 100 years, consistent with ETL-1110-2-1.

The period of economic analysis for USACE projects has generally been limited to 50 years because economic forecasts beyond that time frame were not considered reliable. However, the potential impacts of SLC over a 100-year period can be used in the formulation of alternatives and for robustness and resiliency comparisons. ETL 1100-2-1 recommends that predictions of how the project or system might perform, as well as its ability to adapt beyond the typical 50-year economic analysis period, be considered in the decision-making process.

The initial assessment that evaluates the exposure and vulnerability of the project area over the 100-year planning horizon was used in assisting planners and engineers in determining the long-term approach that best balances risks for the project. The three (3) general approaches are anticipatory, adaptive, and reactive strategies. These strategies can be combined or they can change over the life cycle of the project. Key factors in determining the approach include consequences, the cost, and risk. This consideration is of particular importance under a climate change condition where loading and response mechanisms are likely to transition over the life of the project.

Using the high SLC curve elevation at 100 years, the potential future affected area has been approximately defined. This includes both the vertical and the horizontal extents of potential SLC impacts. Since this is an initial screening level, detailed modeling has not occurred yet. This basic approach will provide a first-level assessment of how the project and project area might be impacted, and follows the guidance in ETL-2-1. More detailed engineering analyses will be conducted during PED.

The future affected areas, as defined by the 100-year high rate of RSLC, can impact resources, including economics. These resources can be identified and quantified, such as critical infrastructure (schools, roads, water supply, community buildings, etc.), impacted property, life-safety concerns, and environment and ecosystems. The consideration of the potentially larger area of impact facilitates discussion of what actions may need to be considered at certain trigger points. Community, as well as other stakeholder expectations will be better defined. Evaluation of coastal storm-damage risk reduction in the context of RSLC may also involve societal thresholds. Potential system and cumulative effects should be explored qualitatively when formulating plans.

An essential element of developing a good understanding of the project area's exposure and vulnerability is assessing how quickly the individual scenarios might necessitate an action due to thresholds and tipping points. It is important to identify key milestones in the project timeline when impacts are expected. This involves inputs from all members of the PDT as the threshold or tipping point could be a vast variety of different items or combinations of items.

Response strategies for the project planning horizon range from a conservative anticipatory approach, which constructs a resilient project at the beginning to last the entire life cycle (and possibly beyond), to a reactive approach, which would simply be to do nothing until impacts are experienced. Between these extremes is an adaptive management strategy, which incorporates new assessments and actions throughout the project life based on timeframes, thresholds and triggers. A plan may include multiple measures adaptable over a range of SLC conditions and over the entire timeline, with different measures being executed as necessitated.

For a feasibility-level design, it is important to identify potential cost-risk items and adaptation costs to the stakeholders and decision makers. Further detailed design and analysis may be undertaken during the pre-construction engineering and design phase to optimize project features sensitive to relative sea level change. In this phase, the question of further adaptability beyond the 50-year economic analysis period may be addressed as part of the design optimization. The economic and cost formulation for the project should account for uncertainty in critical design items.

Utilizing the online sea-level calculator referenced in ER 1100-2-8162, estimates of 100-year RSLC, assuming a starting date of 2030 and ending date of 2130, were determined for this project. Table 2-11 lists the predicted low, medium, and high RSLC values for 2130. Figures 2-29, 2-30, and 2-31 graphically show the RSLC information generated by the calculator.

Table 2-11: Predicted RSLC over the First 100 Years of the Project Life (2030 - 2130)

Tide Gage	Measured Relative SLR Rate (NOAA)	Low (ft)	Intermediate (ft)	High (ft)
Sabine Pass, TX	5.66 mm/yr	1.86	3.42	8.38
Galveston Pleasure Pier, TX	6.84 mm/yr	2.24	3.81	8.77
Freeport, TX	4.35 mm/yr	1.43	2.99	7.95

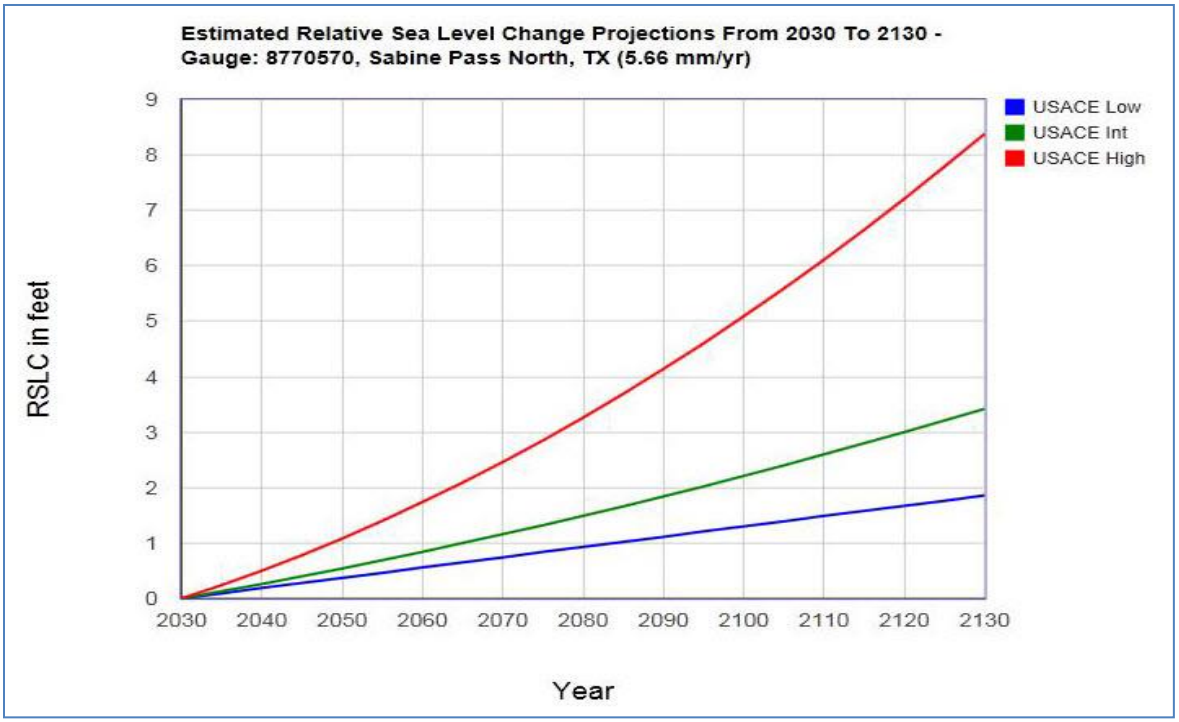

Figure 2-29: Predicted RSLC at Sabine, Texas over 50-Year Period of Analysis

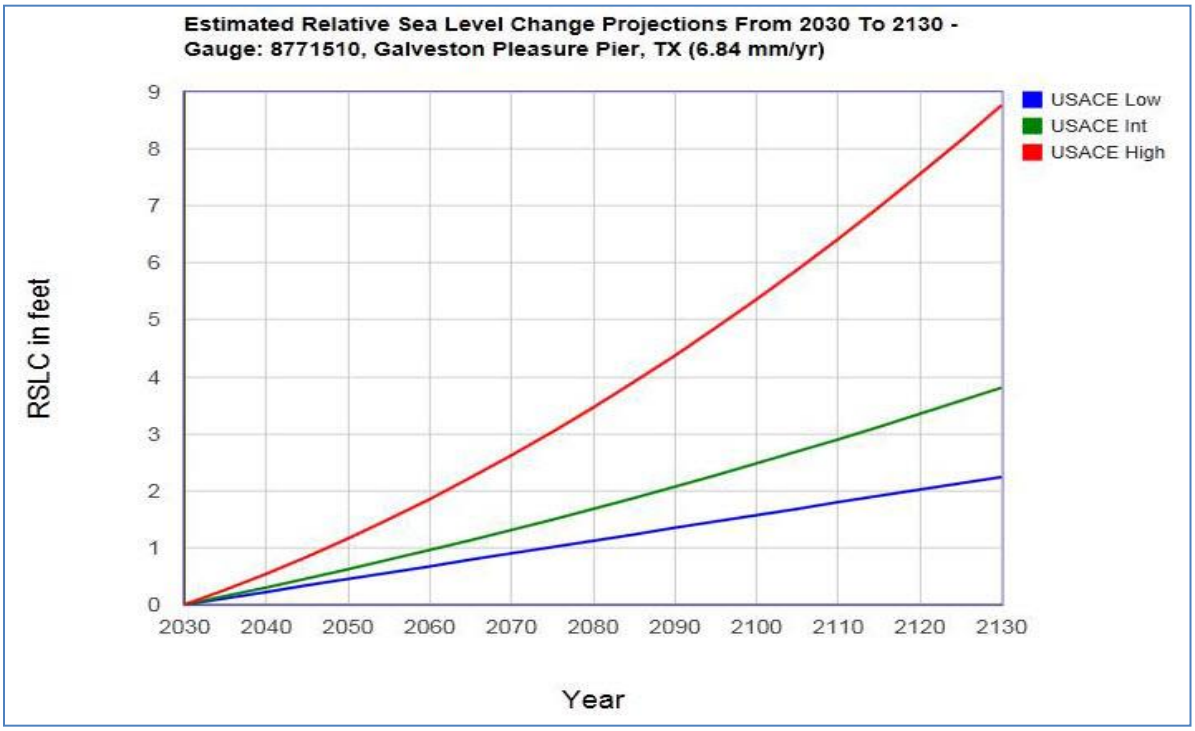

Figure 2-30: Predicted RSLC at Galveston, Texas over 100-Year Period of Analysis

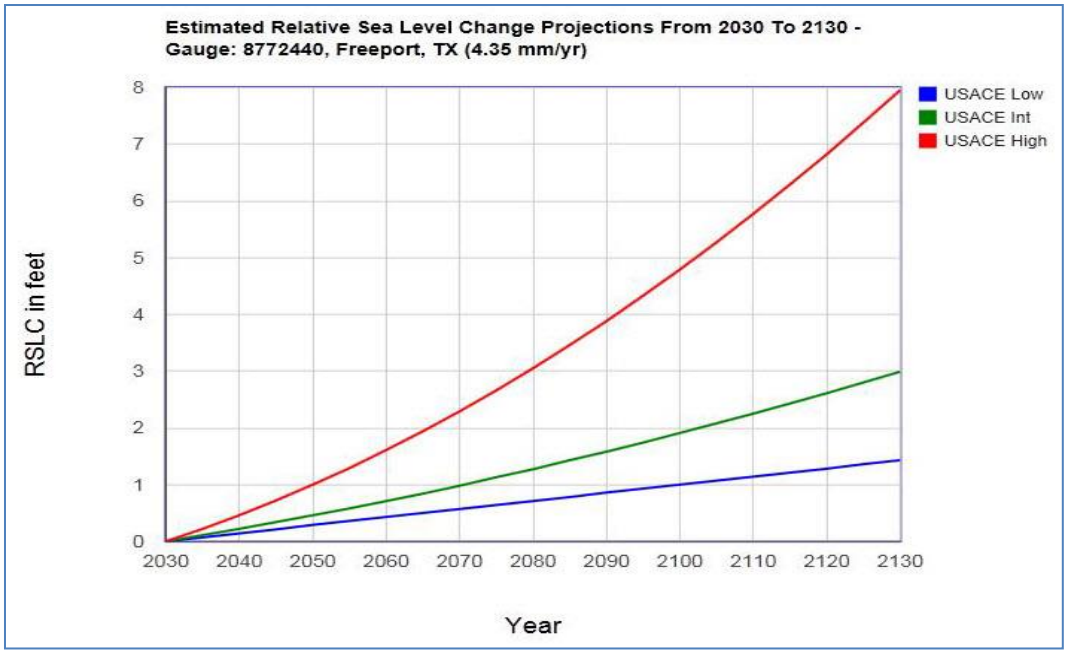

Figure 2-31: Predicted RSLC at Freeport, Texas over 100-Year Period of Analysis

2.13.6 Total Water Level Approach

The Total Water Level Approach framework is designed to emphasize several key principles described in USACE policy and guidance. Procedures to Evaluate the Magnitudes and Effects of Total Water Levels at USACE Projects include:

- Linking Tidal and Geodetic Datums
- Identifying Coastal Design Performance Factors
- Applying Coastal Forcing/Total Water Level Approach
- Applying RSLC and future scenarios
- Scaled analysis and decision making

For the TSP an initial Total Water Level approach was performed to:

- Identify Coastal Design Performance Factors
- Apply Coastal Forcing/Total Water Level Approach
- Observe RSLC and impacts on future scenarios
- Scaled analysis and decision making, such as when a threshold elevation may be reached or levee height may need modification.

Figures 2-32 and 2-33 show the low, intermediate, and high RSLC curves, and the storm surge. The plot shows the impact that RSLC will likely have on surge levels; by 2080 the surge levels

are estimated to be 4 feet higher than currently due to RSLC. Figure 2-34 shows the different components that together make up the total water forcing. This information will be used to determine when modifications will need to be made, when threshold elevations are at risk of being reached, and other design and O&M purposes.

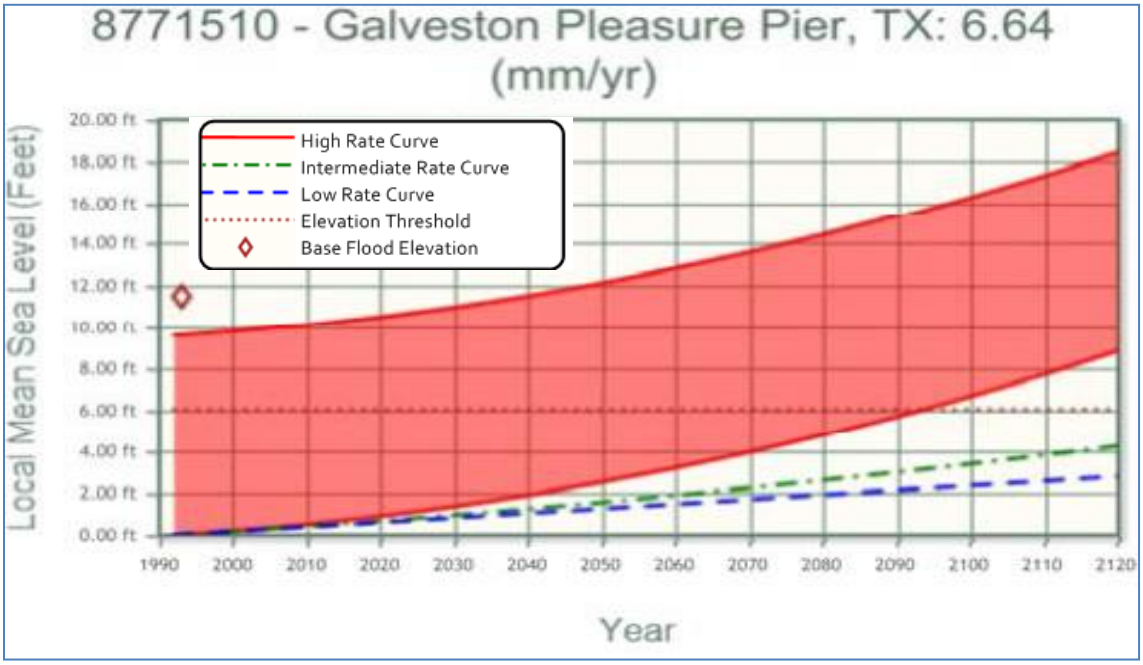

Figure 2-32: RSLC and Total Water Level Plot for Brazoria Region

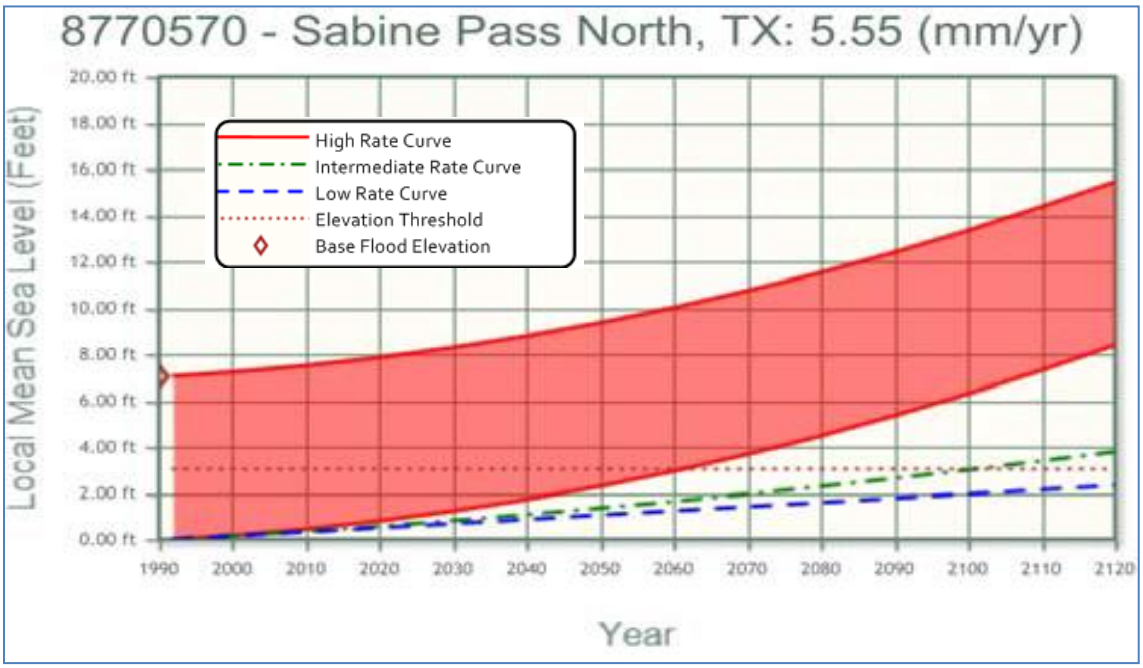

Figure 2-33: RSLC and Total Water Level Plot for Sabine Region

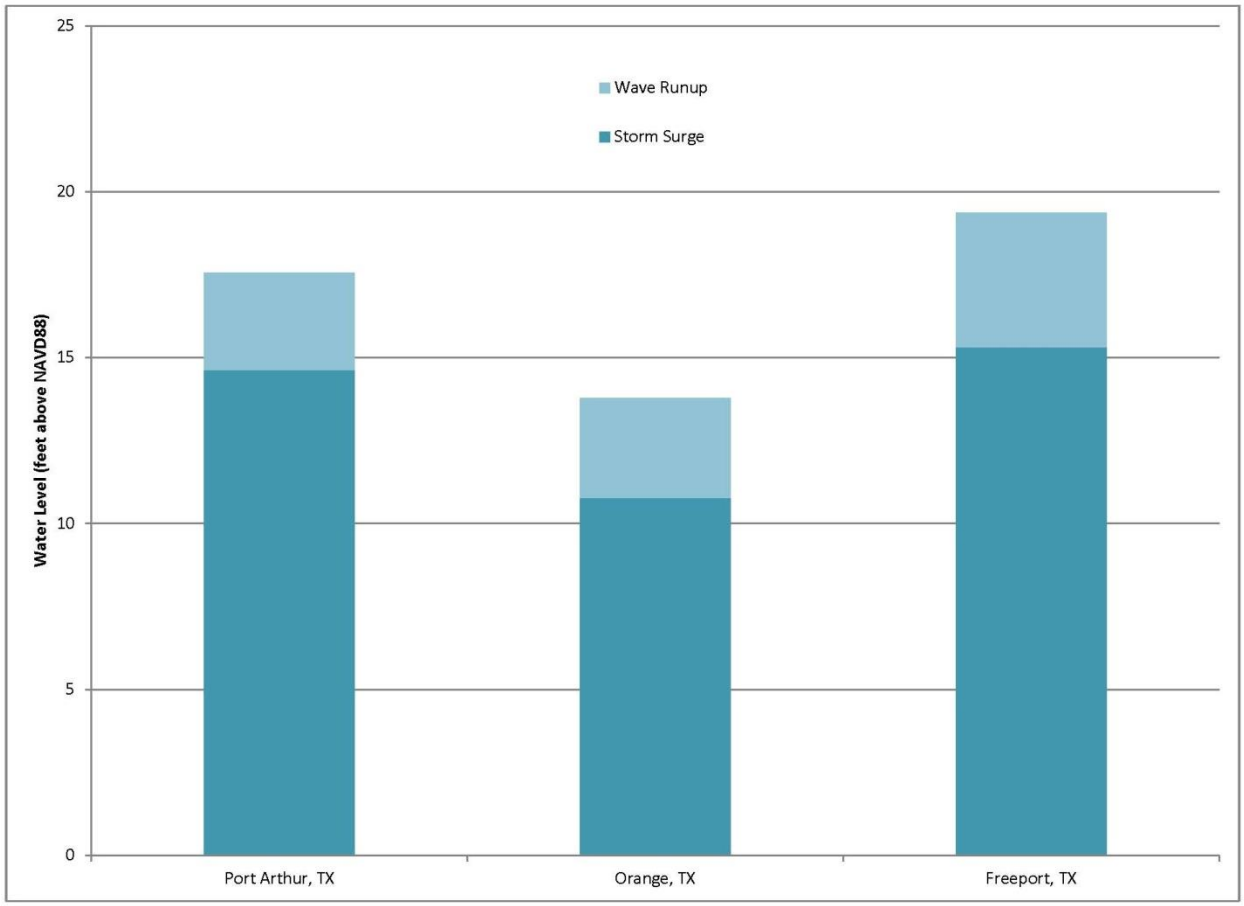

Figure 2-34: Bar Charts to Determine Total Water Level Forcing

Tides are not shown in Figure 2-34 as they are included in the surge model elevations.

2.13.7 Additional Climate Change Considerations

This section discusses future climate change expected based on current scientific evidence and studies. Climate change is expected to pose several challenges along the Texas coast. It is expected to vary greatly along the extensive Texas coast from the Mexican border to the Louisiana border. USACE will be pressed to 1) find ways to resolve increasing competition for land, water, and energy resources, 2) conserve ecological systems, and 3) enhance the resilience of people to the impacts of climate extremes (USACE 2014). These challenges will unfold against a backdrop that includes a growing urban population, incentives for energy production, and advances in technology.

For the current study area, the primary climatic forces with potential to affect the project are changes in temperature, sea and water levels, precipitation, storminess, ocean acidity, and ocean circulation. Air temperatures in the Houston-Galveston mean statistical area, on average,

increased about 1 degree over the past 20 years, a pattern that is expected to continue. Sea surface temperatures have risen and are expected to rise at a faster rate over the next few decades. Global average sea level is rising and has been doing so for more than 100 years, and greater rates of sea-level rise are expected in the future (Parris 2012). Higher sea levels cause more coastal erosion, changes in sediment transport and tidal flows, more frequent flooding from higher storm surges, and saltwater intrusion into aquifers and estuaries.

Patterns of precipitation change are affecting coastal areas in complex ways. The Texas coast saw a 10 to 15 percent increase in annual precipitation between 1991 and 2012 compared to the 1901-1960 average (Figure 2-35). Texas coastal areas are predicted to experience heavier runoff from inland areas, with the already observed trend toward more intense rainfall events continuing to increase the risk of extreme runoff, flooding, and possibly creating life safety issues.

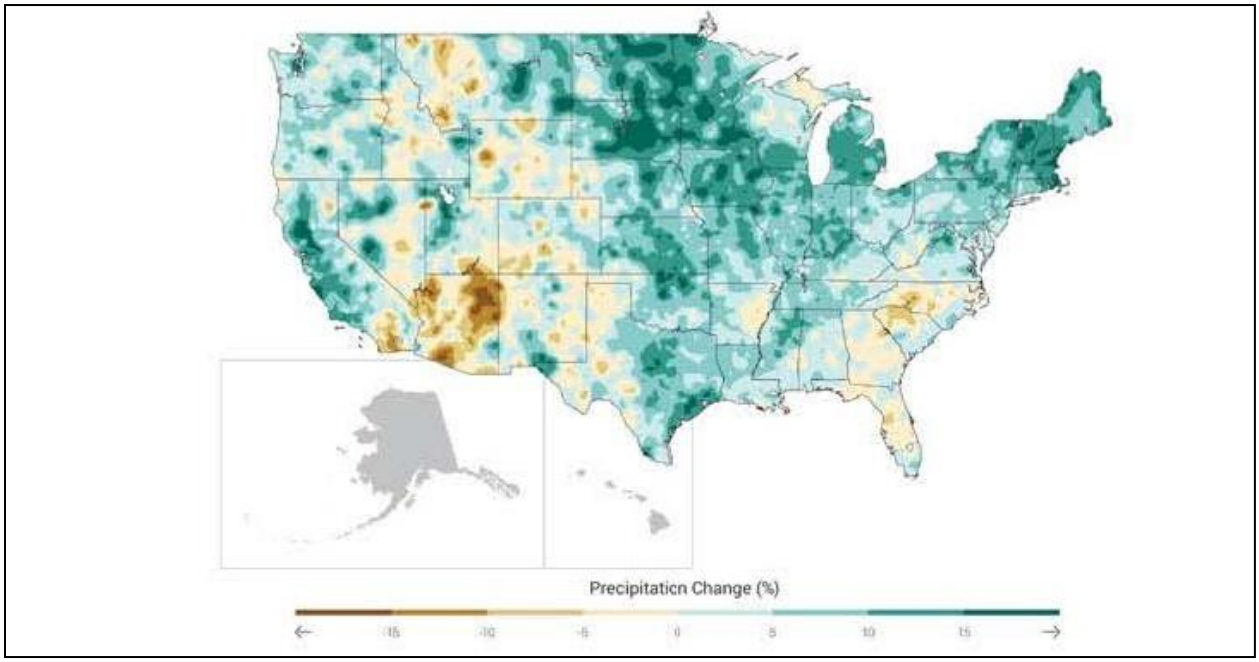

Figure 2-35: Percent Change in Annual Precipitation for 1991-2012 Compared to 1901-1960

Texas' Gulf Coast historically averages three (3) tropical storms or hurricanes every four (4) years, generating coastal storm surges and sometimes bringing heavy rainfall and damaging winds hundreds of miles inland. The estimated change in sea level will result in the potential for greater damage from storm surge along the Texas Gulf coast and miles inland. Tropical storms have increased in intensity in the last few decades. Future projections suggest increases in hurricane rainfall and intensity (with a greater number of the strongest - Category 4 and 5 - hurricanes) (Melillo 2014).

As the concentration of carbon dioxide in the atmosphere increases, the oceans will continue to absorb CO_2, resulting in increased ocean acidification. This threatens coral reefs and shellfish (Hoegh-Guldberg 2007). Coastal fisheries are also affected by rising water temperatures and climate-related changes in oceanic circulation. Wetlands and other coastal habitats are threatened by sea-level change, especially in areas of limited sediment supply or where barriers prevent onshore migration. The combined effects of saltwater intrusion, reduced precipitation, and increased evapotranspiration will elevate soil salinities and lead to an increase in salt-tolerant vegetation (Craft 2009). For additional information, reference the Environmental section of the DIFR-EIS.None of these changes operate in isolation. The combined effects of climate changes with other human-induced stresses make predicting the effects of climate change on coastal systems challenging. However, it is certain that these factors will create increasing hazards to the Texas coast. Heavily industrialized cities and ports containing critical infrastructure along the Texas coast, including Freeport, Port Arthur, Galveston, Corpus Christi, Matagorda, Brazos Island Harbor, Houston, Port Orange, and additional areas will be adversely affected by climate change.

The projected change in sea level will result in the potential for greater damage from storm surge along the Texas coast. About a third of the GDP for the state of Texas is generated in coastal counties. Coastal areas in Alabama, Mississippi, Louisiana, and Texas already face losses that annually average $14 billion from hurricane winds, land subsidence, and sea-level change. According to a recent study, projected sea-level change increases average annual losses from hurricanes and other coastal storms (Building 2010).

Diminishing water supplies and rapid population growth are critical issues in Texas. Along the coast, climate change-related saltwater intrusion into aquifers and estuaries poses a serious risk to local populations. In 2011, many locations in Texas experienced more than 100 days over 100°F, as the state set high temperature records. Rates of water loss were double the long-term average, depleting water resources. This contributed to more than $10 billion in direct losses to agriculture alone (Melillo 2014). Typically, many of the water shortages occur in the drier east parts of Texas.

The agricultural economy along the Texas coast, including livestock, rice, cotton, and citrus cultivation, is threatened by the combination of salt or brackish water from sea-level change and reduced freshwater levels from changes in temperature and precipitation. Coastal ecosystems are particularly vulnerable to climate change because many have already been dramatically altered by human interventions creating additional stresses. Climate change will result in further reduction or loss of functions these ecosystems provide.

Successful adaptation of human and natural systems to climate change will require commitment to addressing these challenges. Regional-scale planning and local-to-regional implementation will prove beneficial. Finding a way to mainstream climate planning into existing processes will save time and money. It is important that information be continually shared among decision-makers to facilitate the alignment of goals.

2.13.8 Conclusions and Recommendations regarding RSLC

The RLSC values in Tables 2-12, 2-13, and 2-14 should be included in all aspects of the feasibility designs and analyses for all three levee systems and study area. This includes modifications of existing levees and design of proposed levees and gate structures. Additionally, these values should be used when evaluating drainage features and for the environmental assessment of the project. RSLC estimates for 20-year, 50-year, and 100-year planning horizons, following guidance in ER 1100-2-8162, are summarized in the following tables.

Table 2-12: Estimated RSLC over the First 20 Years of the Project Life (2030 - 2050)

Tide Gage	Low (ft)	Intermediate (ft)	High (ft)
Sabine Pass, TX	0.37	0.54	1.08
Galveston Pleasure Pier, TX	0.45	0.62	1.16
Freeport, TX	0.29	0.46	1.00

Table 2-13: Estimated RSLC over the First 50 Years of the Project Life (2030 - 2050)

Tide Gage	Low (ft)	Intermediate (ft)	High (ft)
Sabine Pass, TX	0.93	1.49	3.26
Galveston Pleasure Pier, TX	1.12	1.68	3.46
Freeport, TX	0.71	1.27	3.05

Table 2-14: Estimated RSLC over the First 100 Years of the Project Life (2030 - 2050)

Tide Gage	Low (ft)	Intermediate (ft)	High (ft)
Sabine Pass, TX	1.86	3.42	8.38
Galveston Pleasure Pier, TX	2.24	3.81	8.77
Freeport, TX	1.43	2.99	7.95

Consideration should be given to raising levee crown heights to the optimum elevation based on the range of RSLC combined with CSRM and economic considerations. This includes assessing the benefits and costs associated with the different scenarios to select the TSP.

Design of the various components studied in the project may require alteration due to RSLC. There are several possible ways to integrate RSLC and climate change into the design of the project features being studied. This section recommends some possible solutions to the PDT, while there are many more and other solutions that could be analyzed during PED.

- For the existing levee systems in Port Arthur and Freeport:

  - Threshold elevations should be determined by the PDT and used to assess what actions need to be taken due to RSLC alone. The threshold elevation is the elevation at which RSLC will impact the functionality of the existing projects. Examples of a threshold elevation could be the toe of a levee, components of gated structures, or the elevations and configuration of drainage structures.
  - When evaluating the existing levee systems, consideration should be given to raising levee crown heights for future coastal storms combined with sea level change over the projects life. An adaptive approach is recommended for earth embankment portions of the existing levees to raise the crest as needed at different times in the projects life. For the earthen levee sections, additional ROW could be purchased to allow for expansion of the levee footprint and raising the levee height. The side slopes of the existing earthen levee embankments should be evaluated for possible increases in steepness that would allow for raising the crest height within the current ROW. It should be taken into consideration that steeper levees are more easily overtopped by waves. Floodwall sections should be assessed for their vulnerability to the possible relative sea-level rise scenarios. Raising of floodwalls may be justified to protect against increased coastal storm damages due to higher surge heights when RSLC is considered. If floodwalls are to be replaced entirely for structural or other reasons, it is advised to set the top elevation of the new floodwalls to account for sea-level rise.

- For new levee systems in Orange and Jefferson Counties:

  - An adaptive approach or an anticipatory/conservative approach is recommended for the proposed new levee components where justified.

- An adaptive approach for earthen levees could involve acquiring additional ROW to utilize when raising levees, providing a larger footprint than would be needed. The crown width could be set greater than the width required. Current regulations require a 10-foot crown. A larger crown width, for example 15 feet, would provide the opportunity to raise the levee with a decrease in the crown width. Earthen embankments could be constructed with flatter side slopes than required. This would provide the opportunity to steepen the sides slope in the future when raising the levees, but may alter the levees performance during surge events. For earthen levees, if ROW is available and not expensive, an anticipatory approach should be considered.
- An anticipatory approach is recommended for sections of floodwall, which should be analyzed and designed to include RSLC.
- Gate designs for Adams and Cow Bayous should evaluate the impacts of the RSLC scenarios and be designed to accommodate possible RSLC scenarios. The large costs of these gates make this a critical design parameter for the project.
- A conservative/anticipatory design is recommended for floodwall sections. Adaptive designs are recommended for earth embankment sections. A reactive approach is not recommended for any component of the proposed system. Anticipatory approaches are the most costly initially, but may yield the highest overall benefit-to-cost ration and net excess benefits over the project design life.

➢ Drainage structures:

- It is recommended that the design of drainage structures incorporate the potential effects of RSLC and climate change.
- To account for expected increase in the precipitation intensity on the upper Texas coast, the size of the culverts should be increased by 5-10 percent. This is to allow the interior drainage to function as needed and allow increased discharges.
- To accommodate RSLC, culvert slopes will be conservative to account for RSLC impacts. The downstream flow-line for many culverts will be adjusted as needed to account for at least the low RSLC condition to prevent inundation behind the line of protection.
- Other alternatives for meeting the recommendation of incorporating RSLC and climate change include flap gates on culvert outfalls with positive closure that open to discharge interior runoff when the interior hydraulic head is sufficient to push water out. Culverts may be constructed with an adaptive flow-line breaching the line of protection. This option may be most useful in environmentally sensitive areas and tidally influenced areas.

- It is recommended that pumps be designed conservatively to provide adequate capacity for future coastal storm events that may bring more rainfall runoff than previously experienced due to climate change.

➢ Additional Considerations:

- The jetties for the Freeport Entrance Channel and Sabine Neches Waterway are critical for safe navigation into the project areas. If the sea-level change reaches an elevation that overtops the jetties, measures would need to be taken to modify the jetties and continue to provide safe navigation.
- The Freeport Entrance Channel jetties have a threshold elevation of 6.6 feet NAVD 88 (7.24 feet MLLW). This is the height of both jetties after repairs were made to return the storm-damaged jetties to their pre-Hurricane Ike elevations. Based on this data, it was determined that there will be no need for modification of the jetties over the 50-year period of analysis or for an extended period afterwards.
- The Sabine Neches Waterway jetties have a threshold elevation of 7.5 feet NAVD 88 (7.6 feet MLLW). This is the elevation of both jetties after repairs were made to return the storm-damaged jetties to their pre-Hurricane Ike condition. Based on this data, it was determined that there will be no need for modification of the jetties over the 50-year period of analysis or for an extended period afterwards.

This summary of RSLC is provided to the PDT to assist in making critical designs regarding the project feature designs and economic damages assessments. This includes economic analysis, plan formulation, and the incorporation of this information when determining the TSP.

2.14 INTERIOR DRAINAGE

The existing and proposed levee systems need to maintain drainage of rainfall-induced runoff of the levee interior area during normal rainfall events, and also during tropical events during which the system will be closed to reduce storm surge damages. The following describes the preliminary interior drainage analysis performed and drainage plan for the existing and proposed levee components.

For the proposed new levee systems, flows were calculated using rational and regression methods. Drainage structures were conservatively sized based on the 50-year and 100-year flow events. The calculated flows were increase by a magnitude of 10 percent to account for climate change and the anticipated increases in precipitation predicted. This is further discussed in Section 2.13 - Climate Change.

For the existing systems at Port Arthur and of Freeport, the existing drainage systems and possible modifications or improvements that could be made were evaluated. Known deficiencies in interior drainage structures (pipes, pumps, etc.) are not addressed in this evaluation of existing systems as they would be Operations, Maintenance, Repair, Replacement and Rehabilitation (OMRR&R) issues. Only improvements and modifications with economic benefits that establish a Federal interest were considered for the existing systems. Section 2.15 details the study efforts of interior drainage for both regions.

2.15 EXISTING LEVEE SYSTEMS INTERIOR DRAINAGE

An extensive data collection effort was performed for the Regions of study. Data collected included USACE Design Memorandums, Plans and Specifications, levee inspection report, Hydrologic and hydraulic models from counties, the state of Texas, Cities, Ports, and Levee Districts, among other sources including consultants were gathered and used when appropriate.

2.15.1 Brazoria Region Data (Freeport and Vicinity)

Levee construction plans, hydrologic and hydraulic studies, FEMA data, TXDOT data, county data, Periodic Inspection Reports, and FEMA data for FEMA studied bodies of water were used. Maps of the area and historical data regarding water and inundation paths were used to identify areas of concern. Additionally data from the on-going USACE Risk Management Center Freeport SQRA was obtained including surge, drainage, and other hydrologic and hydraulic models to use. Preliminary investigation determined that current interior drainage infrastructure is adequate and there are no known deficiencies. Some interior drainage components will need reconstruction or repair as work on the TSP plan dictates. One new drainage structure will be needed for the TSP. At the DOW barge canal the TSP calls for a sector gate structure, which will require and expanded pump location to drain water past the proposed gate structure. More detailed study of this structure is recommended during PED. During PED it is recommended that all major waterways, creeks, bayous, and other waterways within or adjacent to the levee system be surveyed and hydrologic/hydraulic models be update or recreated.

2.15.2 Sabine Region Data (Port Arthur and Vicinity)

Data from DMs, plans and specifications other studies for existing Port Arthur and the surrounding areas, Periodic Inspection Reports, the current Alligator Bayou Pump Station 408 study, and FEMA data for the area was used to investigate the interior drainage of Port Arthur. Preliminary hydrologic and hydraulic investigation determined that the current interior drainage infrastructure is adequate and there are no known deficiencies or need to change the interior drainage features besides some of the pump stations. Five pump stations that discharge rainfall

runoff during surge events need reconstruction or repair as work on the TSP plan dictates. These pumps are shown below in Figure 2-36.

Figure 2-36: Port Arthur Pump Stations in Need of Rehabilitation

The pumps will need constructed with the capability to discharge 10 percent more cfs than the current pumps. More detailed study of this structure is recommended during PED. During PED it is recommended that all major waterways, creeks, bayous, and other waterways within or adjacent to the levee system be surveyed and hydrologic/hydraulic models be updated or created if they do not or no longer exist.

2.15.3 Preliminary Screening of Neches River Gate Alternative

An alignment for a closure gate on the mouth of the Neches River recommended by Orange County Study was selected for additional H&H study and analysis. The original Orange County Report alignment was refined to minimize environmental and navigation impacts, and identify a more specific location for a pumping station. This pumping station would need to have the ability to pump discharges from the inland Neches River into Sabine Lake.

Both alternatives were configured to provide the same level of protection (and benefits). USACE must recommend a plan that maximizes net excess benefits. With the benefits for each

alternative providing the same benefits the alternatives could be compared based on cost data. A joint probability analysis of riverine discharge and storm surge on the Neches River was conducted to assist in determining the feasibility of an alternative that would place a closure gate on the Neches River. The analysis calculates the probability of discharge with respect to extreme water level. This analysis is appropriate for initial screening. This preliminary screening was performed to determine if the Neches River gate continued to remain a viable alternative or would be dropped from further consideration.

Figure 2-37 shows the location of gages that provided data used in this analysis. The nearest gage measuring river discharge was an USGS gage at the Neches River Saltwater Barrier. The USGS gage has a period of record (POR) from 04 June/2003 until present. The nearest gage measuring water level was a NOAA gage at Rainbow Bridge. The NOAA gage has a POR from 01 January 1993 to present.

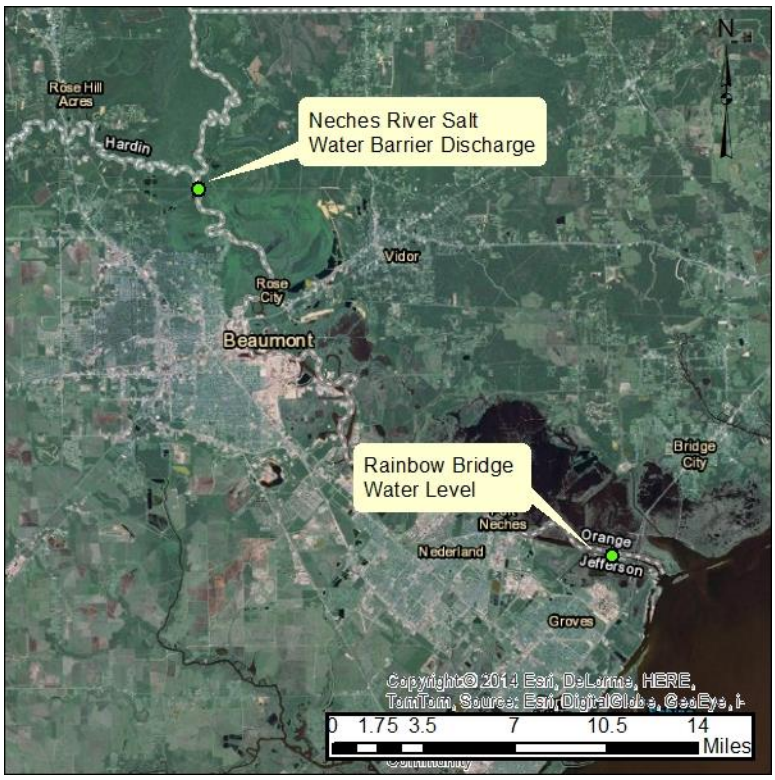

Figure 2-37: Location of Gages Used in this Analysis

Figure 2-38 plots all available overlapping water level and discharge data. The time period from 2003 to present was used for this analysis. Figure 2-39 plots discharges and water levels during Hurricane Rita (2005). Rita made landfall in the study area as a Category 3 Hurricane. Since water levels and discharges are both influenced directly by tropical storms, a joint probability

analysis is required to determine the probability of discharge volumes during variable surge events that would require the gate to be closed.

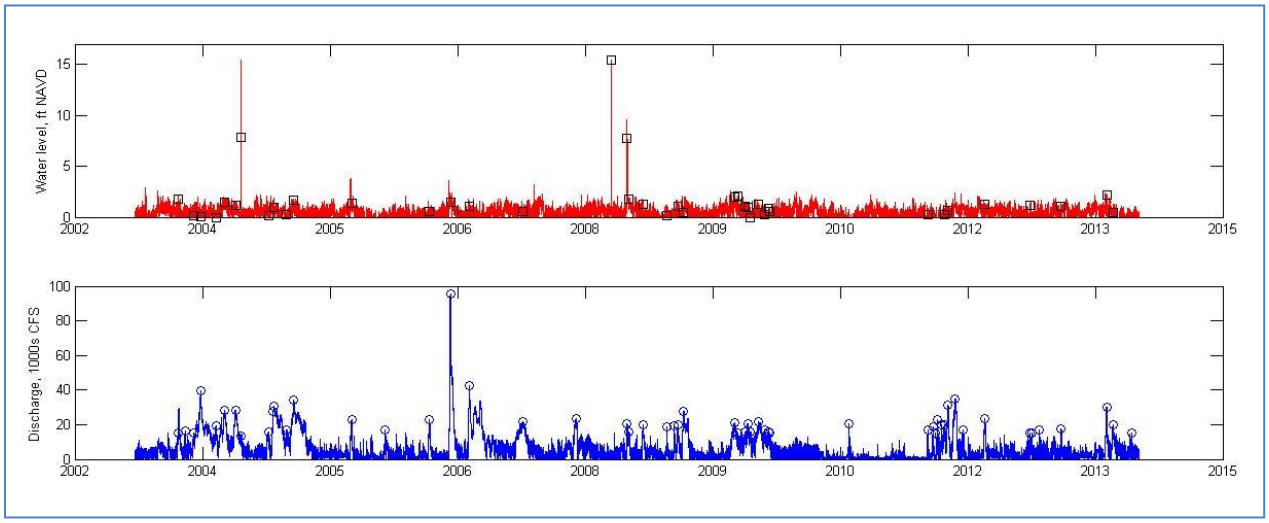

Figure 2-38: Water Level and Discharge Data from 2003 to Present

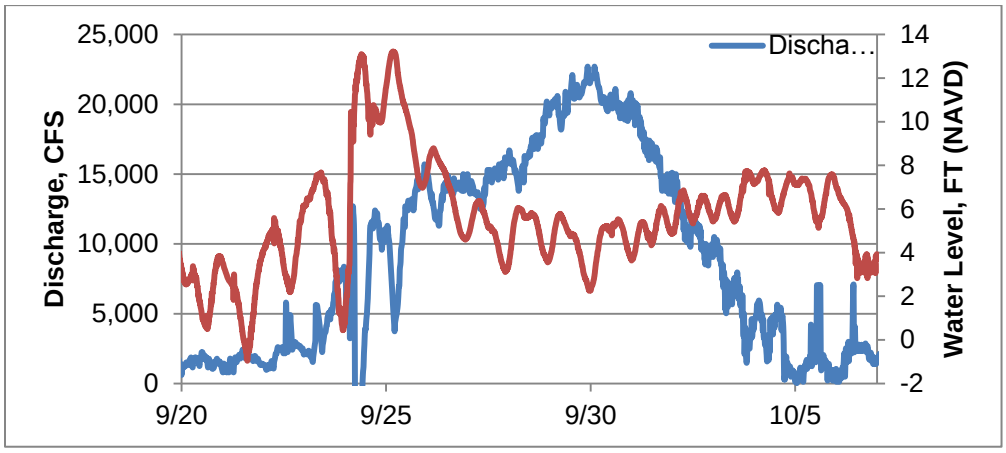

Figure 2-39: Discharge and Water Level during Hurricane Rita

The data gathered from NOAA and USGS gages were utilized in performing a joint probability analysis of discharge and water level. First, the peak over threshold approach was used to determine extreme water level and discharge events. Water levels over 3.3 feet and discharges over 15,000 CFS were specified as extreme and included for analysis. Frank and empirical Copula bivariate distribution functions were then fit to the data to calculate the distribution following the method applied in Michalsen (2014). Figure 2-41 plots the probability distribution calculated with the Frank (top) and empirical (bottom) Copula functions. The colors and contours show probability in return period. Figure 2-40 shows that the highest discharges tend to occur at lower water level. It is important to point out that this is a relatively short data record.

A longer data record would need to be synthesized to attempt to improve the accuracy of these results. It is also noted the Neches River downstream of the USGS gage would incorporate additional drainage area and runoff so it should be expected that flow near the proposed gate location would be higher.

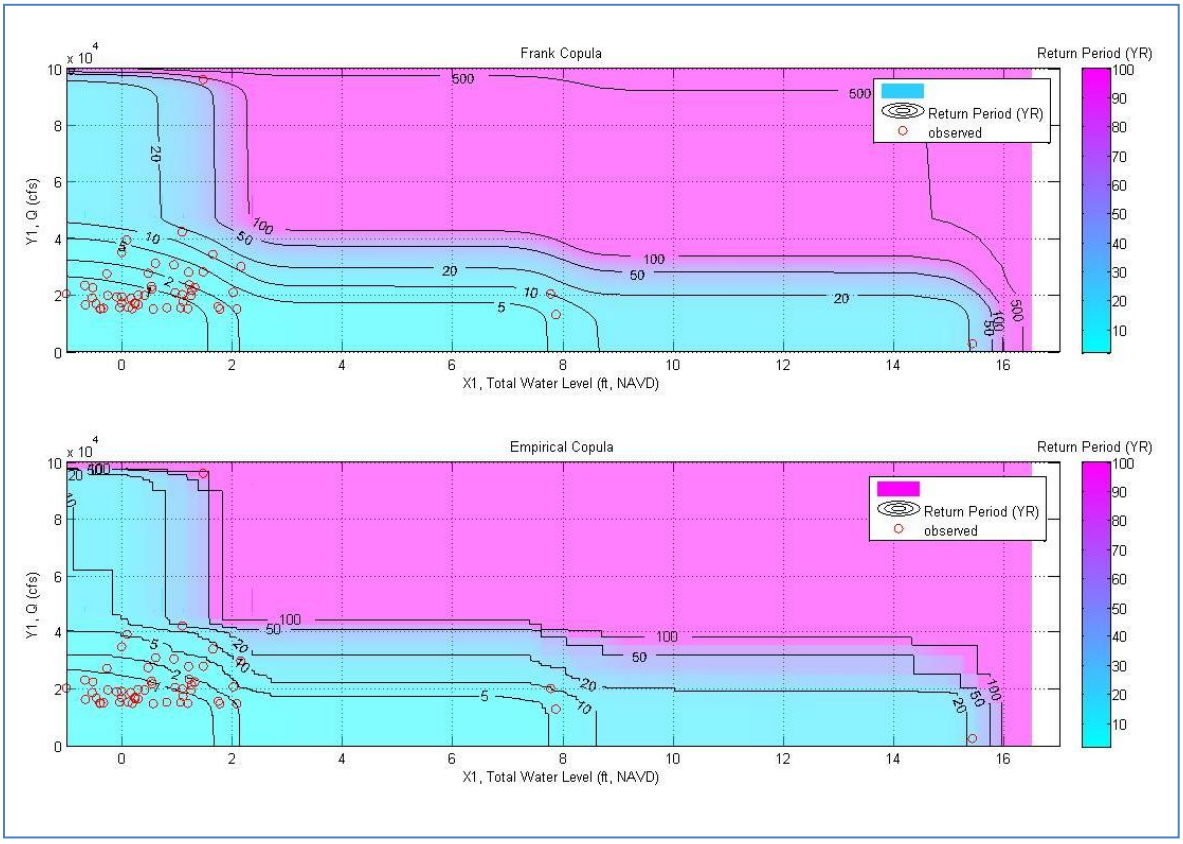

Figure 2-40: Joint Probability of Discharge (Q) and Water Level

In summary, the analysis leads to the following general conclusions:

- 100-year return period Neches River discharge could reach levels up to 40,000 cfs for coincident riverine/surge events that would occur during gate closure.
- If the gate remains the preferred alternative, more detailed analysis of joint probability of water level and discharge should be conducted to inform operations and design.

2.15.4 Consideration of Storm Surge Damages in Port/City of Beaumont

A preliminary investigation was conducted by USACE to evaluate the Beaumont areas vulnerability to storm surge, and if the alternatives being considered could provide beneficial protection in the area. For this investigation USACE collected data, studied inundation maps for

a range of storm frequencies, and contacted local and national entities with knowledge of flooding issues in the area. During this investigation USACE contacted the Port of Beaumont, Jefferson County Drainage Districts 6 and 7, the FEMA local flood administrator, FEMA Regions VI and IV, the City of Beaumont Water Utilities Department, and the Sabine Neches Drainage District.

The Port of Beaumont stated that surge in the Port did occur during Hurricane Ike, but it caused only minor damage to docks and a few electrical systems. The Port of Beaumont was fully operable 2 to 3 days after Hurricane Ike passed. Hurricane Rita caused almost no surge at the Port. Damages from Rita in Beaumont were almost entirely due to wind.

The local floodplain administrator (Adena Ward) provided additional information on surge related damages in the Beaumont area. Ike flood damages were focused in two areas. The first area was along Pine Street in Beaumont, which experienced significant flooding. Most of the properties damaged at this location have since been bought out. The other location that was damaged by surge was the Exxon Mobil facility area located just south of the Port of Beaumont. FEMA Region VI provided damage claim amounts for the Ports of Orange and Beaumont during Hurricanes Ike and Rita. For Ike, 87 percent of damage claims were Category A (debris removal) with minimal damages to infrastructure or facilities. Damages claimed during Rita only amounted to $109,000.

Sabine Neches Navigation District (SNDD) had little info on Port of Beaumont. SNDD did relay that considerable damages had occurred along Taylors Bayou during Ike. They have since constructed a large diversion culvert to route water around the area and prevent flood water damages on Taylors Bayou during future rainfall events. The Water Utilities Department noted that the salt water barrier intake on the Neches River was damaged during Ike, but the cost of repair was minimal. Jefferson County Drainage District 6 provided data on high water marks during Ike that correlated well with the information other contacts had provided.

In summary, surge events have historically caused minimal damages to the Port and City of Beaumont. Drainage features have been constructed to alleviate flooding along Taylors Bayou, and buyouts have been performed in Beaumont to remove structures from flood-prone areas. The only area that has experienced damages and not been protected or removed from flood prone areas is the Exxon facility area (note that this area would be protected by the alternatives currently being considered in this USACE study). During surge events, water is almost entirely contained within the undeveloped Neches floodplain in the vicinity of Beaumont and causes minimal damages. The inundation in the vicinity of Beaumont from a 100-year frequency storm is displayed in Figure 2-41.

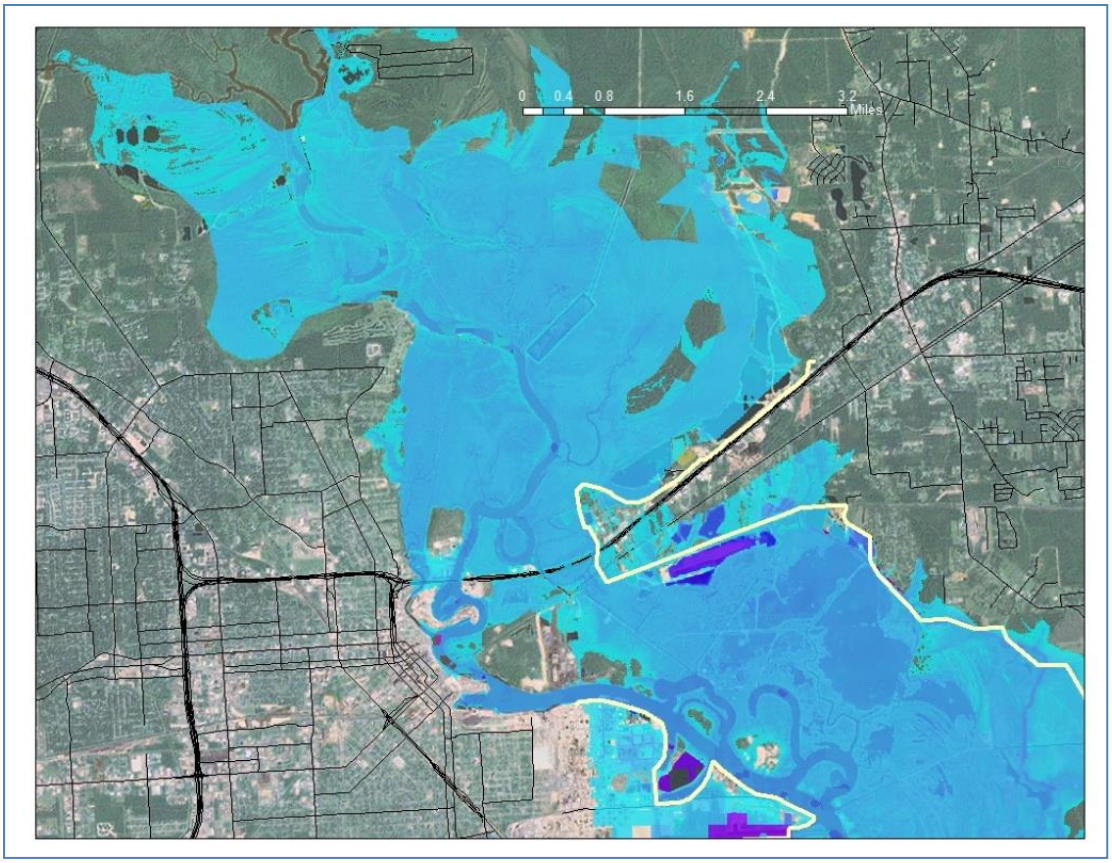

Figure 2-41: 100-year Frequency Inundation in Beaumont Vicinity

Orange County Levee/Gate Alternatives: Alignments and Preliminary Feasibility Approach

USACE used levee alignments established in the Orange County Flood Protection Planning Study (2012). The levee alignment was refined in some areas to maximize benefits, reduce cost, reduce environmental impacts, and protect critical infrastructure. Additionally, steps were taken to avoid major pipeline corridors/conflicts and identify potential properties for buyouts. For additional information and details on the alignment study, alignment selection, economics, cost, real estate, and other factors that led to the TSP alignment, please refer to those sections of this report.

2.15.5 Interior Drainage Analysis of Proposed New Levee Systems (TSP)

2.15.6 Drainage Area Delineation

Drainage areas for the interior of the levees were delineated using a combination of LiDAR, USGS maps, aerial maps, and documents gathered from the county and cities in the area. A closure gate on the Neches River was considered and eliminated due to cost**.** Drainage Area Maps for the entire proposed Orange, Beaumont, and Jefferson sections of the TSP are included

in the H&H exhibits section of this H&H. These maps also contain preliminary drainage structure locations and sizes.

2.15.7 Drainage Area Discharge Estimates

Runoff was calculated using the Rational method for Areas under 200 acres, and using Regression methods for areas large than 200 acres. Details of the runoff calculations are summarized in the following sections. Measured gage data in the area is sparse, but what is available is being used. Hydrologic and Hydraulic Models of Cow and Adams Bayous were obtained from the Orange County Economic Development center were use.

2.15.8 Rational Method

For areas 200 acres or less, the Rational method was used to calculate runoff due to rainfall events. The Rational Equation is the simplest method to determine peak discharge for smaller drainage basin runoff. It is not as sophisticated as the SCS TR-55 method, but is the most common method used for sizing sewer systems and adequate for the purposes used in this study.

The Rational Equation is: $Q=CIA$

where:

Q = Peak discharge (cfs)

C = Rational method runoff coefficient

I= Rainfall intensity (inches/hour)

A = Drainage area (acres)

The Rational method runoff coefficient (C) is a function of the soil type and drainage basin slope. C is reflective of the type of land coverage. For example, C for pervious grassy/forest areas that allow infiltration and slow down rainfall runoff would have a C value in the range of 0.35. An impervious area such as a concrete lot or roadway would have a C value as high as 0.95, signifying increased runoff. Areas of mixed land coverage would have a value reflecting the coverage of that specific area. For each drainage area, a weighted C value was calculated to reflect each drainage areas land coverage.

The Rainfall intensity (I) is typically found from Intensity/Duration/Frequency curves for rainfall events in the geographical region of interest. The duration is usually equivalent to the time of concentration of the drainage area. The rainfall intensity was calculated using USGS pub (reference). The 2-hour rainfall in inches was used in this analysis. The Rational method requires a value in inches per hour at the outfall location. To obtain the intensity in inches per hour at the outfall location, the time of concentration was calculated for each watershed. The

total rainfall in inches was divided by the time of concentration to obtain the intensity used in the runoff calculations.

Time of concentration is the time it takes for a point rainfall to travel to the outfall, and creates the maximum contribution of runoff from the drainage area. It is calculated by evaluating different travel paths to the outfall and calculating the time it would take for the entire drainage area to contribute to the discharge at the outfall.

As discussed previously, there is little to no data available to calibrate/verify/validate runoff estimates in many of these remote areas. Therefore, Rational method calculations were performed using a second method to calculate the intensity. The Intensity was based on IDF curves, time of concentration calculations, and runoff "C" Coefficients for the drainage areas. Using this independent method produced runoff results that showed good agreement (typically within 5-10 percent) with the previous flow estimates. This increased confidence that the previous estimates were fairly accurate and were adequate to be used later to size the structures associated with these areas. Table 2-15 tabulates the flows estimated for Orange County using the Rational method.

Table 2-15: Rational Method Calculated Discharges for the Sabine Region

Watershed ID	2-Year Discharge	5-Year Discharge	10-Year Discharge	25-Year Discharge	50-Year Discharge	100-Year Discharge
JN1	183	271	273	353	455	601
JN2	83	132	124	160	207	273
JN3	173	293	259	335	433	572
JN4	171	301	256	331	427	565
JN5	207	356	310	401	518	685
JN6	139	218	207	268	345	456
JN7	193	177	285	371	470	590
JN8	55	37	82	107	136	172
JN9	102	121	152	197	249	311
JS1	115	177	171	222	280	349
JS2	418	483	606	787	979	1,191
JS4	141	167	195	247	296	324
JS5	145	187	214	279	353	441
JS6	180	272	266	345	437	543
JS7	42	37	60	78	98	120
JS8	258	371	379	491	619	764
JS9	241	338	355	460	579	715
JS11	332	408	485	630	794	982
JS12	223	310	331	432	550	696
JS13	162	235	239	310	391	485

Watershed ID	2-Year Discharge	5-Year Discharge	10-Year Discharge	25-Year Discharge	50-Year Discharge	100-Year Discharge
JS14	83	84	122	158	199	247
OCE00	125	157	185	240	313	414
OCE0	150	187	220	287	372	491
OCE1	188	236	278	361	469	621
OCE2	92	114	134	174	226	299
OCE3	57	71	84	109	142	187
OCE4	180	223	263	342	444	585
OCE6	73	68	107	139	181	238
OCE7	94	79	137	178	231	304
OCE8	83	80	121	158	205	269
OCE9	46	37	66	86	112	147
OCE11	244	201	356	463	600	788
OCE12	127	100	185	240	311	409
OCE14	126	100	185	239	310	406
OCE15	85	70	125	161	210	276
OCE16	113	87	166	216	279	365
OCE17	83	68	122	159	206	270
OCE18	113	96	165	215	278	365
OCE19	61	43	90	117	151	197
OCE20	106	99	155	201	260	341
OCE22	167	154	245	318	412	541
OCE23	103	81	151	196	254	332
OCE24	116	101	170	221	286	374
OCE25	166	154	245	317	411	539
OCE26	83	62	122	159	206	269
OCW1	166	263	218	284	370	487
OCW3	183	316	295	384	499	656
OCW5	148	263	218	284	370	487
OCW6	178	309	262	341	443	584
OCW7	201	316	295	384	499	656
OCW8	128	151	186	243	315	413

2.15.9 Regression Method

Regression equations were used to calculate runoff for areas over 200 acres. Two Regression methods were used to limit uncertainty and compare results of the two methods. The first Regression method is one used by the FHWA.

The regression equation used for the FHWA Regression analysis is:

$$Q_T = P^c S^d \times 10^{[e\Omega + a + bA^{\lambda}]}$$

Q_T = peak discharge of recurrence interval T years (cfs)

P = mean annual precipitation in inches, from Texas Parks and Wildlife Board maps of the mean annual precipitation

S = dimensionless main channel slope

Ω = Omega value (Dimensionless parameter for specific areas of Texas, taken from TXDOT Hydraulic Manual 2014)

A, b, c, d, e = regression coefficients specific for the recurrence interval

The omega value for each location is taken from 2004 USGS maps for interior areas.

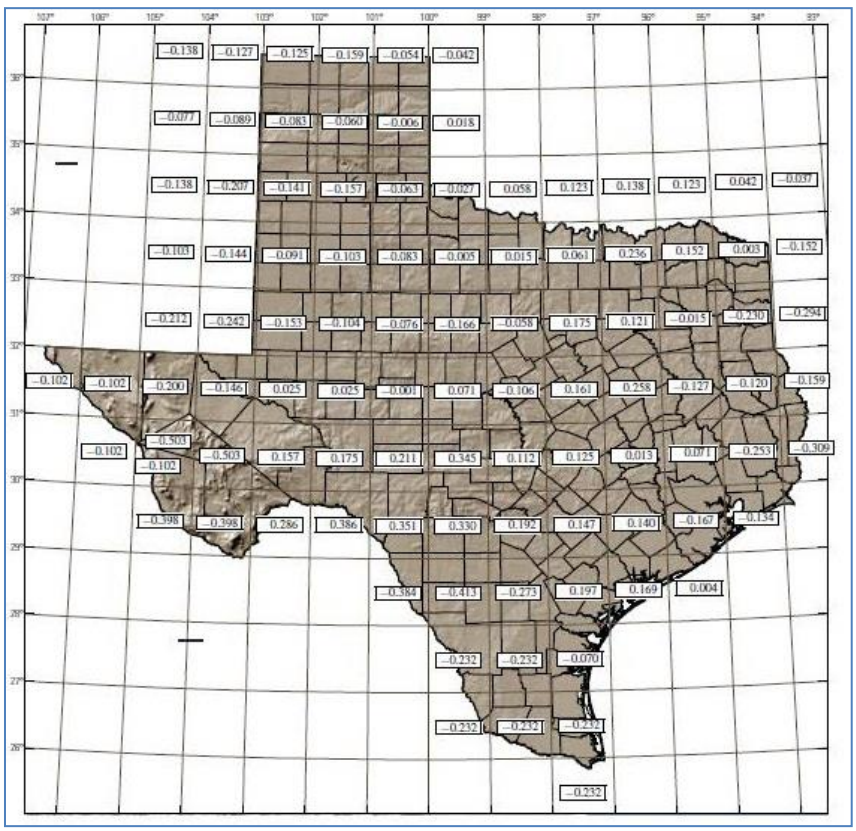

Figure 2-42: Mean Annual Precipitation Values from TXDOT 2014 Hydraulic Manual

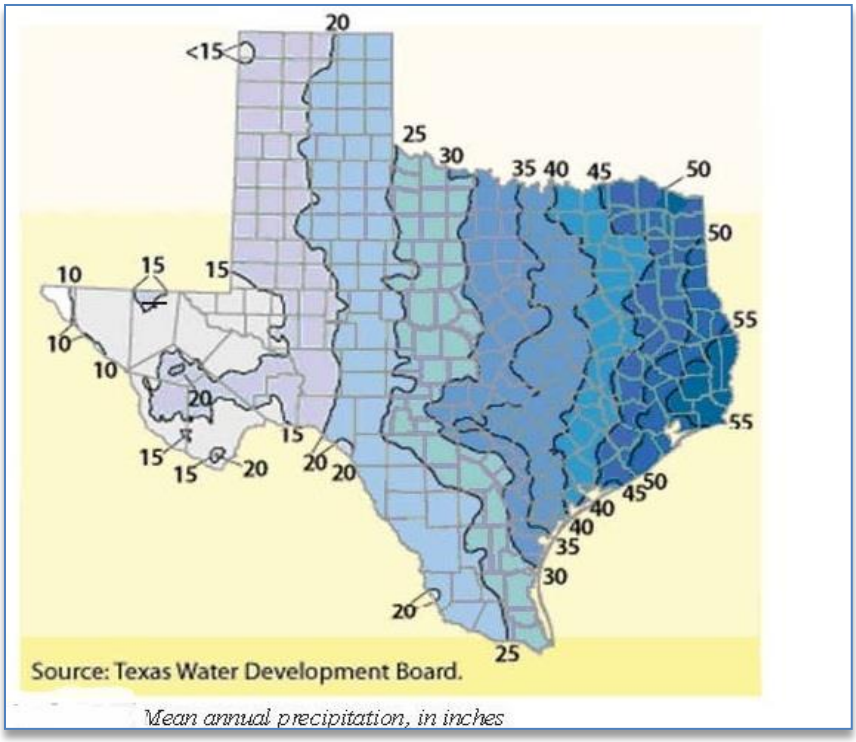

Figure 2-43: Omega Values Used for Regression Runoff Estimates

Table 2-16: The Equations Used for each Frequency Storm Event

Watershed ID	2-Year Discharge	5-Year Discharge	10-Year Discharge	25-Year Discharge	50-Year Discharge	100-Year Discharge
OCE5	158	234	280	351	396	665
OCE10	1,052	1,879	2,304	2,965	3,393	5,076
OCECB	2,009	3,596	4,329	5,542	6,228	8,637
OCE13	122	156	171	204	211	322
OCE21	121	175	213	266	303	528
OCW2	748	1,188	1,472	1,520	1,854	3,252
OCW4	214	316	380	435	502	867
OCW9	95	131	158	195	221	384
OCW10	260	402	483	601	679	1,111
OCW11	241	397	492	653	752	1,265
OCW12	81	114	140	182	210	376
OCW13	148	233	295	384	453	819
OCW14	359	604	738	999	1,124	1,770
OCW15	144	202	237	286	317	524
OCW18	196	321	403	550	636	1,088
OCW21	139	213	267	338	399	725
OCW29	133	205	258	330	390	708
JS3	88	132	170	230	278	531
JS10	335	574	739	901	1,099	1,997

*** All dischares in cfs**

Table 2-17: Regional Regression Discharge Summary Table

Regression Equations	RSE	Adj. R-squared	AIC statistic	PRESS statistic
$Q_2 = P^{1.398} S^{0.270} \times 10^{[0.776\Omega + 50.98 - 50.30A^{-0.0058}]}$	0.29	0.84	273	64.6
$Q_5 = P^{1.308} S^{0.372} \times 10^{[0.885\Omega + 16.62 - 15.32A^{-0.0215}]}$	0.26	0.88	122	49.1
$Q_{10} = P^{1.203} S^{0.403} \times 10^{[0.918\Omega + 13.62 - 11.97A^{-0.0289}]}$	0.25	0.89	86.5	46.6
$Q_{25} = P^{1.140} S^{0.446} \times 10^{[0.945\Omega + 11.79 - 9.819A^{-0.0374}]}$	0.26	0.89	140	49.5
$Q_{50} = P^{1.105} S^{0.476} \times 10^{[0.961\Omega + 11.17 - 8.997A^{-0.0424}]}$	0.28	0.87	220	55.6
$Q_{100} = P^{1.071} S^{0.507} \times 10^{[0.969\Omega + 10.82 - 8.448A^{-0.0467}]}$	0.30	0.86	320	64.8
$Q_{500} = P^{0.988} S^{0.569} \times 10^{[0.976\Omega + 10.40 - 7.605A^{-0.0554}]}$	0.37	0.81	591	98.7

Again, two different methods were used to check runoff estimates, as measured data are not available for calibration/verification/validation. Methodology for these estimates is based on equations and guidance outlined by the U.S. Department of Interior and U.S. Geological Survey (USGS) Water-Resources Investigations Report 96-4307.

The Regression Equation for this approach is: $Q_T = aA^bSH^cSL^d$

where:

A = Drainage Area (Mi2)

SH = Basin Shape Factor (SH) (Mi.2/Mi.2)

SL = Mean Channel Slope (SL) (Ft./Mi.)

A, b, c, d = Regional Regression Coefficients from the TXDOT 2004 Hydraulic Manual

Regional regression coefficients were taken from maps created by the USGS. Orange and Jefferson Counties are in Region 11, as seen in Figure 2-44. The Region 11 Regression Coefficients for 2-year, 5-year 10-year, 25-year, 50-year, and 100-year are listed in Table 2-18.

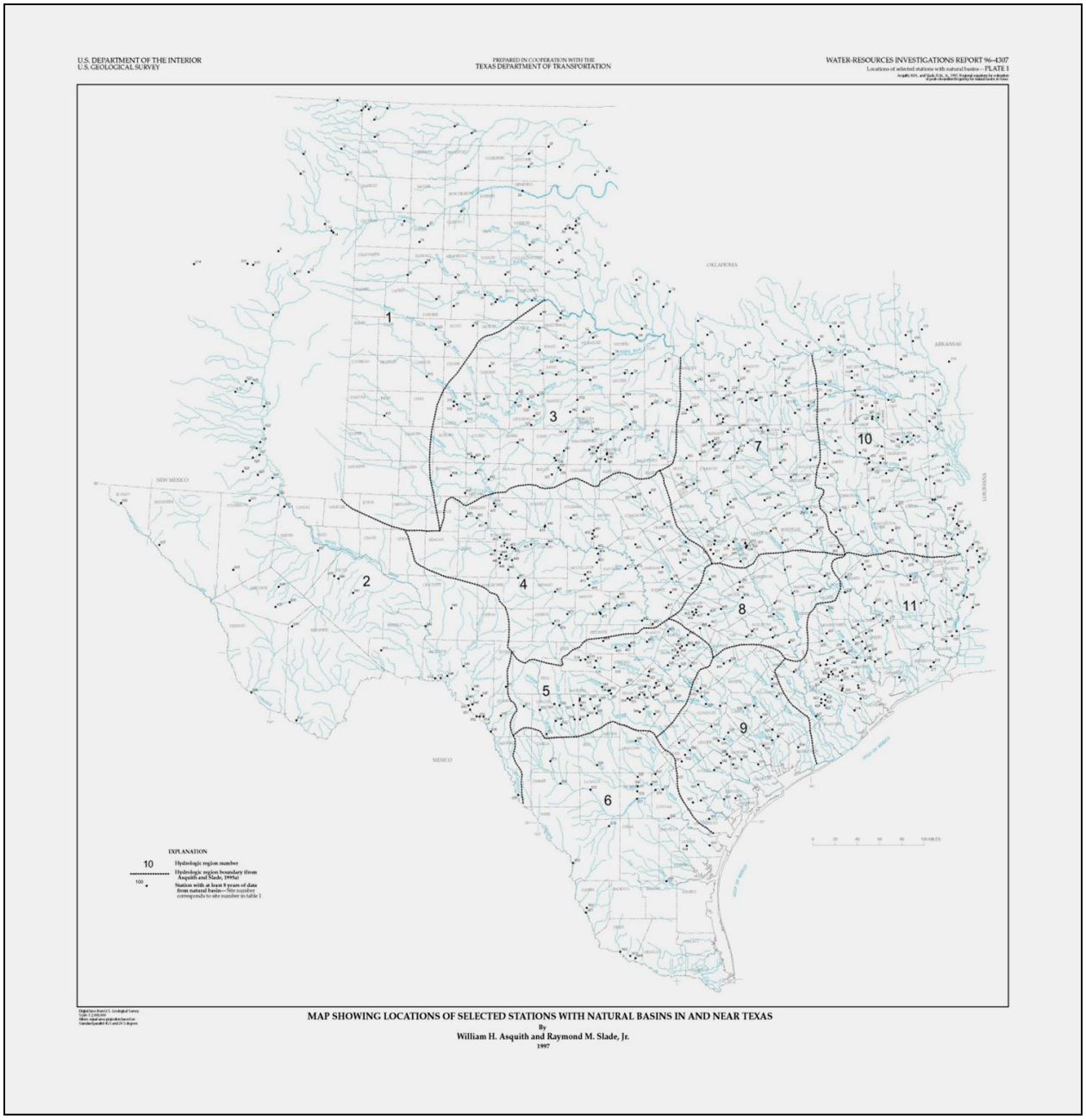

Figure 2-44: Region Map for the State of Texas

Table 2-18: Region 11 Regression Coefficients for Orange and Jefferson County

	a	b	c	d
2-Year	159	0.669	-0.262	0.000
5-Year	191	0.696	-0.186	0.130
10-Year	199	0.718	-0.151	0.221
25-Year	201	0.713	0.000	0.313
50-Year	207	0.735	0.000	0.380
100-Year	213	0.755	0.000	0.442

Results using the USGS/USDI Regression methods compared well with the Results calculated with the FHWA Regression method. The difference in flow estimates fit within the expected error of the previously used method, increasing confidence in the flow estimates. The Rational method can sometimes have considerable error and uncertainty, and being able to use two different Regression methods and obtain similar Discharge estimates provided verification that the results calculated using the Regression method were sufficient to use. These estimates were used to size structures for the new levee sections of the Sabine Region. Table 2-19 summarizes flows calculated by the Regression Methods.

Table 2-19: Average Regression Method Discharges Using USGS and FHWA Methodology

Watershed ID	2-Year Discharge	5-Year Discharge	10-Year Discharge	25-Year Discharge	50-Year Discharge	100-Year Discharge
OCE5	158	234	280	351	396	665
OCE10	1052	1879	2304	2965	3393	5076
OCECB	2009	3596	4329	5542	6228	8637
OCE13	122	156	171	204	211	322
OCE21	121	175	213	266	303	528
OCW2	748	1188	1472	1520	1854	3252
OCW4	214	316	380	435	502	867
OCW9	95	131	158	195	221	384
OCW10	260	402	483	601	679	1111
OCW11	241	397	492	653	752	1265
OCW12	81	114	140	182	210	376
OCW13	148	233	295	384	453	819
OCW14	359	604	738	999	1124	1770
OCW15	144	202	237	286	317	524
OCW18	196	321	403	550	636	1088
OCW21	139	213	267	338	399	725
OCW29	133	205	258	330	390	708
JS3	88	132	170	230	278	531
JS10	335	574	739	901	1099	1997

2.15.10 Pumps

When the system is closed during a tropical event, pumps will be required to discharge internal floodwaters. Preliminary requirements for pump discharges were estimated to offset any interior flooding due to the lack of outfalls during system closure. Currently, 11 new pump stations are proposed for the proposed new levee segments. The largest pumps will be located on Cow and Adams Bayous. Locations of pumps are shown on drainage area map plates in the engineering appendix. Many will require detention basins, routing features, and acquisition of land. These areas have been preliminarily identified and there is adequate space to construct these pump features.

For the proposed new levee sections, two existing pumps are currently in operation. An existing pump station exists along Coopers Gully, draining the majority of the City of Orange south of Interstate 10. An additional pump exists south of the Port of Beaumont and is operated and maintained by Exxon.

The Orange County pump has sufficient capacity to drain the watershed currently connected to it, and should only require minor modifications (1994 City of Orange Report). No increase in flows to the Orange pump will be created by the proposed project as the drainage area and runoff will not be altered by the proposed project. The pump is in need of maintenance and some part replacements; this is being addressed by the City of Orange. Some additional pump capacity (5-10 percent) may be needed for expected increases in precipitation (for climate change as discussed in Section 4 of this appendix).

The Exxon pump was constructed by Exxon after Hurricane Ike in 2008. The pump is known to be deficient and has failed multiple times since its construction due to rainfall runoff volumes exceeding the capacity of the pump. If the levee system proposed to protect the Exxon area remains as part of the selected plan, it will need to be replaced. The Exxon pump built after 2008 has not been tested during a hurricane and it is likely it will fail, as it was designed for a "Category 1" hurricane, as stated by Exxon.

2.15.11 Gate Structures

The proposed levee system would include two major gates structures with necessary appurtenances. The gates structures would be on Cow Bayou and Adams Bayou, which are both used for small ship navigation. The channel dimensions are 100 feet by 14 feet MLLW for Cow Bayou and 100 feet by 13 feet MLLW for Adams Bayou.

Preliminary gate configurations were determined and modeled in simple HEC-RAS models to determine and minimize impacts on the upstream floodplains. These models should be expanded upon and follow the guidance from HEC in the latest HEC-RAS manual. Regression equations were used to estimate flows. It is recommended that HEC-HMS models be constructed during PED. This was not possible during the feasibility phase due to the large and complex watersheds discharging into the Bayou

The Cow Bayou closure gate system would include a sector gate in the main channel and vertical lift gates on either side for rainfall runoff to pass through. The Adams Bayou gate structure would include a sector gate in the main channel and a vertical lift gate on the west sides of the channel. On the east side of the proposed Adams Bayou gate location, are two old placement areas that will be used as part of the levee system. Therefore, no vertical lift gate or other relief structure is proposed on the east side of the Adams Bayou gate. Both gates will require substantial pump stations to discharge interior runoff during a system closure. Orange County is currently working on these models and it is recommended that USACE team up with the county on the modeling efforts if possible. It is conceivable that Orange will have completed their HEC-HMS and HEC-RAS models of the Bayou by the time USACE enters the PED phase. If so, the models from Orange County should be utilized and modified as needed to meet USACE regulations and standards.

2.16 FLOODPLAIN IMPACT ANALYSIS

The preliminary design was performed in method to minimize impacts on all existing floodplains. Outfalls for interior drainage were sized to pass the 100-year storm plus a 10 percent increase in flow for climate change. The culvert outfalls were aligned and sized in a manner that mimics the existing waterways. Culvert spans and heights were chosen to provide widths that would prevent head build-up on the upstream side of the culverts, which could cause adverse impacts. This is because of the flat topography in the project area. The Cow and Adams Bayou gate structures were configured to allow a 100-year flood event to be discharged without impacting their respective floodplains.

For most of the waterways, only basic hydrologic and hydraulic models were created for outfalls. As the levee was refined, many outfalls were eliminated. Use of HEC-HMS and HEC-RAS (or similar acceptable H&H models) is recommended to model the final outfalls. Quantitative impacts for Neches River floodplain and a Qualitative assessment for Sabine River indicate minimal or insignificant impacts. The vast majority of the existing and proposed levee system is outside the banks of the rivers and is not in the 100-year floodplains. The Neches River passes between levee systems and the Sabine River passes along the east side of levee. Levees were

kept out of the floodplains of the rivers as much as possible, minimizing impacts and with the intention of not disturbing the natural courses of the rivers.

The selected alignment, outfall location/type/size, and materials used were selected to minimize impacts on tidal areas, some of which are quite sensitive along the south portion of the Orange levee and adjacent Bessie Heights. No proposed levees infringe on Bessie Heights. This is further discussed in the H&H section on environmental considerations.

2.17 ENVIRONMENTAL IMPACTS OF PROPOSED DRAINAGE SYSTEM

Modifications to the existing systems and the construction of new levee systems have the potential to cause adverse environmental impacts. This section details studies done to assess possible impacts and discussions and decisions made to minimize impacts of drainage structures on environmental aspects of the levee systems.

New drainage components were evaluated for possible impacts on the existing environment in Orange and Jefferson Counties, and to the extent possible efforts were made to minimize any adverse impacts. ERDC-CHL conducted a study to determine possible impacts due to the closure gate structures that would be needed on Cow and Adams Bayou gate as part of the levee. Outfalls consisting of box culverts and concrete pipe culverts were sized and placed in a manner minimizing impacts on the environment. Overall, a least impact configuration was established through coordination and meetings with the EPA, NMS, USFW, TXDOT, TWDB, and TPWD.

The details discussed herein support the environmental assessment of the project as established during the study feasibility phase. The exact configuration and additional details regarding the proposed drainage structures design shall be refined as needed in PED. Continuous coordination with all involved environmental agencies shall occur through PED and construction. It is worth noting that the initial levee footprint shown to the environmental agencies has significantly decreased and so have the environmental impacts.

2.17.1 Gate Structures on Cow and Adams Bayous

ERDC-CHL conducted a study to qualitatively and quantitatively assess possible environmental impacts of the proposed sector gates on Cow and Adams Bayous (Gunkel and Brown, March 2015). The implementation of the gate structures on the bayous has the potential to constrict the inlets to both bayous (near the bayous confluence with the Sabine River). The constriction on the bayou inlets created by the proposed gates could impact velocities, salinity, and cause storm water impoundment. ERDC-CHL utilized a Desktop Off-Channel Wetland Salinity Mitigation Model (DOWSMM) to perform an analysis to quantitatively assess the impacts of the proposed gates. DOWSMM is a mass and energy balance model that assumes each bayou can be

represented as a single control volume. This model was used in lieu of more sophisticated numerical models for several reasons. These include:

- The paucity of available data for the Bayous (especially velocity and discharge data) makes calibration and validation of a numerical model impossible without a significant data collection effort.
- The Bayous being evaluated fit the description of systems for which DOWSMM is designed (i.e. small, single inlet tidal systems with a single inflow and rainfall/evaporation).
- The DOWSMM analysis, in the absence of sufficient field data for calibration, is designed as a screening analysis only: i.e., bracketing potential impacts. The intent is to use the results of this analysis to determine whether or not a more significant investment in more detailed numerical modeling is necessary.

Figure 2-45 shows the Cow and Adams Bayous areas of interest. The blue lines indicate major and minor streams and the yellow line indicates the proposed structure alignment.

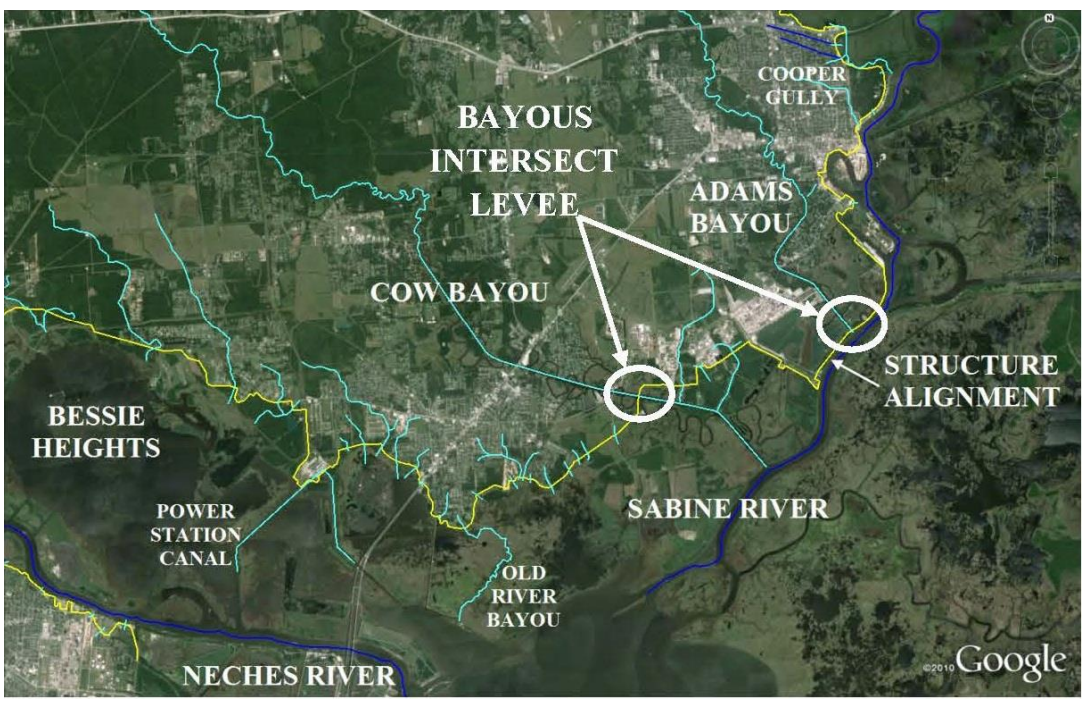

Figure 2-45: Cow and Adams Bayou Intersection with Gate Structures

DOWSMM requires time-varying boundary conditions. These include tide and salinity at the inlet, rainfall/evaporation over the wetland (or bayou) and freshwater inflow into the wetland (or bayou). For this study, these data were taken from a TABS-MDS model study performed in

support of a larger feasibility study associated with proposed channel deepening in the Sabine Neches Estuary (Brown, et. al. 2006).

For this DOWSMM exercise, data associated with an observation point in close proximity to the intersection of the Sabine River and Adams and Cow Bayous were chosen for the tide and salinity boundary condition data. The data point is identified as Gage 9 (the location of Gage 9 is depicted in Figure 2-46). This gage was used to obtain low and median flow tide and salinity boundary conditions. Applied net rainfall data (rainfall minus evaporation) for low and median flow simulations were used to calculate discharge. This discharge was calculated by multiplying net rainfall rate by the surface area of the drainage area of each bayou.

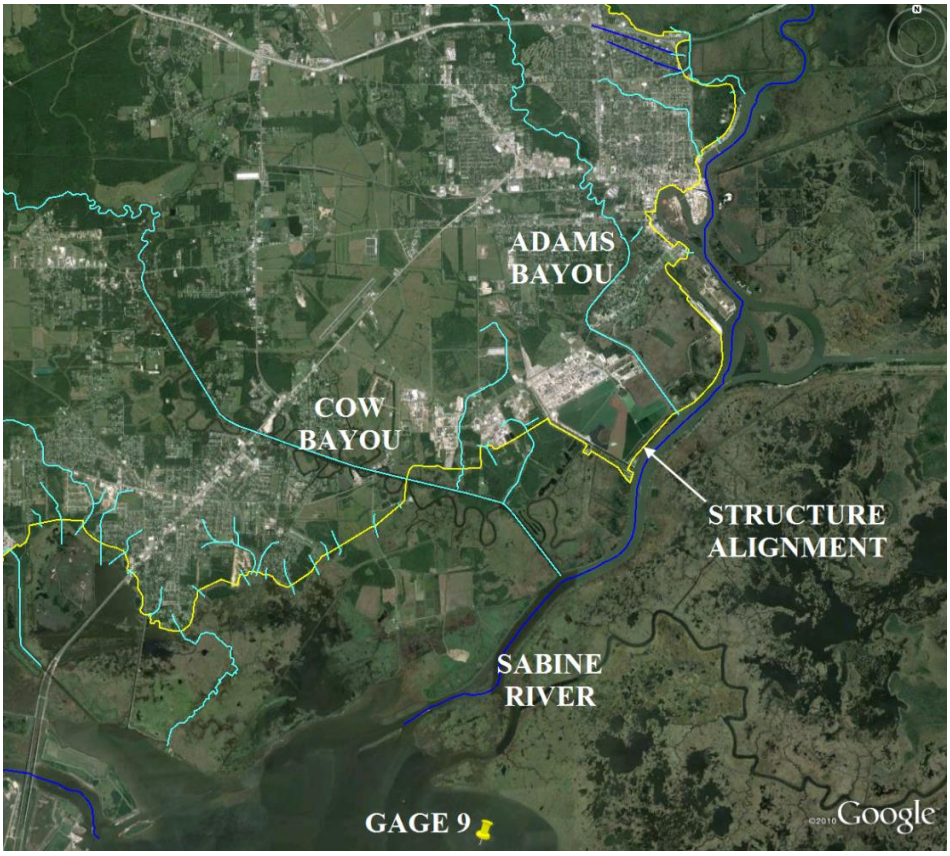

Figure 2-46: Gage 9 Location

2.17.2 Cow Bayou Analysis

The intersection of Cow Bayou and the proposed structure is approximately 2.5 miles north of the mouth where Cow Bayou meets Sabine River. Figures 2-45 and 2-46 show the location of the proposed gated structure on Cow Bayou. A series of varying inlet widths were tested, including 120 feet, 110 feet, 100 feet, 80 feet, and 50 feet widths. Table 2-20 contains all base parameters used for the Cow Bayou model runs.

Table 2-20: Cow Bayou DOWSMM Model Parameters

Parameter	Base
Wetland surface area (ft^2)	21000000
Wetland width (ft)	100
Wetted surface area factor (0=wet,1=dry)	0.75
Roughness height for the wetland	0.1
Width of the inlet (ft)	100
Elevation of the bed in the inlet (ft)	-11
Elevation of the top of the sill in the inlet (ft)	-11
Elevation of the bed in the wetland (ft)	-2.0
Gravitation constant (ft/s^2)	32.2

Low flow conditions inlet widths of 120 feet, 110 feet, 100 feet, 80 feet, and 50 feet were tested and results for 120 feet and 50 feet are provided here. Tables 2-21 and 2-22 show resulting statistics from the low flow runs. The minimum and maximum columns are the minimum and maximum values, respectively, of the respective parameters. The remaining 90, 50, and 10 percent columns represent percent exceedance values; meaning that 90 percent of the values for that parameter exceed the value.

Table 2-21: Cow Bayou Base Parameters: Low Flow, 120-foot Inlet Width

Parameter	Minimum	90 % exceedance	50 % exceedance	10 % exceedance	Maximum
Inlet Water Surface Elevation	-0.310	0.420	1.180	1.730	2.760
Inlet Salinity	5.040	8.050	16.420	20.170	22.260
Wetland Freshwater Inflow	0.000	0.000	0.000	134.758	1395.312
Inlet Discharge Magnitude	0.000	91.904	465.462	919.008	1552.101
Inlet Velocity Magnitude	0.000	0.062	0.321	0.632	1.150
Wetland Water Surface Elevation	-0.288	0.420	1.171	1.735	2.760
Wetland Salinity	0.479	5.232	13.915	19.207	20.565

Table 2-22: Cow Bayou Base Parameters: Low Flow, 50-foot Inlet Width

Parameter	Minimum	90 % exceedance	50 % exceedance	10 % exceedance	Maximum
Inlet Water Surface Elevation	-0.310	0.420	1.180	1.730	2.760
Inlet Salinity	5.040	8.050	16.420	20.170	22.260
Wetland Freshwater Inflow	0.000	0.000	0.000	134.758	1395.312
Inlet Discharge Magnitude	0.000	93.268	466.529	914.058	1547.946
Inlet Velocity Magnitude	0.000	0.152	0.775	1.507	2.759
Wetland Water Surface Elevation	-0.286	0.420	1.172	1.735	2.760
Wetland Salinity	0.486	5.221	13.910	19.207	20.562

Under low-flow conditions, the velocity at the inlet increases roughly in proportion to the degree of contraction of the inlet. This is because the energy loss across the inlet is negligible, and hence the discharge though the inlet is nearly the same for the 120 feet and 50 feet inlet width conditions. No significant impacts were seen for the salinity or water surface elevations. When comparing the results from the maximum inlet width tested of 120 feet to the minimum inlet width tested of 50 feet, the only differences seen in the water surface elevation or salinity are on the order of 0.001, and the differences in salinity are on the order of 0.05 ppt.

For median flow the same inlet widths were tested, and results for 120 feet and 50 feet are provided here. Tables 2-23 and 2-24 show resulting statistics from the median flow runs with the different inlet widths.

Table 2-23: Cow Bayou Base Parameters: Median Flow, 120-foot Inlet Width

Parameter	Minimum	90 % exceedance	50 % exceedance	10 % exceedance	Maximum
Inlet Water Surface Elevation	-0.930	0.530	1.320	1.960	3.050
Inlet Salinity	-0.130	0.160	2.370	11.360	17.010
Wetland Freshwater Inflow	0.000	0.000	0.000	195.938	5425.234
Inlet Discharge Magnitude	0.000	93.419	461.537	934.180	5759.486
Inlet Velocity Magnitude	0.000	0.063	0.314	0.637	3.837
Wetland Water Surface Elevation	-0.868	0.520	1.319	1.964	3.178
Wetland Salinity (ppt)	0.000	0.235	1.297	10.140	14.153

Table 2-24: Cow Bayou Base Parameters: Median Flow, 50-foot Inlet Wwidth

Parameter	Minimum	90 % exceedance	50 % exceedance	10 % exceedance	Maximum
Inlet Water Surface Elevation	-0.930	0.530	1.320	1.960	3.050
Inlet Salinity	-0.130	0.160	2.370	11.360	17.010
Wetland Freshwater Inflow	0.000	0.000	0.000	195.938	5425.234
Inlet Discharge Magnitude	0.000	95.524	459.812	926.542	5757.070
Inlet Velocity Magnitude	0.000	0.152	0.755	1.518	9.204
Wetland Water Surface Elevation	-0.866	0.522	1.318	1.966	3.298
Wetland Salinity (ppt)	0.000	0.235	1.295	10.144	14.144

According to these results, for a large rainfall event (the event tested is the observed rainfall associated with Tropical Storm Allison) only about a 0.10-foot impact was seen on the water surface elevation. Inlet constricts the outflow such that there is some increase in both the magnitude and duration of the stormwater flooding in the marsh. To mitigate this effect, any significant constriction of the inlet will include design elements (such as flap gates, vertical lift gates, equalizer culverts, or gated culverts) to allow stormwater release from behind the structure and allow outflow of water avoiding adverse impacts upstream of the gate structure.

2.17.3 Adams Bayou Analysis

The proposed structure on Adams Bayou is very near the inlet to the Sabine River. The same set of flows and salinity data collected from Gage 9 that were used for Cow Bayou were also used for Adams Bayou. Figure 2-43 shows the location of the structure alignment in relation to Adams Bayou and the Sabine River.

Base parameters for Adams Bayou were chosen from the HEC-RAS model provided by Carroll & Blackman, Inc. (CBI) for the width of the inlet, depth, and length of the section. These parameters were modified to some extent by information from Google Earth (2015). Figure 10 shows the wetland surface area that was approximated by using Google Earth (2015); the remaining parameters were estimated. A series of varying inlet widths were tested, the results from the maximum width of 350 feet and minimum width of 100 feet are shown here. Table 2-25 contains all base parameters used in the runs.

Table 2-25: Adams Bayou DOWSMM Model Parameters

Parameter	BASE
Wetland surface area (ft^2)	50000000
Wetland width (ft)	350
Wetted surface area factor (0=wet,1=dry)	0.75
Roughness height for the wetland	1.0
Width of the inlet (ft)	350
Elevation of the bed in the inlet (ft)	-5
Elevation of the top of the sill in the inlet (ft)	-5
Elevation of the bed in the wetland (ft)	-2.0
Gravitation constant (ft/s^2)	32.2

Low flow conditions modeling was performed as described previously in 6.2.2. Tables 2-26 and 2-27 contain the statistical results from the low flow runs for Adams Bayou.

Table 2-26: Adams Bayou Base Parameters: Low flow, 350-foot Inlet Width

Parameter	Minimum	90 % exceedance	50 % exceedance	10 % exceedance	Maximum
Inlet Water Surface Elevation (ft)	-0.310	0.420	1.180	1.730	2.760
Inlet Salinity (ppt)	5.040	8.050	16.420	20.170	22.260
Wetland Freshwater Inflow (cfs)	0.000	0.000	0.000	45.158	467.578
Inlet Discharge Magnitude (cfs)	0.000	235.329	1075.041	1910.239	2871.270
Inlet Velocity Magnitude (ft/sec)	0.000	0.111	0.509	0.896	1.239
Wetland Water Surface Elevation (ft)	-0.204	0.417	1.154	1.723	2.759
Wetland Salinity (ppt)	5.080	7.139	15.270	19.415	20.553

Table 2-27: Adams Bayou Base Parameters: Low Flow, 100-foot Inlet Width

Parameter	Minimum	90 % exceedance	50 % exceedance	10 % exceedance	Maximum
Inlet Water Surface Elevation (ft)	-0.310	0.420	1.180	1.730	2.760
Inlet Salinity (ppt)	5.040	8.050	16.420	20.170	22.260
Wetland Freshwater Inflow (cfs)	0.000	0.000	0.000	45.158	467.578
Inlet Discharge Magnitude (cfs)	0.000	261.733	1069.031	1771.663	2580.447
Inlet Velocity Magnitude (ft/sec)	0.000	0.407	1.754	2.944	3.857
Wetland Water Surface Elevation (ft)	-0.167	0.439	1.150	1.713	2.754
Wetland Salinity (ppt)	5.080	7.150	15.128	19.433	20.501

As with Cow Bayou, the velocity at the inlet increases roughly in proportion to the degree of contraction of the inlet. This is because the energy loss across the inlet is minimal, and hence the

discharge though the inlet is nearly the same for the 350 ft and 100 ft inlet width conditions. Similar to Cow Bayou, no significant impacts are seen in the water surface elevation or salinity. Median flow conditions were also modeled as described previously. Tables 2-28 and 2-29 contain the statistical results for the median flow runs for Adams Bayou.

Table 2-28: Adams Bayou Base Parameters: Median Flow, 350-foot Inlet Width

Parameter	Minimum	90 % exceedance	50 % exceedance	10 % exceedance	Maximum
Inlet Water Surface Elevation (ft)	-0.930	0.530	1.320	1.960	3.050
Inlet Salinity (ppt)	-0.130	0.160	2.370	11.360	17.010
Wetland Freshwater Inflow (cfs)	0.000	0.000	0.000	56.109	1553.590
Inlet Discharge Magnitude (cfs)	0.000	248.127	1064.117	1929.731	3507.700
Inlet Velocity Magnitude (ft/sec)	0.000	0.113	0.491	0.888	1.489
Wetland Water Surface Elevation (ft)	-0.751	0.532	1.305	1.952	3.058
Wetland Salinity (ppt)	0.067	0.337	1.767	10.387	14.075

Table 2-29: Adams Bayou Base Parameters: Median flow, 100-foot Inlet Width

Parameter	Minimum	90 % exceedance	50 % exceedance	10 % exceedance	Maximum
Inlet Water Surface Elevation (ft)	-0.930	0.530	1.320	1.960	3.050
Inlet Salinity (ppt)	-0.130	0.160	2.370	11.360	17.010
Wetland Freshwater Inflow (cfs)	0.000	0.000	0.000	56.109	1553.590
Inlet Discharge Magnitude (cfs)	0.000	265.851	1050.655	1813.801	3329.004
Inlet Velocity Magnitude (ft/sec)	0.000	0.412	1.693	2.900	5.021
Wetland Water Surface Elevation (ft)	-0.729	0.549	1.298	1.946	3.072
Wetland Salinity (ppt)	0.071	0.348	1.744	10.353	13.972

As with Cow Bayou, an increase in the water surface elevation associated with the storm event is observed. The effect of the constriction is qualitatively similar to that observed at Cow Bayou, but is less in magnitude. This is because Adams Bayou has more wetland surface area, and hence the impounded stormwater can spread over a larger area (the same storage volume requires less depth). The structure will designed with relief structures including vertical lift gate structures to allow additional flow to pass and mitigate any impacts on the upstream floodplain.

2.17.4 Neches River Gate

A closure gate on the Neches River near Sabine Lake was considered as an alternative during the screening process. The gate was eliminated from inclusion in the proposed plan based on benefit/cost considerations. Therefore, no detailed modeling was done to assess environmental impacts a gate on the Neches River would have. If the gate is later determined to be a Locally Preferred Alternative, an analysis of environmental impacts will need to be performed.

2.17.5 Discussion and Conclusions of Cow and Adams Proposed Gate Structures

It is likely that minimal potential impacts would be created by increased velocities in the inlets on larval transport into the bayous. This can be inferred from higher order model work that was performed at ERDC to investigate similar impacts for the Keith Lake Fish Pass Baffle (Brown and Lackey, 2011). In this work, it was demonstrated that the larval transport is not impeded by increases in velocity due to a constriction, but is impeded by the formation of large eddies associated with flow around blunt obstructions. Therefore, if the constrictions are designed with smooth transitions from wide to narrow, it is unlikely that the increased velocities alone will be a significant hindrance to larval recruitment.

Impacts imparted to the regular, tidal variation of water surface elevation and salinity within Adams and Cow Bayous from the proposed inlet constrictions were found to be negligible. This negligibility was determined by the sensitivity analysis conducted on the inlet size for each bayou. It was determined that the limited tidal prism associated with the bayous results in minimal energy loss across the connection between the bayous and the Sabine River; hence, constriction of this access point results in little change in the tidal energy passing into the bayou. The median flow simulation contains a significant rainfall event (Tropical Storm Allison), so the extent to which these constrictions tend to impound stormwater within the bayous is also examined. For both Cow Bayou and Adams Bayou, the inlet constriction causes some increase in both the magnitude and duration of the stormwater flooding in the marsh. This flooding will be mitigated by inclusion of design elements (flap gates, vertical lift gates, or gated culverts) that allow stormwater release from behind the structure.

Additional sensitivity analyses were conducted to investigate the impact of changes on each of the estimated parameters that define the bayous. The values were independently perturbed by 25-50 percent, and the results compared to the results given in this report for the “base” parameters. In no case were significant impacts observed.

Hence, in spite of the paucity of data available to properly define and calibrate/validate these desktop models of Adams and Cow Bayous, the insensitivity of the tidally varying water surface

elevation and the salinity impacts on a wide range of estimated parameters give high confidence that the general conclusions of the ERDC study are robust. They are as follows:

- For general tidal conditions, the limited tidal prism associated with each of these bayous results in little energy loss across the inlet and hence, constriction of the inlet, even significant constriction, results in minimal impacts on water surface elevation and salinity within the bayous.
- For large freshwater inflow events, a significant constriction at Cow and Adams Bayous could result in additional impoundment of stormwater behind the structure. To mitigate for this additional stormwater drainage features will be utilized in the design.

2.17.6 Culverts and additional Interior Drainage Structures

Additional structures were preliminarily assessed to allow rainfall runoff from the interior of the proposed levee system to discharge rainfall runoff from the interior of the levees. Culverts and pump structures were placed along the proposed levee alignments and preliminary design parameters for these structures were determined. Existing outfalls and pumps were identified and data gathered on them where available. It is recommended more data be gathered in the field during PED. Locations and sizes of proposed culverts and pumps are discussed in Section 5 of this appendix. This section is focused on the environmental aspects of the proposed drainage system. The interior drainage structures were strategically placed to:

- Maintain existing drainage and minimize or eliminate any adverse impacts on floodplains
- Provide interior drainage via pump systems to evacuate floodwaters during a tropical event that would be associated with a system closure
- Maintain connectivity of environmental areas such as marshes and wetlands
- Minimize constriction of waterways by drainage structures and maintain cross sectional areas as best practicable
- Minimize environmental impact by utilizing and configuring the proposed drainage structures in a manner that aims to mimic existing without-project conditions

This section discusses how possible environmental impacts associated with the proposed interior drainage systems were considered and how possible impacts were addressed using BMPs and principles.

To provide interior drainage of the proposed levee system, minimize impacts on areas that are tidally influenced, and maintain connectivity between environmentally linked areas, a

preliminary plan was developed for the culverts and pumps that would be necessitated by the construction of the proposed levee. Bayous, creeks, gullys, and all waterways that cross the levee systems were identified. All watersheds that the levee systems intersect or impact were identified. Detailed drainage area maps are included in the Exhibits section of this appendix. These maps include locations of all proposed outfall and pump stations. Drainage areas were delineated using a combination of LiDAR, USGS maps, aerial maps, historical photos, survey data, construction plans and specifications, agency input from meetings and discussions with TPWD/USFWS/NMFS/USEPA/TXDOT/TWDB, and historical reports and documents.

Culvert locations were identified using all the information obtained from data gathering, state and agency input, and the interior drainage analysis performed (Section 5 of the H&H section of engineering appendix). Several distinct types of culverts were distinguished with regards to their required functionality draining the interior of the levee system, surrounding environments, upstream watershed characteristics, and characteristics of the land downstream of the outfall. The culverts were broken into four subgroups.

1. Culverts at high elevation, typically surrounded by dry land that would have minimal if any environmental impact.
2. Culverts that serve as drainage outfalls in lowlands and/or environmentally sensitive areas.
3. Culverts that are tidally influenced in low-lying coastal areas, including those that would need to allow tidal flow to pass through.
4. Culverts that serve as equalizer culverts were identified in discussions with state and agency representatives and by reviewing aerial maps. These culverts are not required to drain the interior. The purpose of these culverts is to maintain connectivity between environmentally sensitive area such as marshlands or wetlands, and would rarely, if ever, serve as a pathway for interior drainage.

Culverts have been strategically placed and sized to best mimic the natural waterways and environment as much as practicable. All culverts placed for interior drainage are of a multiple structure configuration (i.e., have numerous openings) with widths and locations intended to mimic the natural waterways. This includes utilizing culverts with more width than height in an attempt to maintain cross sectional areas and natural channel cross sections. This approach serves multiple purposes, including minimizing impacts on culverts located in tidal passes. Additionally, having larger span culverts will reduce the backwater (upstream head) that would occur during storm runoff events. The study area is in general very flat and high water surface

elevation on the interior of the culvert is undesirable, as it could produce adverse impacts on the upstream floodplain.

Culverts will include will include shoreline baffles and/or ramps (e.g., rock rubble, riprap, articulated concrete mats) that slope to the structure invert to enhance organism passage where appropriate. Various ramp designs will be considered depending on site specific conditions. Culverts have been sized and preliminarily designed to produce velocities of 3 ft/s for a 2-year storm event to prevent siltation and prevent debris build-up, as is standard practice. Culverts will use sluice gates and flap gates to close openings during storm events. At all other times, the culverts should remain fully opened, with the exception of short duration closures for maintenance and inspections. The specific details and design of these riparian access features and culvert flow-lines will be refined during PED.

Drainage pathways, including sheet flow, over flow, and shallow concentrated flow, shall remain the same inside of the levee. The flows will be collected by toe drains at the base of the levee and directed to the outfall. Detailed design of these drains will occur during PED; it is anticipated the toe drains will vary on a case by case basis in term of material, slope, size, and configuration. Once the water is discharged through the multiple dispersed culverts crossing to the exterior of the levee, the relatively flat culverts will allow for the water to disperse rapidly and follow its natural course.

During conversations and meetings between environmental agencies and USACE, several areas were identified to place ‘equalizer’ culverts to maintain environmental connectivity and decrease environmental impacts and decrease mitigation needs. Most of these culverts will be 24 to 36-inch pipes, but three will be box culverts, including a sizable multiple box culvert equalizer culvert connecting the east side of the marsh near the Adams Bayou/Sabine River confluence.

Low lying tidally influenced culverts are sized to maintain tidal prisms/cross sectional areas, and minimize changes in velocities to the extent practicable. These culverts are to be designed to best match velocities correlating to flood and ebb tides. The current practice is to limit the maximum velocity of tidal velocities to 2.6 ft/s (preferably less, in the range of 0.5 ft/s to 0.82 ft/s) to minimize impacts on larval fish (NMFS 2008).

NMFS Fisheries 'Friendly Design and Operation Considerations for Hurricane and Flood Protection Water Control Structures' (NMFS 2008) was utilized for additional guidance on drainage structure placement and design considerations. This document was used to help identify design and operational guiding principles that would optimize passage of estuarine dependent marine fisheries species, or at least, minimize adverse impacts on their passage

through hurricane and flood protection water control structures. The number of drainage structures and distances between structures closely match without-project conditions, and shall be further optimized to minimize migratory distances from the openings to enclosed wetland habitats during PED.

An operational plan will be completed in conjunction with the PED phase of the project. The plan will include the direction that culverts and gates will remain fully open at all times except during surge events, for short duration operational testing, and maintenance checks and inspections. The operational plan will also include direction on timing of closing and opening of culverts and gates as a storm approaches and passes. The operational plan shall include procedures to allow timely opening of culvert and gate structures in the absence of an off-site power source.

2.17.7 Pumps

Proposed pump stations will be designed and located to have minimal environmental impact. Preliminary selected locations for pump stations are included on the drainage area maps in the exhibits of this section of the engineering appendix. Pumps will not be used under normal conditions, only during storm events to evacuate water from the interior of the levee. One exception is the existing pump station used by the City of Orange. This pump station drains the majority of the City of Orange south of Interstate 10 via storm sewer, open ditches, and diversions. It is active during normal conditions for drainage of rainfall runoff and will remain so. This station will remain active during storm events when the levee system is closed, as it will need to continue to evacuate interior rainfall runoff.

Some areas will be disturbed or altered on the interior of the levee to place the proposed pump stations with associated features. The footprint and impacts will be optimized, reassessed, and detailed during the PED phase of the project. These features could include detention/retention ponds, toe drains along the levee to direct flow to the pumping stations, and other typical pump station ancillary features. The pumps shall be designed to avoid impacts on wetlands as much as possible. Smaller features such as riprap and stepped structures along the toe drains and other features for wildlife will be included as appropriate and detailed during PED.

For the existing Freeport and Port Arthur systems it is not anticipated that any new culverts, pumps, or other drainage changes besides some minor modifications and possibly some replacements/removal of older drainage structures may be needed. Existing pump stations currently have adequate capacity and will be studied in further detail during PED. More information and design calculations will be needed during PED to further assess existing pump stations.

2.17.8 Drainage Environmental Impacts Summary and Conclusions

The proposed levee system will require numerous drainage structures, including culverts, pumps, and two large closure gate structures. Best Management Practices were used extensively to minimize environmental impacts caused by the proposed levee system. Culverts were sized and placed in configurations that attempt to mimic the natural without-project characteristics to the extent practicable. This included using multiple structures at each drainage outfall for the proposed levee system. Additional reinforced concrete pipes were strategically placed to maintain connectivity of environmental area, with substantial coordination with the USEPA, USFW, TPWD, TXDOT, TBWD, and NMFS. These 'connectivity' culverts are not needed for discharging rainfall runoff from the interior of the proposed levees; their purpose is solely to minimize the environmental impacts of the proposed levee.

Closure gate structures will be required on Cow and Adams Bayou to prevent surge from entering the proposed levee interior. A variety of gate configurations were modeled by ERDC using DOWSMM to determine possible impacts on velocities, tidal prisms, and stormwater impoundment due to the gate structures. The study found that for general tidal conditions, the limited tidal prism associated with each of these bayous results in little energy loss across the inlet, and that even significant constriction results in minimal impacts on water surface elevation and salinity within the bayous. For large freshwater inflow events, a significant constriction at Cow and Adams Bayous could result in additional impoundment of stormwater behind the structure. To offset stormwater impoundment, additional drainage features will be constructed adjacent to the main gate structures (Gunkel and Brown 2015).

The drainage components of the levee system were optimized to minimize environmental impacts. Further refinement and optimization will occur during the PED phase of the project, and changes shall be documented and provided to the environmental agencies to review and submit recommendations.

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3 SURVEYING, MAPPING, AND OTHER GEOSPATIAL DATA REQUIREMENTS

FEMA LiDAR data from 2010 was used in the H&H storm surge modeling. This data was also imported into Bentley InRoads to create ground surfaces along the proposed new HFPP alignments that were used to determine the relative levee and floodwall heights and to calculate associated fill quantities for the levee construction. The voluminous data for the entire region was isolated to the project areas and thinned out to be within the program's capability of processing it. Elevations from the LiDAR surveys were compared to elevations physically taken at the ground surface of each core boring using Real Time Kinematic (RTK) system equipment. It was found that the LiDAR elevations near the core boring locations compared favorably with the core boring elevations, with differences typically being between 0.10 and 0.60 foot.

Other surveying, mapping, and geospatial information/tools came from the following resources:

- Satellite imagery and data published by Google Earth Pro
- Satellite imagery published by ESRI
- FEMA Flood Insurance Rate Maps
- Published tide and water level data from NOAA stations
- Oil and gas pipeline GIS database maintained by the Texas Railroad Commission (TRRC)

4 GEOTECHNICAL

4.1 SUMMARY

The objective of this document is to provide a detailed background of the geotechnical work performed throughout the preliminary design of a proposed Hurricane and Storm Damage Risk Reduction (HSDRR) system. The system will include levee embankment, floodwall and other features. This feasibility document focuses on foundation conditions and levee embankments, floodwall details are covered in Structural Appendix.

4.2 INTRODUCTION

This geotechnical documentation captures the concept design for construction of a new HSDRR system that would protect parts of Orange County and Jefferson County in the state of Texas.

The proposed system is a Hurricane and Storm Damage Risk Reduction system. The segments proposed are divided in three major areas (Orange, Beaumont and Jefferson) as shown and described in Figure 4-1 and Table 4-1 below. This document presents and describes the criteria, assumptions, procedures and results of the geotechnical procedures for the design of levees.

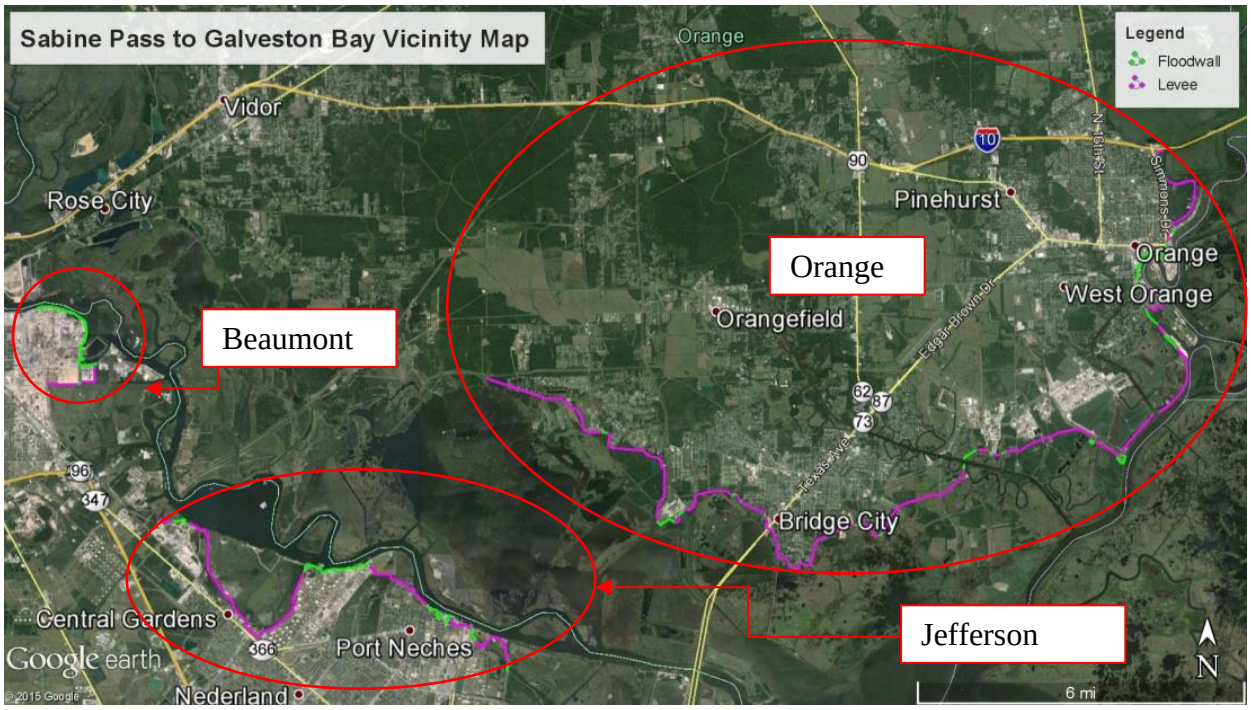


Figure 4-1: Sabine Pass to Galveston Bay Vicinity Map

Table 4-1: Approximate Lengths of Proposed Features per Area

Reach	Total Length (ft)	Length Of Features (ft)	
		Levee	Floodwall
Orange 3	143,400	113,571	29,829
Beaumont A	18,782	5,992	12,790
Jefferson Main	52,179	37,568	14,611

4.3 DESIGN CRITERIA

4.3.1 Selection of Design Criteria

Per Table B-1 of ER 1110-2-1806 [6], the proposed HSDRR system would be classified as a high hazard structure. Therefore, design efforts were required to conform with the most stringent applicable requirements. Several Engineering Manuals (EM) and other types of guidance published by USACE apply to the proposed structures. Main design criteria includes, but is not limited to:

- Hurricane and Storm Damage Risk Reduction System Design Guidelines, June 2012[7]
- EM 1110-2-1913, Design & Construction of Levees, April 2000[2]

Additional criteria applied are listed in Paragraph 4.4.

4.3.1 Historical Documentation and Input Data

Preliminary design included a search for historic, relevant, and useful documentation. Little to no relevant documentation was found for the proposed HSDRR system except for the "Flood Protection Planning Study Hurricane Flood Protection System Orange County, Texas", December 2012 which was prepared for Orange County and The Texas Water Development Board. No geotechnical investigations were performed for such study. Therefore, feasibility level design relies heavily on the geotechnical investigation performed in 2015.

4.3.2 Reference Documents

4.3.2.1 USACE Engineer Manuals

[1] EM 1110-2-1901 Seepage Analysis and Control for Dams, 30 April 1993

[2] EM 1110-2-1902 Slope Stability, 31 October 2003

[3] EM 1110-2-1913 Design & Construction of Levees, April 2000

4.3.2.2 USACE Engineer Technical Letters

[4] ETL 110-2-569 Design Guidance for Levee Underseepage, May 2005

4.3.2.3 USACE Engineering Regulations

[5] ER 1110-2-1150 Engineering and Design for Civil Works Projects, August 1999

[6] ER 1110-2-1806 Earthquake Design and Evaluation for Civil Works Projects, July 1995.

4.3.2.4 Other USACE Engineering Guidelines

[7] Hurricane and Storm Damage Risk Reduction System Design Guidelines – INTERIM, June 2012.

4.3.2.5 Drawings and Reports

[8] Flood Protection Planning Study Hurricane Flood Protection System, Orange County, Texas, December 2012.

4.3.3 Surficial Geology

Jefferson and Orange Counties are in three major land resource areas (MLRAs). About 50 percent of the area lies within the Gulf Coast Prairies MLRA. About 35 percent of the area is in the Gulf Coast Marsh MLRA. About 15 percent of the area lies within the Western Gulf Coast Flatwoods MLRA mostly in the northern part of Orange County. The Gulf Coast Prairie MLRA has mostly dark colored loamy and clayey soils that formed under prairie vegetation. The Gulf Coast Marsh is comprised of sandy, clayey, or loamy soils that are submerged for part of the time with saline or fresh water. The Western Gulf Coast Flatwoods MLRA has mostly light colored loamy and silty soils that formed under pine forest vegetation. The major land uses in the Gulf Coast Prairies include farming and ranching. The major land use for the Gulf Coast Marsh is wildlife. The major land use for the Western Gulf Coast Flatwoods is woodland.

4.3.4 Software

SEEP/W & SLOPE/W Version 8.12.3.7901

4.4 GEOTECHNICAL ANALYSIS

4.4.1 Foundation Conditions

Geotechnical investigations were performed in 2015 to document the general foundation conditions for the proposed features. Investigation consisted of 25 core borings and 46 cone penetration tests (CPT). General overview of the core boring plan and CPT plan are shown in

Figure 4-2 and 4-3, respectively. Investigation addressed portions of the system that have since been removed based on the risk assessment analysis performed at this stage. Draft results of these efforts were used in the performance of shear plots and subsequently in the demarcation of design reaches. The geotechnical investigation data and shear strength plots are not included with the appendix at this time, but can be made available upon request.

Figure 4-2: Core Boring Plan

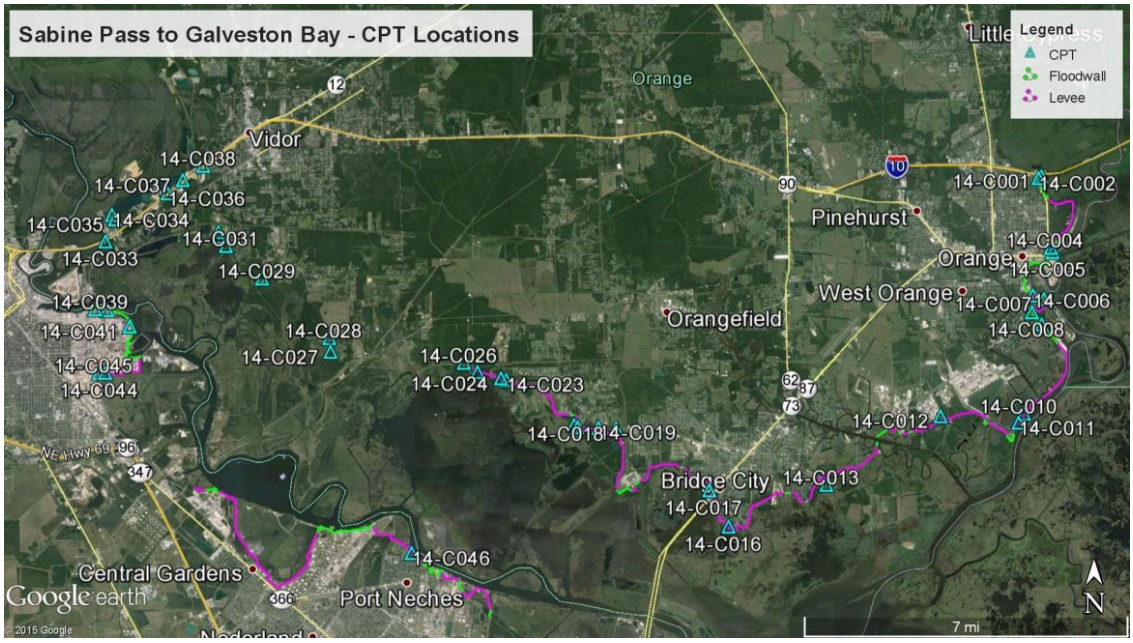


Figure 4-3: CPT Plan

4.4.2 Analysis Cross Section Selection and Soil Parameters

In order to come up with a representative design that would cover essential features of the project, controlling project feature geometry and soil configuration were identified along with representative sections. Three cross-sections were selected based on the shear strength developed with the information collected in the geotechnical investigations performed for the project throughout its alignment. Core boring and CPT were grouped based on proximity and their similarities of strata classification, configuration, and mechanical properties. Three cross-sections were used for the development of typical sections based on the performed analysis. Those cross sections are:

4.4.2.1 Orange Reach

Orange reach was developed within Orange 3 and shear strength plot IV, and is composed of Core Borings 14-B005, 14-B006 and 14-B007 along with CPT 14-C008, 14-C009, 14-C010 and 14-C011. The resulting plot exhibits the weakest soil configuration observed and was therefore identified as potentially producing unique features independent from other areas where the sub-surface conditions are better. Shear strength plot IV and its location can be seen in Figure 4-4, detailed plot is not included with this appendix, but can be obtained upon request.

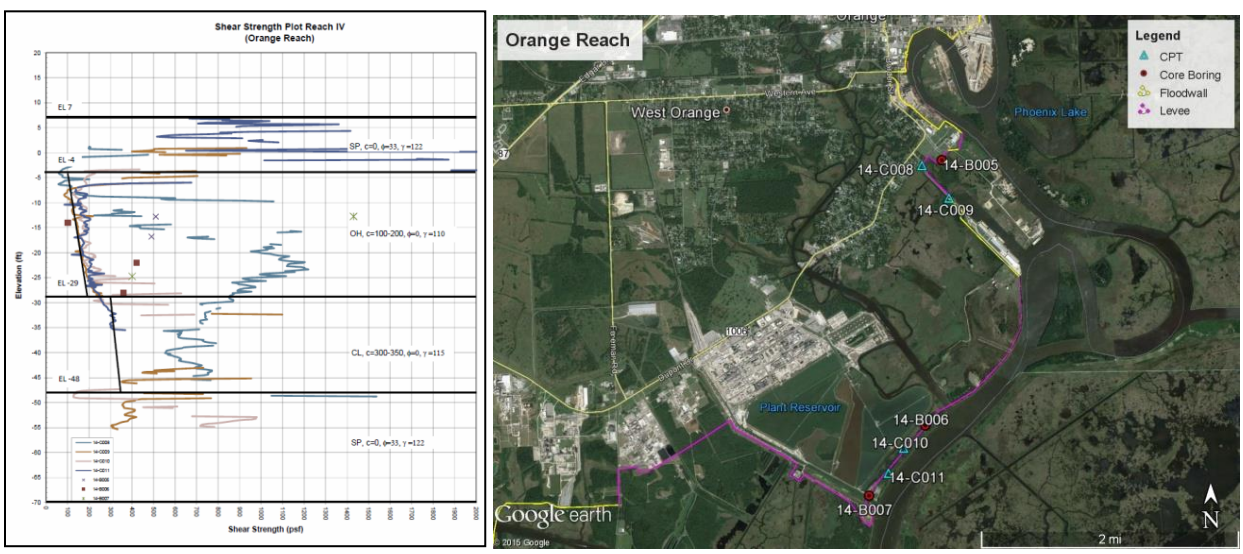


Figure 4-4: Orange Reach Represented by Shear Strength Plot IV (left) and its Location (right)

4.4.2.2 East Bridge City Reach

East Bridge City reach was developed within Orange 3 and shear strength plot V, and is comprised of borings 14-B008 and 14-B009 along with CPT 14-C012. The resulting plot exhibits stronger material strengths than the controlling section (Orange Reach) and was

therefore identified for the development of a typical section where the soils were not as weak as other reaches. Shear strength plot V and its location can be seen in Figure 4-5, detailed plot is not included with this appendix, but can be obtained upon request.

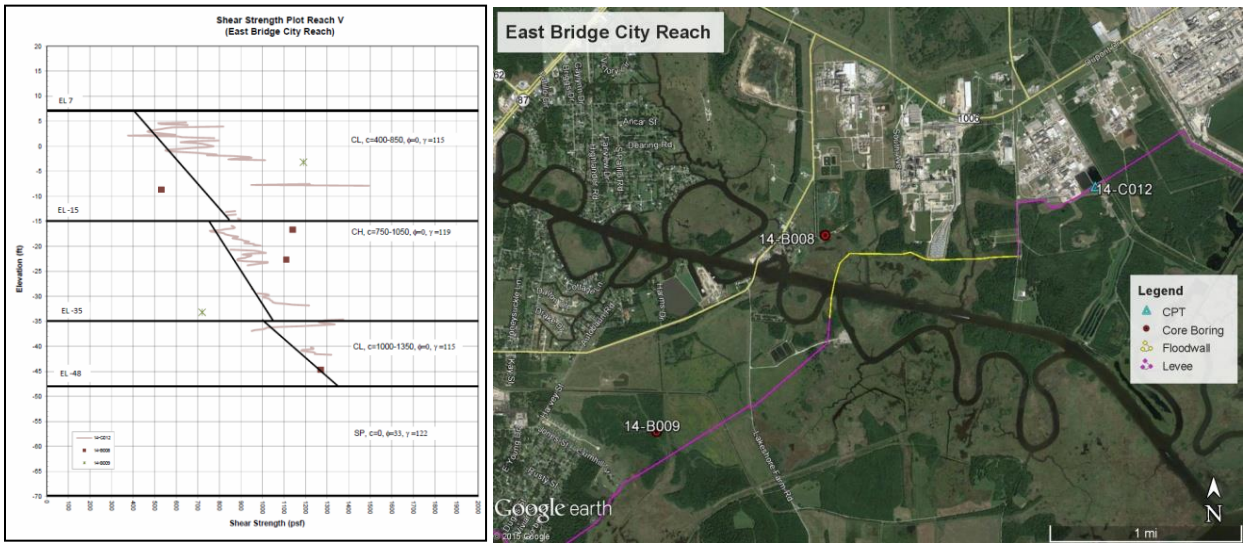


Figure 4-5: East Bridge City Reach Represented by Shear Strength Plot V (left) and its Location (right)

4.4.2.3 Jefferson Reach

Jefferson reach was identified within Jefferson Main and shear strength plot XIII, comprised of core boring 14-C025 and CPT 14-C046. Shear strength plot XIII and its location can be seen in Figure 4-6, detailed plot is not included with this appendix, but can be obtained upon request.

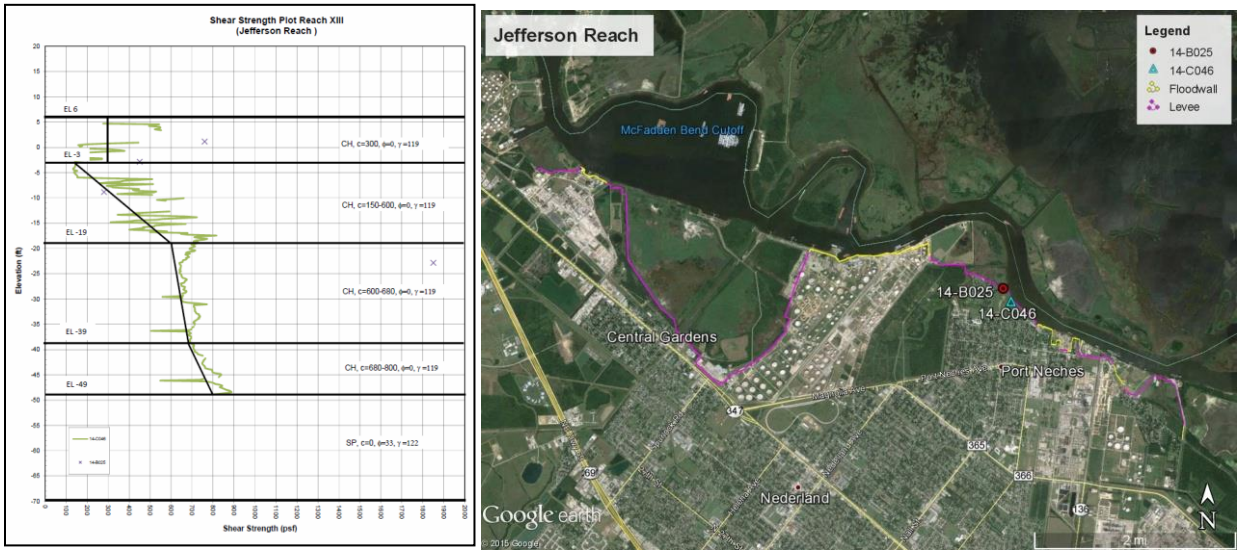


Figure 4-6: Jefferson Reach Represented by Shear Strength Plot XIII (left) and its Location (right)

4.4.3 Geotechnical Design Assumptions

Assumptions made throughout the performance of this study are:

- Steady-state conditions for all seepage analysis
- Proposed material on levee embankment is compacted impervious fill
- No seismic accelerations were considered, see Section 4.5.3 of this document

4.4.4 Material Properties

4.4.4.1 Saturated Unit Weights

- Water 62.4 pcf
- Impervious Embankment Fill 115.0 pcf
- Silt (ML) 117.0 pcf
- Fat Clay (CH) 119.0 pcf
- Lean Clay (CL) 115.0 pcf
- Organic Clay (OH) 110.0 pcf
- Sands (SP & SM) 122.0 pcf

4.4.4.2 Design Loads

The following load conditions were considered in all stability analyses unless stated otherwise.

4.4.4.3 Dead Load (D)

Dead load (D) includes the weight of superimposed water and embankment backfill. The unit weight of materials is listed in Paragraph 4.4.1.

4.4.4.4 Hydraulic Load (H)

Hydraulic load (H) includes hydrostatic pressure (Ps) and uplift pressure (U). These loads are developed from the hydraulic head produced from the design pool level listed in Table 4-2 for each load combination. Water elevations in Table 4-2 were developed with a 100-year return period at a 90 percent confidence as per HSDRR guideline and were used for all the design calculations described in this document.

Table 4-2: Hydrostatic Conditions

Case Condition	Hydraulic Condition per Reach and Loading Case (ft)		
	Orange	East Bridge City	Jefferson
End of Construction	-	-	-
Still Water Level (SWL)	12.70	14.96	14.67
Project Grade (WPG)	16.00	19.00	19.00

Water conditions described in Table 4-3 below is based on the results of the risk assessment analysis performed at this stage which identified 12 feet as the elevation that returned the most benefits. These elevations were only used in the recommendations section of this document (Paragraph 4.5).

Table 4-3: Hydrostatic Conditions Produced by Risk Assessment

Case Condition	Hydraulic Condition per Reach and Loading Case (ft)		
	Orange	East Bridge City	Jefferson
End of Construction	-	-	-
Still Water Level (SWL)	12	12	12
Project Grade (WPG)	16	16	16

Hydrostatic Pressure (Ps):

The hydrostatic pressure (Ps) is taken into account as a force acting perpendicular to the surface retaining water as in the following equation:

$$P_s = \gamma_w h$$

where: γ_w = unit weight of water
h = depth of water at calculation point

4.4.4.5 Earthquake Loads (EQ)

According to current USACE criteria, the project area is classified as a Zone 0 on Figure C-1 of ER 1110-2-1806, Earthquake Design and Evaluation for Civil Works Projects. [6] No earthquake loads need to be considered at a Zone 0 site. No seismic loads were taken into consideration as part of the preliminary design of levee embankment.

4.4.5 Seepage Analysis

Background, from EM 1110-2-1901, 30 Sep 86[1], Chapter 4-9 Paragraph B:

"The escape or exit gradient, i_e, is the rate of dissipation of head per unit of length in the area where seepage is exiting the porous media. For confined flow, the area of concern is usually along the uppermost flow line near the flow exit, e.g., at the downstream edge of a concrete or other impermeable structure. Escape gradients for flow through embankments may also be studied by choosing squares from the area of interest in the flow net (usually at or near the exit face and downstream toe) and calculating gradients. If the gradient is too great where seepage is exiting, soil particles may be removed from this area. This phenomenon, called flotation, can cause piping (the removal of soil particles by moving water) which can lead to undermining and loss of the structure. The gradient at which flotation of particles begins is termed the critical gradient, i_{cr}. Critical gradient is determined by the in-place unit weight of the soil and is the gradient at which upward drag forces on the soil particles equal the submerged weight of the soil particles."

For all seepage analysis performed for Sabine to Galveston exit gradients were obtained with the SEEP/W module of SLOPE/W, where modeling results values are displayed by selecting the area of interest. Exit gradient outputs were then used as input variables in the equation below. The quantitative values shown represent the factor of safety calculation for East Bridge City Reach for water to project grade (WPG).

$$\mathrm{FS}_{\mathrm{piping}} = \frac{i_{cr}}{i_e} = \frac{\gamma'/\gamma_w}{(dh/dl)} = \frac{(115-62.4)/62.4}{0.42} = \frac{0.842}{0.42} = 2.0$$

where:

dh, is head loss between each equipotential line.

dl, is the dimension of a flow net square or distance between equipotential lines.

Exit gradients were evaluated at, but not limited to, key feature locations such as land side slopes of the embankment and throughout all proposed stability berms slopes. The following table summarizes the seepage analyses results:

Table 4-4: Seepage Analysis Results

Reach	Exit Gradient		Factor Of Safety (*Required)	
	WPG	SWL	WPG (1.3*)	SWL (1.6*)
Orange	0.07	0.11	13.2	8.3
East Bridge City	0.42	0.33	2.0	2.5
Jefferson	0.37	0.32	2.4	2.8

4.4.6 Slope Stability Analysis

4.4.6.1 Slope Stability Design Criteria

The following factors of safety were considered in the stability analysis, using the Spencer method, according to Table 3.1 of the HSDRRSDG [7], based on criteria established by EM 1110-2-1902 Slope Stability [2]:

End of Construction	1.3
Design Hurricane (SWL)	1.5
Water at Project Grade (WPG)	1.4

4.4.6.2 Results of Stability Analysis

During preliminary design efforts geometric design of levee template was based on guidelines for stability and maintenance on EM 1110-2-1913 [3]. Maintaining a minimum of a 10-foot crown with slopes no steeper than 1H:3V. This geometry was then used with all the determined reaches (Paragraph 4.2). Modifications were made based on findings through the performed stability and seepage analysis. Such modifications are the inclusion of stability berms made of the same material as the proposed levees. The reaches that required stability berms in order to meet criteria are Orange Reach, 68 feet wide and the Jefferson Reach 42 feet wide. The results of the stability analyses are summarized in Table 4-5.

Table 4-5: Stability Analysis Results

Reach	Factors of Safety					
	Required			Computed		
	EoC	SWL	WPG	EoC	SWL	WPG
Orange	1.3	1.5	1.4	1.8	1.5	1.4
E. Bridge City				2.1	2.0	2.0
Jefferson				1.5	1.5	1.5

4.4.7 Settlement Analysis and Results

Settlement analysis was performed with preliminary data on several locations throughout the proposed alignment, results averaged in 4 feet of settlement. Overbuild of the same amount was considered on all design analysis.

4.5 RECOMMENDATIONS

Based on the geotechnical investigations and analysis performed at this feasibility stage, 10-foot crown along the 3H:1V slopes (Figure 4-7) were found to be adequate for the majority of the

project where a levee is being proposed. However an area was identified as having weaker foundation configuration, for such area a stability berm is recommended. The suggested berm should span 3.2 miles of the project area, shown in Figure 4-8. Geometry details on such berm can be seen in Figure 4-9.

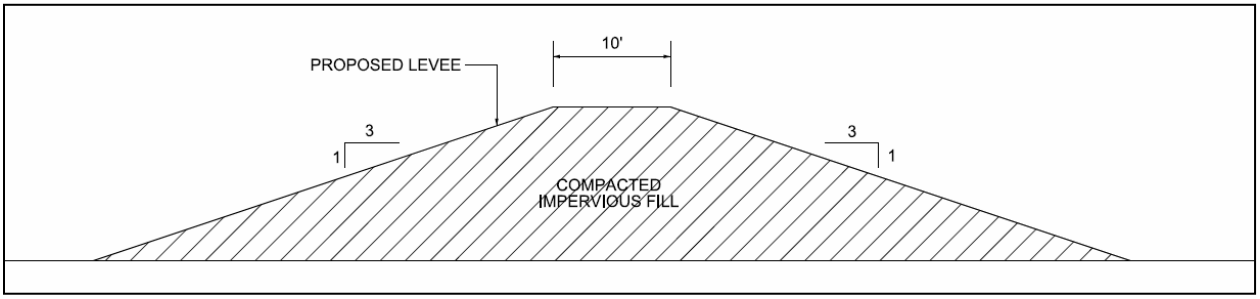


Figure 4-7: Typical Levee Section

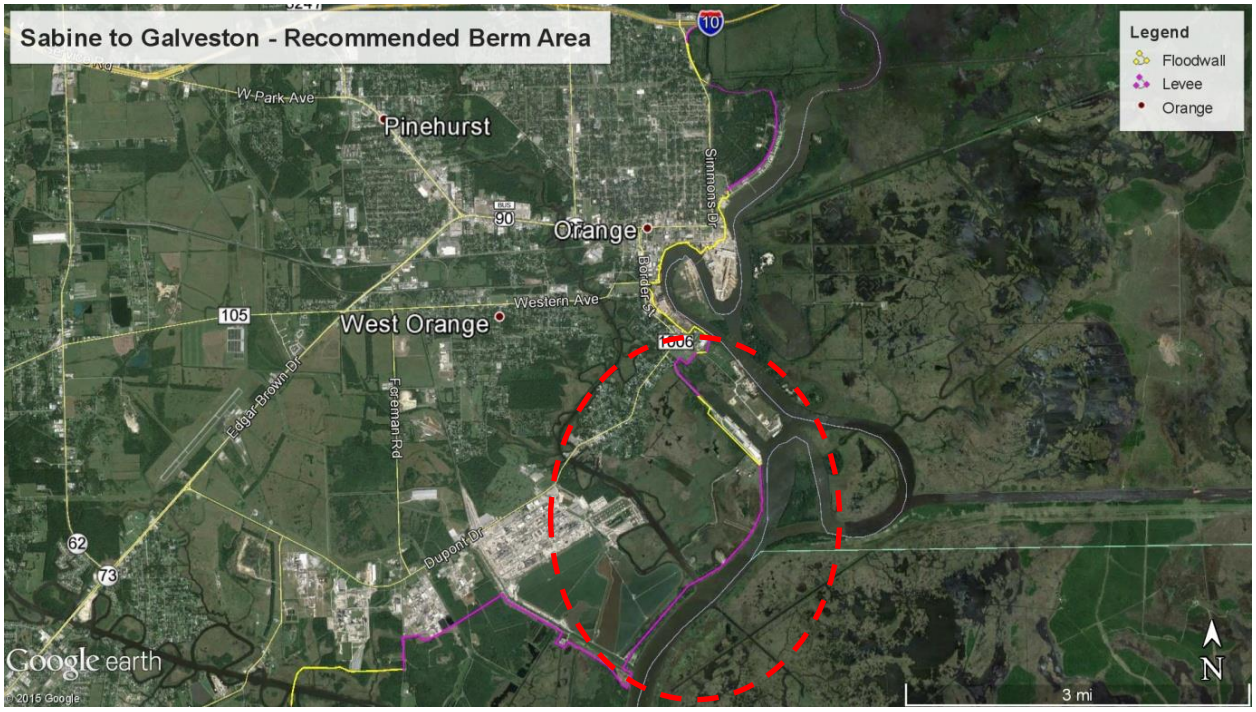


Figure 4-8: Recommended Berm Area in Orange 3, South City of Orange, TX

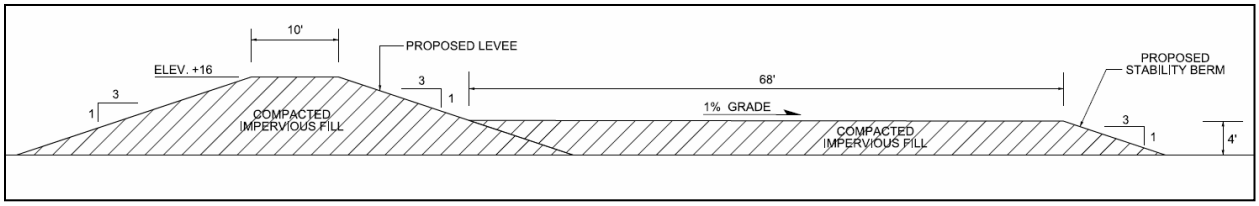


Figure 4-9: Typical Orange 3 Stability Berm Section

5 ENVIRONMENTAL IMPACTS AND ENGINEERING

5.1 USE OF ENVIRONMENTALLY RENEWABLE MATERIALS

Construction of the projects involves earthwork to build and raise levee embankments, and to excavate the ground for the floodwall footings; the placement of reinforced concrete for the floodwalls; installation of sheet pile cutoff walls; the building of gate structure and pump station housing; installation of steel gates; riprap placement; installation of resiliency elements; and pump installations. Soil excavated incidental to the levee and floodwall construction that is satisfactory for use as structural fill material will be used for this purpose. Beyond that, the fill material will be imported from local commercial sources. Stripped topsoil will be conserved and used to plate the levee embankment. Although there is little opportunity to incorporate renewable materials into the project due to the nature of its construction, much of the project will or can be built using materials that are reusable or recyclable, such as concrete, steel, and material made of polymers (e.g., high-performance turf reinforcement mattress (HPTRM), fiber-reinforced polymer (FRP) sheet piling, and high-density plastic drain pipe).

5.2 DESIGN OF POSITIVE ENVIRONMENTAL ATTRIBUTES INTO THE PROJECT

Incorporating positive environmental attributes into the project feature designs was a primary consideration in deciding the proposed alignments for the HFPPs in Orange and Jefferson Counties. These alignments were laid out, and the types of structures (i.e., levee or floodwall) tentatively decided taking into account the direct impacts the construction easements would have on existing forests and wetlands and indirect impacts the systems, as configured, would have on affected floodplains. Consequently, positive environmental attributes are largely built into the project designs by way of deliberately circumventing habitat areas and reducing the project footprints, which avoids adverse environmental impacts altogether or otherwise minimizes them (ER 1110-2-1150, Paragraph 13.6.8).

For the proposed HFPPs and existing Freeport and Port Arthur HFPPs to be modified, resiliency features are to be built in to withstand erosion forces from wave run-up and overtopping. To a considerable extent, these resiliency features will be constructed using high performance turf reinforcement mats wherever deemed acceptable, which is a more environmentally friendly, cost-effective alternative to hard armor systems. The levee slopes will be vegetated with native grass. Additionally, drainage structures will be strategically located and appropriately sized to maintain freshwater flow balances within affected habitats.

Because much of the HFPP construction will be in areas that are already developed, and avoids environmental habitats, there is little opportunity to design environmental attributes into the recommended plans that would enhance the existing project areas. Given the limited opportunities, the principal focus of the engineering effort related to designing-in environmental attributes was to avoid impacting critical habitats in the first place.

5.3 INCLUSION OF ENVIRONMENTALLY BENEFICIAL OPERATIONS AND MANAGEMENT FOR THE PROJECT

There is little opportunity or means of operating and managing the projects in such a way that will benefit the environment. The grassed levees will have to be regularly mowed and the floodwalls and gate structures routinely maintained. Occasional maintenance and repairs of the roadway on the levee crown will also be required. Other than that, the levees and floodwalls will remain in a passive state. Operationally, the functionality of the affected floodplains will not be compromised. Openings at closure points will be kept open and drainage structures allowed to flow freely when the system is not activated.

5.4 BENEFICIAL USES OF SPOIL OR OTHER PROJECT REFUSE DURING CONSTRUCTION AND OPERATION

While it is assumed that all fill material necessary to build the levees comprising the proposed Orange and Jefferson County HFPPs will be brought in from local commercial sources, it is anticipated that much of the material from required excavations can be used for some purpose in the construction. No material from the construction is expected to be reused for beneficial purposes. Spoil probably will be disposed of in placement areas that, as of yet, have not been identified. The plan for the disposal of this material however will avoid or minimize additional adverse impacts to the maximum extent practicable. The projects should not generate much refuse during their operation, but refuse and debris will collect at the gated drainage structures, mostly during flooding events. This debris will be removed and conventionally disposed of in approved landfills.

5.5 ENERGY SAVINGS FEATURES OF THE DESIGN

Other than the pump stations and navigation gate facilities, there are no features available where energy savings can be realized due to the nature of the CSRM projects. The projects are horizontal construction projects that consist of earthen and concrete barrier structures. Nevertheless, opportunities to economize maintenance of the levees and floodwalls will be explored when designing the project features.

5.6 MAINTENANCE OF ECOLOGICAL CONTINUITY WITH THE SURROUNDING AREA AND WITHIN THE REGION

The landscape/horizon of the Orange and Jefferson County project sites will be altered by the new levees and floodwalls. These levees and floodwalls will result in a prominent line of earthen embankment and concrete wall along ground surfaces that are relatively flat. Forest areas within the HFPP corridors will be cleared. Some existing drainage systems will be altered. To the extent practicable however, the project designs preserve existing forest and wetland habitats. Where environmental impact is unavoidable, the designs minimize the project footprints. The levee slopes will be turfed with native grass. Resiliency elements, to the maximum extent possible, will be designed to be "green" to blend in with the natural setting. Over time, the HFPPs will have less of an effect on the ecology of the area as the ecology adapts to the relatively modest changes in the environment.

Terrestrial wildlife would still be able to access habitats divided or cut off by earthen levee segments, as it does now across the Port Arthur HFPP levees. Floodwall segments would generally be located in developed areas and limited in length; wildlife would be able to utilize nearby levee segments for access as needed. Fisheries access would be maintained at FWOP levels. The recommended projects are not expected to impact migratory birds or their habitat within the project areas.

The recommended projects have been determined to be the best at satisfying the purpose and need of the projects to provide increased CSRM in a cost-effective manner with minimized impacts to the environment. They best meet the balance of providing a higher level of protection against coastal storm surge, minimizing environmental impacts, and being compatible with the surrounding environment.

5.7 CONSIDERATION OF INDIRECT ENVIRONMENTAL COSTS AND BENEFITS

Indirect environmental costs and benefits were considered in the preliminary layouts of the proposed HFPPs in Orange and Jefferson Counties. Their impacts on the environment are discussed in the DIFR-EIS. To the extent practicable, the proposed alignments were purposely routed to avoid environmental habitats. Where such avoidance was not possible, the project footprints were maximally reduced in several places by assuming more expensive floodwall segments where levees, which would have had a wider footprint, would have sufficed. Even with the deliberate efforts to avoid impacting forested areas and wetlands, the indirect environmental costs are considerable given the scale of the projects.

Section 7 of the DIFR-EIS describes each project's potential impact on soils, water quality, air quality, aquatic and terrestrial habitats, wildlife, threatened and endangered species, HTRW, and social and cultural resources. Essentially all of the environmental impacts are associated with the proposed Orange and Jefferson County HFPPs. The construction of these systems will negatively affect, indirectly, 2,264 acres of fisheries access to extensive marshes within the lower Cow and Adams Bayous floodplains (under the intermediate sea level rise scenario). In total, approximately 153 acres of forested wetland and 2,412 acres of coastal marsh would be impacted. Mitigation would be necessary to compensate for the consequential loss of these wetlands. Improvements to the existing Port Arthur and Freeport HFPPs are not expected to significantly disrupt the environment. However, potential exists for impacts due to buried hazardous and toxic materials during construction of improvements. The proposed projects do not impact Federally listed threatened or endangered species or their designated critical habitat.

5.8 INTEGRATION OF ENVIRONMENTAL SENSITIVITY

Project features will be designed with environmental sensitivity in mind.

5.9 CONSIDERATION OF ENVIRONMENTAL PROBLEMS ON SIMILAR PROJECTS WITH RESPECT TO THE ENVIRONMENTAL REVIEW GUIDE FOR OPERATIONS (ERGO)

Environmental issues/concerns on similar projects and lessons learned will be considered during the design of the project features to make sure that systems and facilities comply with applicable environmental laws and regulations and will comply with these laws and regulations during operations. Environmental concerns will be appropriately addressed/mitigated for in the project designs. Construction of the projects will not proceed until the Non-Federal Sponsor has provided a clean corridor free of any HTRW contamination.

5.10 INCORPORATION OF ENVIRONMENTAL COMPLIANCE MEASURES

As the projects comprising the TSPs are further developed and designed, environmental compliance measures will be incorporated into the feature designs.

5.11 ENVIRONMENTAL IMPACTS

Potential impacts to terrestrial and aquatic habitat and the need for environmental mitigation associated with the proposed projects were evaluated and coordinated with appropriate resource agencies**.** The initial assumption for the impact analysis and alternatives comparison was that all habitat within the construction easement would be destroyed or otherwise adversely impacted. Construction easements for the proposed HFPPs in Orange and Jefferson Counties were intentionally set to be considerably wide to account for possible modest shifting of the HFPP

alignment and variation of the levee template during PED, as well as to be conservative in the environmental impact estimate. Essentially all the habitat within the assumed construction easements, most of which will also comprise permanent maintenance easements, will either be destroyed or disturbed during construction (where there will be significant clearing, grubbing, stripping, and equipment traffic). The disturbed areas, however, will be planted with native grasses following construction. Forest clearing would be conducted in such a manner as to avoid disturbing nesting bald eagles and migratory birds. Terrestrial wildlife would be able to cross earthen levee segments to access remaining habitat on either side, as it does now across the levees of the Port Arthur HFP. Floodwall segments would generally be located in developed areas and limited in length; wildlife would be able to utilize nearby levee segments for access as needed. Fisheries access would be maintained at FWOP levels.

The impacts of the proposed HFPPs to terrestrial habitats will come from new work construction in building earthen levees and concrete floodwalls having considerable footprints, particularly those of the levee, with the possibility that some levee sections will also include underseepage berms and landside-toe embankment sand drains. In some instances, these impacts will extend linearly several hundred feet, upwards to a few thousand feet, through forested areas. For the most part however, forests and wetlands are being circumvented and existing cleared corridors taken advantage of. Impacts will also come from the associated drainage, closure gate, and navigation gate structures that will have to be built. For the existing HFPPs, the impacts will result from lateral expansion of the levee footprint from the levee raise. The impacts resulting from levee raising will be limited to the immediate area flanking the levee, which is developed.

6 CIVIL DESIGN

This section presents the general civil design considerations that were made for the projects comprising the TSP.

6.1 SITE SELECTION AND PROJECT DEVELOPMENT

The general project areas were identified through the Plan Formulation process, discussed in Appendix B of the DIFR-EIS, where structural measures were developed to reduce the risk of flood damages from coastal storm surges and to provide environmental benefits. These structural measures included the construction of new regional HFPPs in Orange and Jefferson Counties and improvements to, and the reconstruction of existing HFPP elements comprising the existing Port Arthur and Freeport systems. For the Freeport HFPP, the structural measures also included adding a new navigation gate structure near the entrance of the Dow Barge Canal to serve as a flood barrier. After screening the measures, alternative structural plans were formulated for the Sabine, Galveston, and Brazoria Regions comprising the six-county study area. The initial arrays of structural plans for the Sabine and Brazoria Regions are listed in Tables 5-1 and 5-3, respectively, of Appendix B and in Table 1-1 of this appendix. Of these structural plans, Alternatives Nos. S5 (Sabine Inland Barrier CSRM Focus (Neches Gate/Sabine Levees/HFP)) and B2 (Brazoria Coastal Barrier CSRM Focus (revised)) were ultimately carried forward for further detailed analyses and development as the TSPs, where the plans were economically and environmentally optimized. The Neches River gate component of Alternative S5 was ultimately dropped from further consideration due to the very high difference in first cost between it and the construction of additional levees along southwest Orange County and the west bank of the Neches River in Jefferson County that would provide a comparable level of protection. Appendix B discusses the gate structure and the rationale for eliminating it from the alternative.

6.1.1 HFPP Alignments

6.1.1.1 Orange-Jefferson County Alignments

Preliminary alignments for the proposed Orange-Jefferson County HFPP were initially laid out referencing preliminary layouts that a joint group of engineering firms had previously investigated and recommended for Orange County and eastern Jefferson County as a basis. This group conducted a flood-protection planning study for a countywide HFPP in Orange County, which is documented in the Orange County Report. The alignments recommended by the report are called the “Neches Crossing and Sabine River Alignment” and the “Industries Alignment”. These alignments were chosen based on their ability to meet the requirements of providing countywide protection and protection to the major industrial area within Orange County.

Factoring into the decision on the Neches Crossing and Sabine River Alignment were assessments of the valuations of the properties to be protected and potential flood damage losses that would be prevented. In addition, this alignment would protect industrial areas and the majority of the land area within Orange and Jefferson Counties.

The TSP alignments draw on the "Protection System on East & West Bank of Neches River (SR + NR + NRW)" alternative alignments presented in the Orange County Report (see Figure 6-1 on the next page). To a considerable degree therefore, the alignments comprising the TSP generally coincide with the earlier recommended alignments. With these well-defined alignments as a starting point, a parametric approach was used to modify and refine the alignments to what became the TSP alignments. Site assessments were made based on existing information and aerial photos to selectively decide the property and environmental assets that would be worth protecting, and that would be economically viable of protecting. These assessments were augmented by site visits and limited site investigations. When routing the HFPP alignments, consideration was given to the environmental impacts to bottomland hardwood and wetland areas. This consideration significantly dictated the course of the alignment. Other principal considerations were taken into account as well. Considerations were made to avoid cutting through or getting too close to existing buildings and infrastructure, crossing low areas constantly under water, crossing areas with foundation conditions that are likely to be poor, water bodies, and crossing or paralleling too close to major pipeline corridors. All this was being done within the framework of the H&H modeling results in which the potential economic losses from flood damages corresponding to assumed SWEs were evaluated against the costs of providing the respective levels of protection.

After refining the HFPP alignments, the Orange County system was broken down into three (3) separable reaches, rationally based on existing geographical features and the areas that would be protected to maximize the economic benefits. These reaches (each of which was evaluated as an alternative in deriving the TSP) are called "Orange 1," "Orange 2," and "Orange 3." They are described in Table 1-1 and depicted on Plate C-1. The reaches were evaluated as discrete projects independent of the other reaches. They were not amalgamated in any combination of increments and evaluated in that manner. The "Jefferson Main" reach and Beaumont "A", "B", and "C" reaches were also evaluated as distinct alternatives. Each of these reaches is also described in Table 1-1 and shown on Plate C-1 as well. The alternative projects that produced net excess economic benefits became the Orange-Jefferson CSRM component of the TSP.

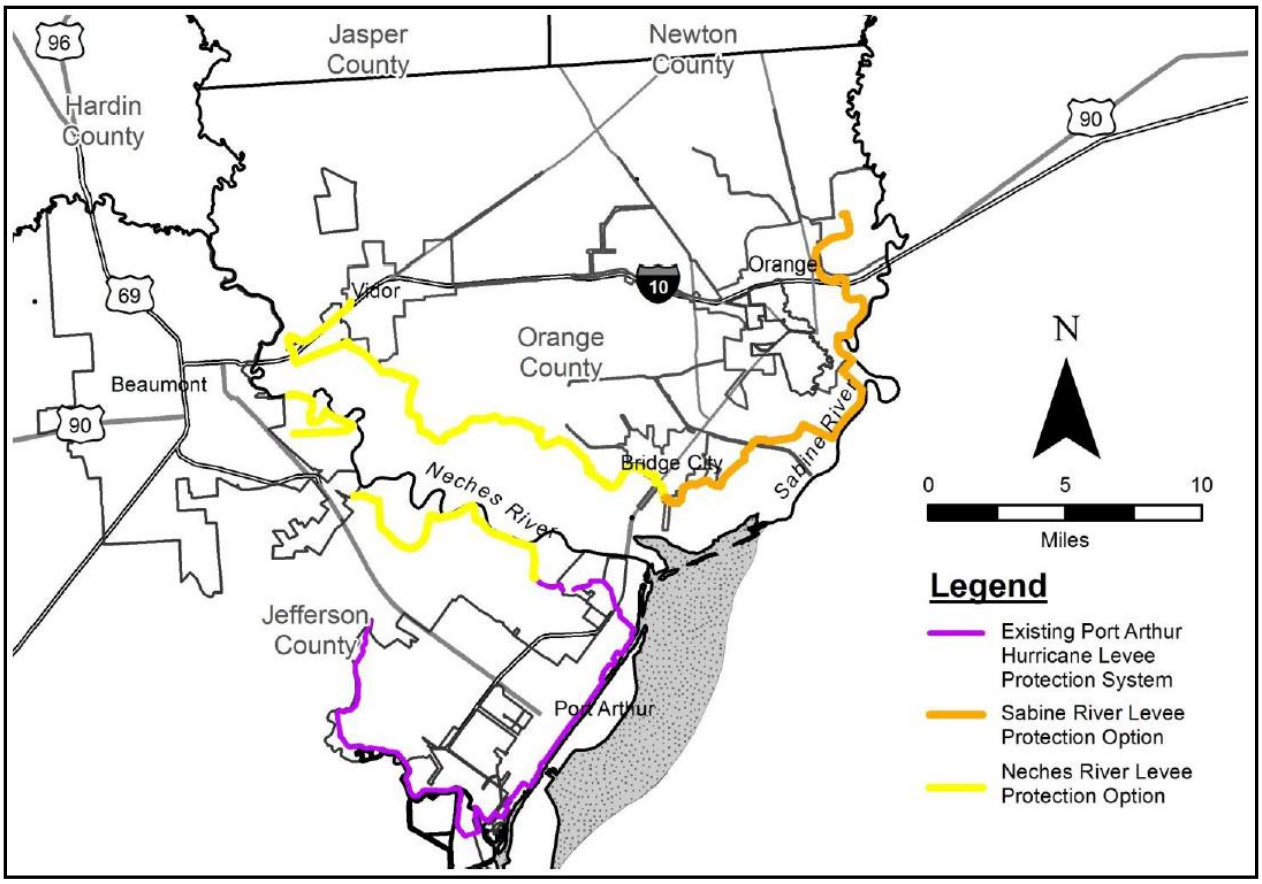


Figure 6-1: Levee Alignment to Provide Full County Protection-Levee on East and West Bank of Neches River (from Orange County Report)

6.1.1.2 Port Arthur HFPP Alignment

The Port Arthur HFPP is an established flood protection system. No realignments are proposed. The proposed HFPP along the south bank of the Neches River, that is to provide a greater level of flood protection to eastern Jefferson County, will tie into the Port Arthur system, which greatly extends the line of protection along the river.

6.1.1.3 Freeport HFPP Alignment

The Freeport HFPP is an established flood protection system. No realignments are proposed. Notably, however, that part of the system flanking the Dow Barge Canal, which is extensive (about 13 miles long), will effectively be rendered obsolete, as it will be cut off by the proposed navigation gate structure (with pump station).

6.1.2 Site Development

6.1.2.1 Orange-Jefferson County HFPP

Much of the areas traversed by the new levee system are highly or moderately developed, represented by industrial, residential, and commercial properties. The intent of a flood protection system is to reduce flood-damage risk to vulnerable populations and valuable assets, while at the same time minimize the environmental impacts; therefore, it is logical that levees and floodwalls would be constructed within and near sizably developed areas. The proposed HFPP alignments were appropriately routed with this in mind. All of the Jefferson Main reach in fact flanks or crosses industrial areas. Within developed areas, only a modest amount of clearing is anticipated. That said, several single-family homes, industrial and commercial buildings, structures, utilities (excluding pipelines), and pavements will have to be removed, relocated, or modified to provide necessary clearances and to construct the project. The number of affected structures was not counted for the TSP cost estimate. The default assumption however was that where a grouped number of structures or utilities would be adversely impacted by the construction of a levee, because of the embankment's large footprint, the more expensive floodwall structure, having a comparatively small footprint, would be built instead where reasonable for accommodation (assuming avoidance was not otherwise practical). This assumption was also made for situations in which there would be considerable impacts on sensitive environmental habitats. Assuming the more expensive floodwall structure option takes into consideration public acceptance and the political ramifications of the project where local public support for it is crucial. As the NED Plans are refined for the ADM, the number of structures and utilities impacted can be better assessed.

The proposed Orange County reach alignment will cut through several forested areas that will require a lot of clearing and grubbing within the entire area of the temporary construction easements. In deriving the TSP cost and NED Plan costs, the acreage of forests within the preliminary construction easements was not estimated. Instead, a uniform amount of clearing, grubbing, and stripping was assumed per lineal foot of levee/floodwall construction and parametric cost estimates applied. The assumption was made that all cleared materials will be hauled to and disposed of at offsite locations.

After clearing and grubbing the area and appropriately addressing structures within the temporary construction easements, the foundation areas within the levee embankment footprint, and 5 feet beyond the toes, will be stripped and generally excavated to a depth of one foot. The subgrade surface will then be proof-rolled and scarified afterwards before receiving fill. For the floodwall footing, the area within its footprint will be stripped and excavated to the required footing depth.

6.1.2.2 Port Arthur and Vicinity HFPP

The improvements proposed for the existing system are to provide scour protection along the backside (i.e., protected side) of three (3) discrete floodwall sections and a closure structure on the Sabine Lake side of the system and modestly raise the levees in these areas. The subject areas are considered soft points in the system vulnerable to possible structural failure (in the technical sense) and being breached from wave overtopping. Scour protection with reinforced-concrete pads is proposed along the 8- to 10-foot I-wall at the very south corner of the system; the I-walls near the Valero Refinery plant and tank farm, both at the south corner; and along the closure structure near the easternmost corner of the system. The levees will be raised by adding a fill lift atop the crown and interior-side slope. The completed improvements will be entirely within the existing perpetual easement. Where needed to accommodate construction activities however, additional temporary work area easements will be acquired. Because the existing system already is a developed project that is routinely maintained, no significant additional site development is anticipated to construct the improvements. The assumed construction operations will involve the stripping of surfaces to receive pavement and fill, modest excavations, removing road pavement (on the levee crown), placing concrete, placing select fill, constructing paved roadway, and turfing. These operations will be conducted in a developed environment.

6.1.2.3 Freeport and Vicinity HFPP

Four (4) of the six (6) improvements proposed for the existing system are modest levee raises of one foot. These raises will be done at potential failure points of the system located along the Old River Levee around the Dow "thumb," at the Tide Gate I-wall, along the East Storm Levee, and along the west bank of Oyster Creek. The Tide Gate I-wall will also have to be reconstructed to raise it a foot higher, as will existing floodwall along the Freeport dock. The TSP for the Freeport CSRM component also includes the construction of a new navigation structure near the entrance of the Dow Barge Canal. The levees will be raised by adding a fill lift atop the interior-side slope. This will be done entirely within existing rights-of-way. Where needed to accommodate construction activities however, temporary work area easements beyond the perpetual easement will be acquired. Except for the proposed navigation gate structure, little additional site development will be necessary to construct the improvements because the project is already a developed project that is maintained.

Construction of the navigation gate structure will require the construction of a cofferdam and provision for allowing the continued passage of barge traffic. Consequently, a considerable amount of logistics coordination and accommodation will go into the construction of this feature. Selecting the site for the structure will require the deliberate assessment of possible locations that would be practical from construction, functional integrity, and operational perspectives given the constraints of available land area and maintaining navigation on the barge canal, and to a lesser

extent, the characteristics of existing foundation soils. Significant site development will be required because the structure will be constructed in the dry. A possible site location will be decided, and the construction scheme for a conceptual gate structure developed, after the ADM. The gate structure will be designed at the time the plans and specifications for this structure are prepared.

6.2 REAL ESTATE

6.2.1 General

For a feasibility study, USACE determines real estate requirements and associated cost based on the selected plan footprint and a gross appraisal. More exact real estate requirements are developed during the design phase following completion of the feasibility study.

According to Federal law, the non-Federal sponsor is responsible, within USACE guidance, to undertake (pay for) the required real estate actions. Real estate actions and acquisition required for project construction will begin prior to award of the individual construction contracts. The proposed Orange-Jefferson County HFPP will require a lot of pipeline and utility relocations, accommodation of existing roadways, and the removal of existing structures. USACE evaluates the compensable (or non-compensable) nature of the various utility relocations in conjunction with the sponsor. It then assigns relocation costs when the utility ownership and real estate rights information is adequate for a compensability determination. Utility relocation design details are developed during the design phase. For the alternative comparison analyses and determining the TSP projects, the associated project costs of pipeline and utility relocations and other infrastructure modifications were not considered.

6.2.2 Orange-Jefferson County HFPP

In developing the preliminary costs for the alternative plans for the separable project elements in Orange and Jefferson Counties, temporary construction easements and perpetual easements of uniform width were assumed for the new levees and floodwalls respectively. For the levees, a conservative 180-foot-wide temporary construction easement and 200-foot-wide perpetual easement were assumed. The temporary construction easement assumes minimum 30-foot-wide work areas along each side of the levee embankment as measured from its projected slope toe. The perpetual easement assumes 40-foot widths along each side of the levee for operations, maintenance, and monitoring. For the floodwalls, which have a smaller footprint than the levees (except for those 1 foot to 8 inches high or less), a uniform 60-foot-wide easement was assumed for both construction and permanent use.

The uniform 200- and 60-foot-wide construction easements assumed for the levee embankment and floodwall construction, respectively, are sufficient to construct the project. For most of the project though, particularly with regard to the levee construction, these widths are at least moderately conservative. That is because the levee and floodwall heights assumed in deriving the TSP easements were not related to the existing ground surface. They were instead referenced to an elevation of 0.0 foot. Taking the varying ground surface elevations into consideration, the final-design structure templates implemented for most of the project will be the same as or smaller than those assumed, even when adding structure height to account for future sea-level rise, wave run-up, freeboard, and foundation settlement and consolidation (overbuilding of the levee embankment). There will be instances too along the alignments where narrower-width work areas are necessary or preferred to minimize impacts on existing infrastructure, facilities, buildings, and environments or because of physical hindrances (e.g., bodies of water, soil conditions, limited construction easement). Conceivably, there could be instances where the easements would need to be made wider, although this is not expected. As the project features are further developed and refined relative to the existing terrain and physical features, the construction easements will be appropriately tailored along the alignment.

For the navigation gate structures proposed to be built across Adams and Cow Bayous, temporary construction easements and perpetual easements will need to be acquired.

It was also assumed that seven (7) temporary staging areas will be needed to construct the Orange 3 reach, three (3) will be needed to construct the Jefferson Main reach, and one staging area will be needed for the Beaumont “A” reach. All the staging areas were assumed to be 2.0 acres in size except for the Beaumont “A” staging area which was assumed at 3.0 acres.

6.2.3 Port Arthur and Vicinity HFPP

Except for possibly the closure structure, most, if not all, of the construction activities to construct the proposed improvements can be performed entirely within the existing rights-of-way. This will ultimately depend however on how high the levees are incrementally raised to accommodate wave run-up, future sea-level rise, and the minimum freeboard requirement. In developing the costs of the alternatives, it was conservatively assumed that 20-foot-wide temporary work area easements would be acquired along the interior-side boundary of the perpetual easement. Five (5) 2.0-acre temporary staging areas were also assumed would be needed for construction.

6.2.4 Freeport and Vicinity HFPP

Except for the navigation gate structure, most, if not all, of the construction activities to construct the proposed improvements can be performed entirely within the existing rights-of-way, depending on how high the levees are incrementally raised to accommodate wave run-up, future sea-level rise, and the minimum freeboard requirement. In developing the costs of the alternatives, it was conservatively assumed that a 20-foot-wide temporary work area easement would be acquired along one side of the existing perpetual easement. Ten (10) 2.0-acre temporary staging areas were also assumed would be needed for construction. For the gate structure with navigable opening, temporary construction easements and a perpetual easement will need to be acquired.

6.3 RELOCATIONS

6.3.1 Pipelines

Due to the prevalence of the petrochemical industry within the study areas, the projects cross or parallel, or will cross or parallel numerous pipelines carrying various petroleum products. The proposed new systems also cross several other utility conduits and storm drains as well. All such conduits are generically referred to in this report as “pipelines”. Plates C-2 through C-6 give the reader an appreciation for the number of pipelines crossed (most of which are multiple pipelines within closely spaced corridors or bundled pipelines).

In most instances, existing pipelines that will cross beneath or through a planned flood protection system, or be close to it, require relocation. This is because most pipelines are buried at a relatively shallow depth when surcharge loading is not anticipated and leaving them in place could cause serious damage to and structural compromise of the levees. The structural integrity of the pipelines can also be adversely affected when putting a large surcharge load over them, as will access to the pipelines. The pipe strength may not be enough to withstand the added loading and pipe joints may be unable to accommodate movements resulting from foundation settlement. The foundation design for the floodwalls may also preclude allowing pipelines to remain in place. As a general rule, pipelines beneath flood protection levees and floodwalls should be avoided altogether, particularly in the case of pressure lines.

When developing the projects to a greater level of design detail/confidence, the necessity for pipeline relocations will be re-evaluated. It may be that some pipelines can be allowed to remain in place within the levee foundation. In assessing this, the following principal items will be considered:

- levee height
- duration of high water stages against the levee
- susceptibility to piping and settlement of levee and foundation soils
- type of pipeline (low- or high-pressure line, or gravity drainage line)
- depth of the pipeline
- feasibility of providing closure in event of ruptured pressure lines, or in the event of failure of flap valves in gravity lines during high water
- ease and frequency of required maintenance and access
- cost of acceptable alternative systems
- possible consequences of piping or failure of the pipe

Since all but a few of the pipelines crossed by the proposed new levee/floodwall systems carry petroleum products and are buried at a relatively shallow depth, and given that their present condition and strength are unknown, the presumption will be that virtually all these pipelines will have to be relocated. Supporting this premise is that significant settlement and consolidation of the compressible foundation from the added levee surcharge load is expected will take place, which undoubtedly will greatly disturb/stress the pipelines embedded within it. The bottom of the concrete footings of the floodwalls will also be set a few feet below the existing grade and in some instances, batter piles may have to be driven for the foundation. Leaving the pipelines in place only increases the risk that either the structures composing the HFPP or the pipeline will eventually be structurally compromised.

6.3.1.1 Pipelines Crossing Orange-Jefferson County HFPPs

Relocations or modifications for the pipelines and utilities crossing the proposed Orange-Jefferson County HFPP alignments or near the alignments, and their associated costs, will be extensive. Essentially all the pipelines, if not all, will require relocation given their shallow burial depths and likely structural inadequacy to handle the greater overburden load, and because they will effectively serve as seepage conduits. Even under short-duration hydrostatic loading, seepage is a concern that needs to be examined. (Current requirement is that a steady-state seepage condition must be assumed for flood-damage reduction structures.)

Information on the pipelines crossing the Orange-Jefferson County alignments was obtained from an oil and gas GIS database maintained by the TRRC. This information included the pipeline's approximate location and orientation by coordinates, system and subsystem names, ownership, operator, diameter, product carried, and permit. However, it did not provide the pipeline depth. Because only a nominal amount of the Orange and Jefferson County project areas is within USACE's regulatory domain, no information on pipeline depths was immediately available that might have been included in as-installed permit records. There was no other

expedient vehicle by which the pipeline depths could be readily assessed. Most oil and gas pipelines though are typically buried at a depth of 3 to 6 feet, as reported by the industry.

6.3.1.2 Pipelines crossing Port Arthur and Vicinity and Freeport and Vicinity HFPPs

While a number of pipelines cross the Port Arthur and Freeport systems, no pipeline and utility relocations or modifications are anticipated as being necessary except for one pipeline at Freeport. Therefore, other than for the one pipeline, no relocations are recommended at this time for the pipelines that cross the Port Arthur and Freeport levee reaches where 1-foot levee raisings are proposed. Modest raising of the levees is not expected to have an appreciable effect on the pipelines. This position could change however as the project is further developed after the ADM. Pipelines crossing both systems where the existing levee heights will remain as they are do not require relocation. These pipelines are not considered as posing a threat to the structural integrity of the levees.

6.3.2 Pipeline Relocation Method

At this point, it is envisioned that all pipelines requiring relocation will be removed by mechanical excavation (i.e., trenching) and then reinstalled at a deeper depth by way of horizontal directional drilling, which is ideally suited for deep burial depths. Directional drilling is a reliable method of relocation and can be done prior to constructing the levee. From a geotechnical perspective, the pipeline needs to be installed deep enough beneath the levee section and any berm sections to avoid stresses from levee and berm subsidence. The required depth and minimum distances the pipeline entry and exit points should be from the levee/floodwall centerline will be investigated after the TSP as the project details are further developed. That said, it is expected that the relocated pipelines will have to be buried at a depth of at least 30 feet below ground at the structure centerline with entry and exit points at least 500 feet away from the centerline.

7 STRUCTURAL REQUIREMENTS

7.1 INTRODUCTION

This section contains the conceptual design and preliminary analysis for the structural components of the proposed Orange-Jefferson CSRM levee system. The Orange 3, Jefferson Main, and Beaumont A Reaches have lengths of floodwall proposed to be included in their alignments.

The current proposed Orange 3 Reach of the Orange-Jefferson CSRM levee alignment crosses two existing navigation channels - Adams Bayou and Cow Bayou. Consequently, the system requires closure at each bayou with a navigation gate structure.

7.2 FLOODWALL

7.2.1 Assumptions

The floodwall will be designed as an inverted T-wall, which is the most appropriate type of floodwall for the project area. The inverted T-wall type also has no height limit and is the recommended type for areas with barge/boat impacts, which are possible with this proposed levee system.

Floodwall in the Orange-Jefferson CSRM levee reaches is being designed to an average top elevation of all portions of floodwall in the Reaches of the alignment. The top elevation includes added height for wave run-up and relative sea level rise, at the predicted intermediate level, on top of the modeled SWLs. For cost estimating purposes, the stem height was varied according to the variations in natural ground elevations, with the base geometry, concrete thicknesses, and pile arrangement remaining the same. Preliminary design parameters for the floodwall are based on hydraulic loadings (surge, wave run-up, etc.) provided by H&H and generalized local soil conditions along the alignment of the levee provided by Geotechnical. From the geotechnical investigations, sand stratums were found in areas the floodwall traversed. The floodwall will utilize a steel sheetpile cutoff (PZ22) for the entire length of floodwall, due to the assumption that a coastal storm event in this area would achieve steady state conditions. The project areas are in a non-seismic zone; therefore, no seismic analysis was done.

For areas of the alignment which require a tie-in between the earthen levee and floodwall, the T-wall will extend into the earthen embankment a distance past the design height of the earthen levee. This extension can be assumed to be 30 to 40 feet, but will depend on heights of the floodwall and adjacent earthen levee.

7.2.2 Structural Analysis

The design process for the floodwall used several EMs and the HSDRRDG. EM 1110-2-2502 was used for most of the floodwall design, except where newer EMs, such as EM 1110-2-2104, provided values that are more conservative.

7.2.2.1 Design Parameters

- Natural ground elevation: EL 5.0'
- K_o: 0.8 (at-rest earth pressure coefficient)
- Cohesion = 0.4 ksf (foundation)
- Φ = 23 degrees, for drained condition
- Unit weight (soil), γ = 110 pcf
- Unit weight (concrete), γ = 150 pcf
- Unit weight (water), γ = 64.0 pcf
- Still-Water Level = EL +11 feet (provided by H&H)
- Wave data for design purposes not provided at this stage of the project
- Concrete: normal weight, f'c = 4ksi
- Reinforcing steel: ASTM A615, fy = 60 ksi

The natural ground elevation was established from LiDAR survey data for the area. The ground elevation used for the design is an average value for all locations of floodwall. The average ground elevation was derived from the available LiDAR survey data by creating a profile along each of the Orange-Jefferson CSRM Reaches and calculating the average ground surface within all locations of floodwall. Geotechnical provided the foundation soil properties information (at-rest earth pressure coefficient, soil cohesion, phi angle, and unit weight) that was obtained through geotechnical investigations. (For more information on these input variables, including how they were derived, see the Geotechnical section of this appendix.) A higher unit weight of water than normally used (62.4 pcf) was assumed for the design due to the higher salinity of the water in this coastal location. The still-water level was provided from modeling performed by H&H.

7.2.2.2 Load Cases and Factors

Load cases for the floodwall design, as shown in Table 7-1, are based on EM 1110-2-2502 along with the HSDRRDG, which provides several additional load cases. The single load factor method, outlined in EM 1110-2-2104, was used to determine the factored moment and shear for the concrete structure. Where guidance overlapped, the more conservative approach was utilized for the design that would satisfy all applicable guidance.

Table 7-1: Floodwall Load Cases

Sabine to Galveston Floodwall Load Cases (Refer to EM 1110-2-2502 Table 4-3 & HSDRRSDG)				
Load Case No.	**C1**	**C4**	**C5**	**C6**
Title	Surge Stillwater	Construction	Wind	Stillwater to Top of Wall
Description	Backfill in place Water to stillwater Level (flood side) Waves excluded Uplift acting	Short Duration Loading Wind Included Construction Equipment Surcharge	Backfill in place Water at usual (non-storm) level Wind on land side	Backfill in place Water to top of wall Level (flood side) Waves excluded Uplift acting
Load Case Classification	Unusual	Unusual	Unusual	Extreme
Flood water Elevation	11.00	-----	-----	16.00
Wave Height	-----	-----	-----	-----
Backfill Elevation - Flood Side	5.00	5.00	5.00	5.00
Backfill Elevation - Land Side	5.00	5.00	5.00	5.00
Surcharge	-----	5 k/ft, 40 mph wind speed	140 mph wind speed	-----
Overturning (Min base in Compression)	100.0%	75.0%	75.0%	75.0%
Sliding FS Required	1.50	1.33	1.33	1.33
Minimum Bearing Capacity (FS)	3.00	2.00	2.00	2.00

*Load Cases C1, C2a, C2b, C2c, C4 and C5 are from EM 1110-2-2502, Table 4-3

**Load Case C6 is from New Orleans HSDRRSDG

***Load Case C6: values for sliding, overturning and bearing from I2, EM 1110-2-2502, Table 4-2

****Information for wave load cases (C2a, C2b, C2c) not provided at this stage (will update design when values are provided by H&H)

7.2.2.3 Design

The floodwall cross-section for the conceptual design (dimensions shown in Figures 7-1 and 7-2) was generalized for all locations of floodwall. The design assumes a stem height of 15 feet and ground elevation of +5 feet NAVD 88. The top of wall height was established based on SWLs of 11 feet NAVD 88, and includes additional height provision for wave run-up and intermediate sea level rise. The SWLs are premised on the economic analysis results that establish the NED Plans. The thicknesses of the concrete base and stem were optimized in the design process to provide the most appropriate cross section. Cohesive soil, having low permeability, will be used to back fill the flood side of the walls to reduce the potential of seepage under the wall. This material will also be used to backfill the land side of the walls where a concrete splash apron will be constructed to prevent scour from wave overtopping. Because of the cohesive nature of soil to be used as backfill and assumed conservative value for the soil foundation material (C = 0.4 ksf), the strength mobilization factor was not applied in the design calculations.

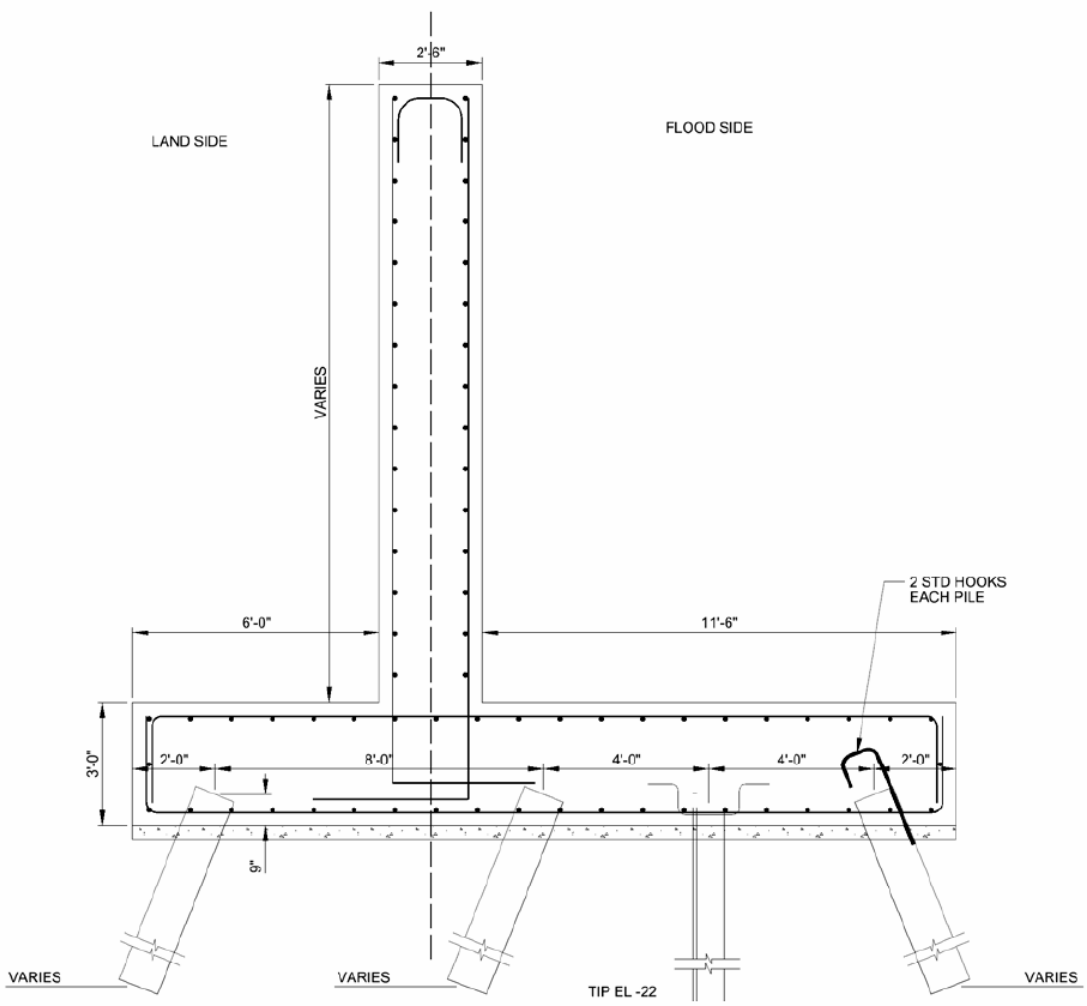


Figure 7-1: Floodwall - Conceptual Cross Section

Sabine to Galveston - Floodwall

Design Parameters

Floodwall dimensions (see figure)	
Top of Wall Elevation =	16
Ground EL (flood side) =	5
Ground EL (land side) =	5
stem height=	15
stem width=	2.5
base width=	20
base height=	3
stem position on base =	7.25
heel length=	11.50
toe length=	6.00
EL, top of base=	1
EL, bottom of base=	-2

Design Parameters		
$\gamma_{saturated}$ (lb/ft^3) =	110	
$\gamma_{submerged}$ (lb/ft^3) =	46	
γ_{water} (lb/ft^3) =	64	
$\gamma_{concrete}$ (lb/ft^3) =	150	
K_o =	0.8	
Wind Velocity (mph) =	140	*Load Case 5
$c_{undrained}$ (ksf) =	0.4	
$\phi_{undrained}$ =	0	
$N_{q,\ undrained}$ =	1.00	(EM 1110-2-2502, Table 5-1)
$N_{\gamma,\ undrained}$ =	0.00	(EM 1110-2-2502, Table 5-1)
$N_{c,\ undrained}$ =	5.14	(EM 1110-2-2502, Table 5-1)
$c_{drained}$ (ksf) =	0	
$\phi_{drained}$ =	23	
$N_{q,\ drained}$ =	8.66	(EM 1110-2-2502, Table 5-1)
$N_{\gamma,\ drained}$ =	4.82	(EM 1110-2-2502, Table 5-1)
$N_{c,\ drained}$ =	18.05	(EM 1110-2-2502, Table 5-1)

Load Factors (per EM 1110-2-2104, 3-3)	
Hydraulic =	1.3
Hydraulic (tension) =	1.65
Dead =	1.7
Live =	1.7
Wind =	0.75

Figure 7-2: Input for Floodwall Analysis

Several stability analyses were performed in accordance with the guidance of EM 1110-2-2502. These included evaluations of overturning, sliding, and bearing capacity. Each of these stability checks has an associated factor of safety for different load cases that the floodwall shall be designed to meet, which is provided in Table 7-1.

The figure below summarizes the design parameters and input values that were used in the stability analyses.

7.2.3 Conclusions

More extensive soils investigations will need to be conducted during PED to provide better understanding of the foundation conditions for the various floodwall sections along the proposed Orange-Jefferson CSRM levee alignment. Foundation analyses and design will be completed during the PED in accordance with applicable USACE engineering guidance.

Several sections of floodwall in the proposed alignment are near or along navigation channels; therefore marine vessels will be traveling near them. For those floodwalls that will be adjacent to the proposed navigation gates, fender systems will be installed to prevent vessel strikes (collisions) on the floodwalls during normal operations and during storms. The relative draft of a typical barge is 10 to 12 feet; therefore, with a top of wall surge loading at elevation +16.00 feet NAVD 88, the fender system will have to be built to a height that would be sufficient to keep vessels from striking the floodwall. The proposed floodwall along the Channel to Orange will

also be exposed to vessel strikes. Consequently, this area will have to be designed accordingly to account for the possibility of vessel strikes. This design will be done in PED.

All floodwall locations were assumed to be constructed with protection against overtopping (splash apron) on the land side of the wall. Erosion protection (riprap) will be placed around floodwall-to-earthen levee tie-ins on both the flood and land sides of the levee.

During the design process, the floodwall was found to require piling due to the bearing stability check not meeting the minimum factor of safety for several load cases. As stated earlier, this assumption was made for the preliminary design. The conceptual design for the floodwall utilizes 16-inch square prestressed concrete piles for all locations, but it may be determined in future analyses that steel pipe or steel H-piles are more suitable for certain floodwall locations. A piling design will be required during PED for all locations which are determined to require piles. The additional soils investigations to be performed during PED will help to determine if floodwall locations will require piles and what type of piles are most suitable. Tests that will need to be performed during the PED phase for the piling design: *pile load tests,* which are intended to validate the computed capacity for a pile foundation and also to provide information for the improvement of design rational, and *field tests,* which are performed to verify or predict driving conditions and/or load capacity of service piles at the construction site. The preliminary configuration for the amount and spacing of the piles is 3 piles/row at 5-foot spacing. A pile group analysis will also need to be performed during PED to determine the most appropriate piling configuration.

For Still Water to Top of Wall loading (Load Case 6), the sliding stability check was found to not meet the minimum factor of safety. Consequently, the possibility of widening or sloping the base of the floodwall or providing a key in the base will need to be further explored during PED. The additional geotechnical investigations during PED will provide higher resolution of the in situ soils at the floodwall locations, which will yield a more accurate design. For the TSP/NED Plan however, the generalized floodwall cross section shown in Figure 7-2 was assumed to calculate quantities for the alternative cost estimates. Steel reinforcement for the floodwall was calculated to be #8 bars at 12 inches on centers. Due to the possibility of other load cases (i.e. the wave load cases) increasing the calculated loads for the reinforcement, for cost estimating purposes, 6 pounds of steel reinforcement per cubic foot of concrete was assumed.

7.3 NAVIGABLE GATE STRUCTURES

7.3.1 Concept Design

The navigable gate structures at Adams and Cow Bayous are proposed as a sector gate with adjacent vertical lift floodgates. The locations of these structures in relation to the alignment of the Orange 3 Reach are shown in Figure 7-3. The gate structures were modeled after the sector gate recently completed at the Caernarvon Canal as part of the New Orleans Hurricane Protection System project work. The structures will be built with an additional height of 2 feet relative to the height of the adjacent levees to provide structural superiority for the structures because of the difficult nature of their construction.

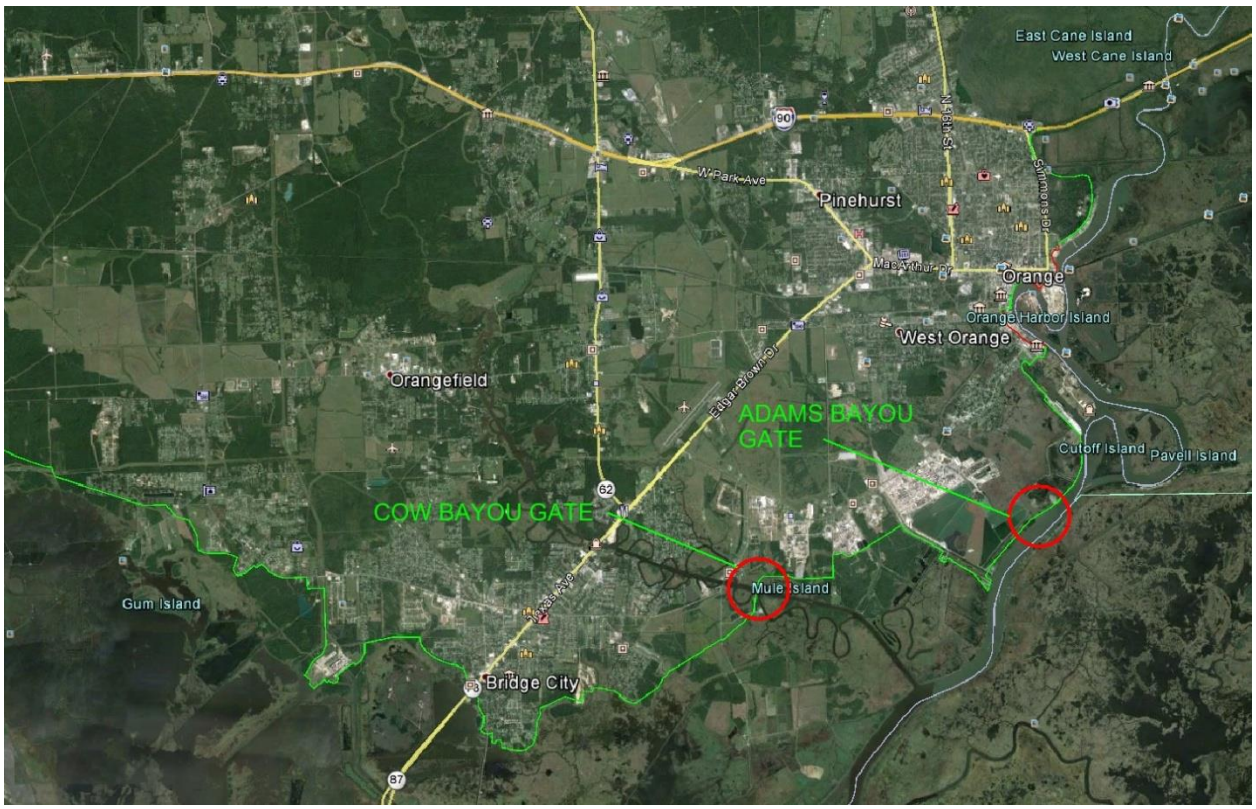


Figure 7-3: Overview Map of Orange 3 Reach – Gate Structures

It is assumed that both sector gate structures will be constructed in line with the existing authorized channels (see Plates S-01 and S-02 for representative plan views of the gate structures, respectively, and Figure 7-4 for a photo of a similar sector gate structure). Concrete floodwalls will be constructed adjacent to these structures and tie into the earthen levee.

Figure 7-4: Aerial Photograph of Navigation Sector Gates with Adjoining Vertical Lift Gates

7.3.1.1 Adams Bayou

The Adams Bayou Gate Structure will be of the sector gate type with a navigable opening of 56 feet. Previous CSRM studies performed on the Orange County area utilized this type and size of structure for the navigable channel crossings. Without further investigations being performed by the PDT, this size will be utilized for the purpose of this study. A structure this size will be large enough to accommodate single barges and other moderate draft vessels likely to use the waterway. The sill of the sector gate structure is assumed to be at the current maintained channel depth of 13 feet MLLW.

Due to the narrowing of the bayou at the proposed crossing, an additional series of non-navigable flood gates are proposed to mitigate impacts to channel flow during normal upland rainfall events. This gate will be a 50-foot-wide vertical lift gate positioned on the west side of the sector gate structure. Its sill depth is assumed to mirror the current channel depth near the banks of the bayou (approximately 8 feet). The size of the vertical lift gate was determined by calculating the normal channel flow with a rainfall event and providing enough open area through the gate structures for this flow. For more information, see the Hydraulics and Hydrology section of this report. Because of the location where this structure is proposed to be sited, only one vertical lift gate is being proposed. On the east side of the channel, there is an

abandoned placement area, which is assumed to be integrated into the proposed levee system. Therefore, the vertical lift gate is proposed to be situated on west side of the sector gate structure to avoid disturbing the placement area levee in which a gate structure would otherwise be constructed through it.

7.3.1.2 Cow Bayou

For the purpose of this study, the same sector gate proposed for Adams Bayou is proposed for the navigation structure at Cow Bayou due to similar site conditions at each proposed location (i.e., type of vessel usage, maintained channel width and depth). The sill of the sector gate structure is assumed to be at the current maintained channel depth of 14 feet MLLW.

Two 60-foot-wide non-navigable vertical lift floodgates will flank the Cow Bayou sector gate structure. These non-navigable floodgates are proposed to mitigate impacts to channel flow during normal upland rainfall events. The depth of the sill for the vertical lift gates is assumed to mirror the current depth of the channel near the banks of the bayou (approximately 8 feet). Cow Bayou is approximately 400 feet wide; therefore, a larger set of vertical lift gates will be required than for Adams Bayou to mitigate the impacts.

7.3.2 Conclusions

The gate structure analyses and design are beyond the scope of this study. Detailed design will be required for all aspects of the combined sector and vertical lift gate structures during PED. For the purpose of this study, only general concepts for these structures are provided, which are based on similar, previously constructed gates. Both gate structures will be constructed within channels used for navigation therefore, a cofferdam will have to be constructed to provide a dry construction area. The construction areas are currently assumed to be below the water table and would therefore require dewatering. Due to the current active use of both of these channels, they will be required to remain operational and therefore will need some type of diversion channel during the gate construction to not inhibit industry from utilizing the channels. It is understood that the foundation soils are very soft at the proposed locations for the gate structures; therefore, the foundation will require strengthening with piles to form a stable foundation for supporting the gate structures. The piles are assumed to be prestressed concrete for cost estimating purposes of this study, but may consist of concrete piles, steel H-piles, or pipe; which will be determined during PED. Floodwall will be directly adjacent to these structures and tie in to the earthen levee sections. Proper investigations should occur prior to study completion to determine the most appropriate size of the navigable opening for each of the sector gate structures.

7.4 REFERENCES

USACE Engineer Manuals

- EM 1110-2-2104 - Strength Design for Reinforced-Concrete Hydraulic Structures, 30 June 1992
- EM 1110-2-2502 - Retaining and Flood Walls, 29 September 1989

Other USACE Engineering Guidance

- Hurricane and Storm Damage Risk Reduction System Design Guidelines (HSDRRSDG) - Interim, June 2012

Drawings and Reports

- Flood Protection Planning Study Hurricane Flood Protection System, Orange County, Texas, December 2012.

8 HAZARDOUS AND TOXIC MATERIALS

A detailed discussion of HTRW and associated risk level definitions is provided in Appendix N of the DIFR-EIS.

8.1 ORANGE-JEFFERSON COUNTY CSRM

The Orange County levee and floodwall corridor (Orange 3 Reach) is approximately 27.2 miles in length from near the intersection of the Sabine River with Interstate 10, around the cities of Orange and Bridge City, Texas, and up to a point less than a mile southwest of FM 1135 where it intersects FM 105 (Orangefield Road) midway between Rose City and Bridge City. The corridor runs near numerous industrial facilities, including the Port of Orange, several shipbuilding yards, DuPont-Invista Sabine River Works, Lanxess Chemical Corporation, Firestone Polymers, and Chevron Phillips Chemical Company.

There are seven (7) major HTRW sites and facilities near or adjacent to the Orange County levee and floodwall alignment corridor identified from the research conducted. These sites consist of industrial facilities currently operating that are listed in databases identifying the generation, handling, or release of hazardous materials and waste. The largest of these, DuPont Chemical Corporation, maintains several large wastewater treatment and cooling ponds along the tentative alignment. The general HTRW risk for the levee alignment in Orange County is classified as *Low*, since no unresolved current or recent hazardous material releases were found, and no significant recent RCRA or CWA permit violations were identified. HTRW facilities in the area should be more thoroughly investigated with visual inspections and interviews with facility managers to confirm the potential HTRW risks along the levee alignment prior to construction or more detailed design.

The Jefferson Main reach levee and floodwall alignment corridor is approximately 14.3 miles in length around the City of Port Neches, Texas, and the ExxonMobil Chemical Plant in Beaumont, Texas. The corridor runs near seven (7) major petroleum and chemical facilities, including the ExxonMobil Chemical Plant, DuPont Chemical Corporation, and the Huntsman refinery, as well as numerous petroleum and chemical tank farms and loading facilities. There are numerous pipelines crossing the levee alignment in Jefferson County that transport hazardous materials for shipment or further processing. These pipeline crossings are identified as points of concern along the TSP alignment where special caution needs to be exercised during construction to avoid damage to the pipelines and release of hazardous materials into the environment.

Most of the refineries and chemical plants have had numerous Clean Air Act violations in the past or are currently in effect due to stack emissions. No currently active spills or land/water

releases of hazardous materials were found however. The Star Lake Canal, emanating from the Huntsman Refinery, runs adjacent to the Jefferson County alignment and is listed as an active NPL site due to past release of wastewater and storm runoff containing hazardous materials. This canal is scheduled for remediation by USEPA with the proposed removal of contaminated bottom sediments. Due to the presence of toxic sediments, this canal would be considered *High* risk; however, minor construction on the existing levee along the canal would not expose any sediments within the canal. Therefore, despite the large number of potential HTRW release facilities, the Orange-Jefferson CSRM project area is classified as generally *Low* risk for HTRW. The HTRW facilities in the area need to be more thoroughly investigated with visual inspections and interviews with facility managers to confirm the potential HTRW risks along the alignment corridor prior to construction or more detailed design. Coordination with USEPA remediation of the Star Lake Canal would also be required.

8.2 PORT ARTHUR AND VICINITY CSRM

The existing Port Arthur HFPP corridor is approximately 34.4 miles around the cities of Port Arthur and Groves, Texas. The corridor runs near five (5) major petroleum and chemical facilities, including the Texaco refinery, the Total-BASF refinery, the Valero refinery, and the Motiva Enterprises refinery, as well as numerous petroleum and chemical tank farms and loading facilities.

Most of the refineries and chemical plants have had numerous Clean Air Act violations in the past or are currently in effect due to stack emissions. No currently active spills or land/water releases of hazardous materials were found however. Despite the large number of potential HTRW release facilities, the Port Arthur CSRM project area is classified as generally *Low* risk for HTRW. The HTRW facilities in the area need to be more thoroughly investigated with visual inspections and interviews with facility managers to confirm the potential HTRW risks along the alignment corridor prior to construction or more detailed design. Although some large refineries and chemical plants are more than 0.25 mile from the project alignment, they could still affect the project corridor as a result of a major release.

8.3 FREEPORT AND VICINITY CSRM

The general risk level for the Freeport area is indicated as *Low* risk, since no current or recent unresolved RCRA or CWA releases were identified for any of the industrial facilities in the Freeport area. Many of the facilities have ongoing CAA violations due to stack emissions. The HTRW facilities in the area need to be more thoroughly investigated with visual inspections and interviews with facility managers to confirm the potential HTRW risks along the alignment corridor prior to construction or more detailed design.

9 COST ESTIMATES

9.1 REFERENCES

ASTM E 2516-11 - Standard Classification for Cost Estimate Classification System

ER 1110-2-1302 – Civil Works Cost Engineering, 15 Sep 08

9.2 CLASSIFICATION

Cost Estimates for screening the different project reaches in Orange and Jefferson Counties (alternatives) were developed utilizing a Class 4 parametric approach using both historical and unit costs. From these screenings, the NED plans for the proposed Orange-Jefferson levee/floodwall system were determined. A similar approach was taken in screening alternatives for the alignment for the Port Arthur and Freeport Hurricane Flood Protection System.

9.3 SCOPE

Costs were developed only to the extent necessary to compare alternatives and determine which projects would comprise the TSP. Therefore, costs are not necessarily reflective of actual construction costs of a fully defined and developed project.

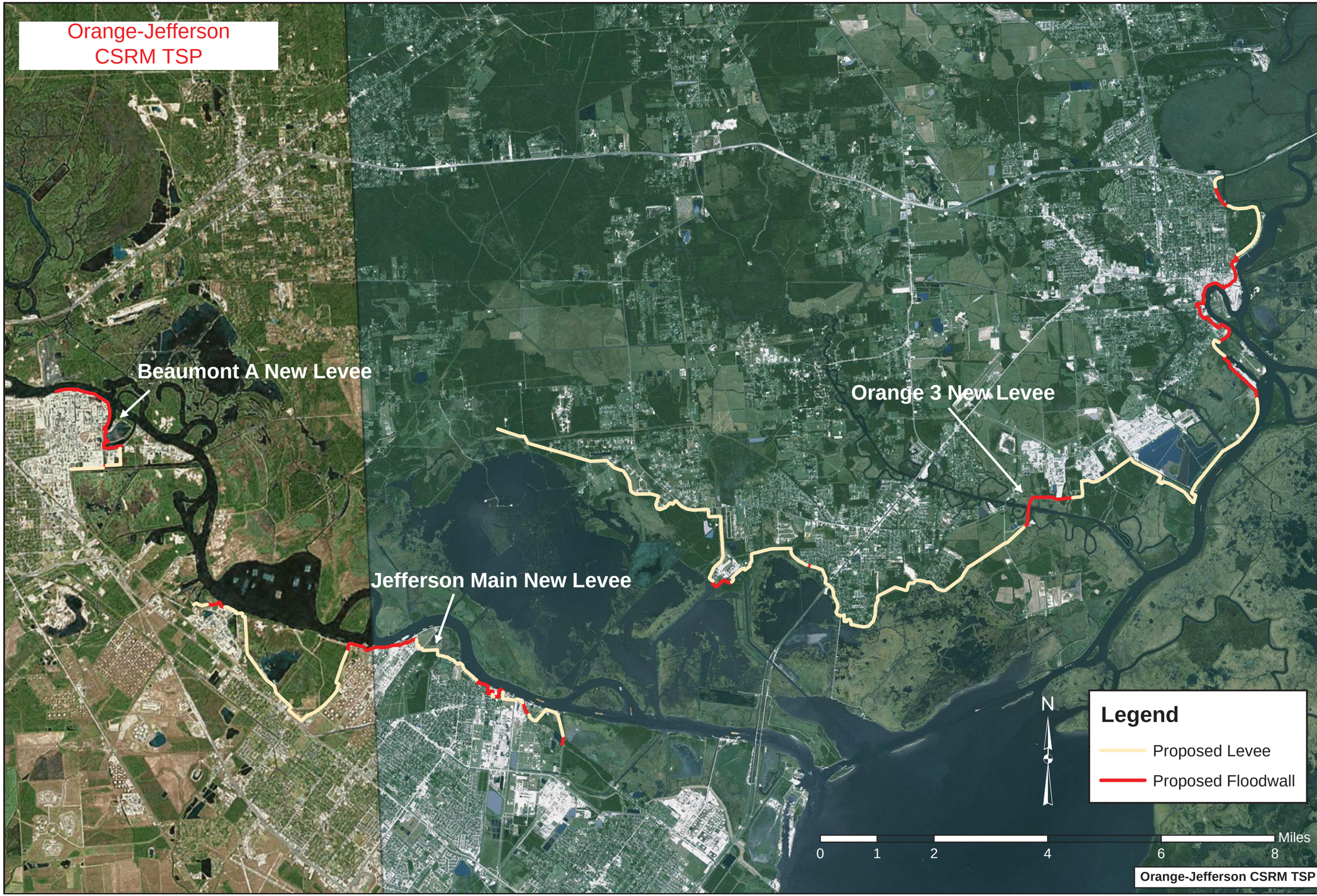
9.4 SCHEDULE FOR DESIGN AND CONSTRUCTION

Construction of the recommended HFPPs for the Sabine and Brazoria sub-regions is currently assumed will take 8 years to complete, in sequential phases. When the feature designs for the projects composing the TSP are further advanced after the ADM, the PDT can make more informed estimates of the amount of time it will take to design the projects and build them, and of the number of construction contracts it probably will take.

Prior to construction of the proposed HFPPs in Orange and Jefferson Counties, numerous pipelines and other utilities, including overhead power lines, that cross or are close to the structures will have to be relocated or modified to accommodate the levee embankments and floodwalls. For the alternative comparison analysis and TSP, it was assumed that all such pipelines would have to be removed and relocated. When constructing the closure structures with navigable opening for these particular systems, the construction contractor will have to provide for the continuity of vehicular traffic on secondary roads, rail traffic, and vessel traffic on Adams and Cow Bayous. Such accommodations will require significant coordination efforts given the agencies, public concern, and industry involved when possible disruptions are a possibility. Raising sections of the existing Port Arthur and Freeport HFPP levees likely will not involve any pipeline and utility relocations, except for one pipeline crossing the Freeport system.

When raising sections of the existing Freeport and Port Arthur HFPP levees and replacing floodwall, the construction contractor will be required to maintain the current flood-protection performance level provided by the system. Emergency response plans for the duration of the construction period, therefore, will have to be coordinated and prepared, reviewed by USACE, and then monitored and executed properly to address the potential for flooding.

Orange-Jefferson CSRM TSP



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Galveston District

Rev.	Description	Date	By

Drawn by:
Designed by:
Reviewed by:
Submitted by:
Chief Geo & Structural Section:
Approved by:
Chief Engineering and Construction Division

Date:
Scale:
Approval Recommended
Chief Engineer Branch

U.S. ARMY ENGINEER DISTRICT,GALVESTON
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GALVESTON, TEXAS

PREPARED UNDER THE DIRECTION OF
RICHARD P PANNELL, COL.
DISTRICT COMMANDER

Sabine to Galveston, Texas
Orange and Jefferson County
Core Borings and CPTs

Drawing No.
G-01

Port Arthur and Vicinity CSRM TSP

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Galveston District

Rev.	Description	Date	by

Drawn by:
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Orange and Jefferson County
Core Borings and CPTs

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Freeport and Vicinity CSRM TSP

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Sabine to Galveston, Texas
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Cove Borings and CPTs

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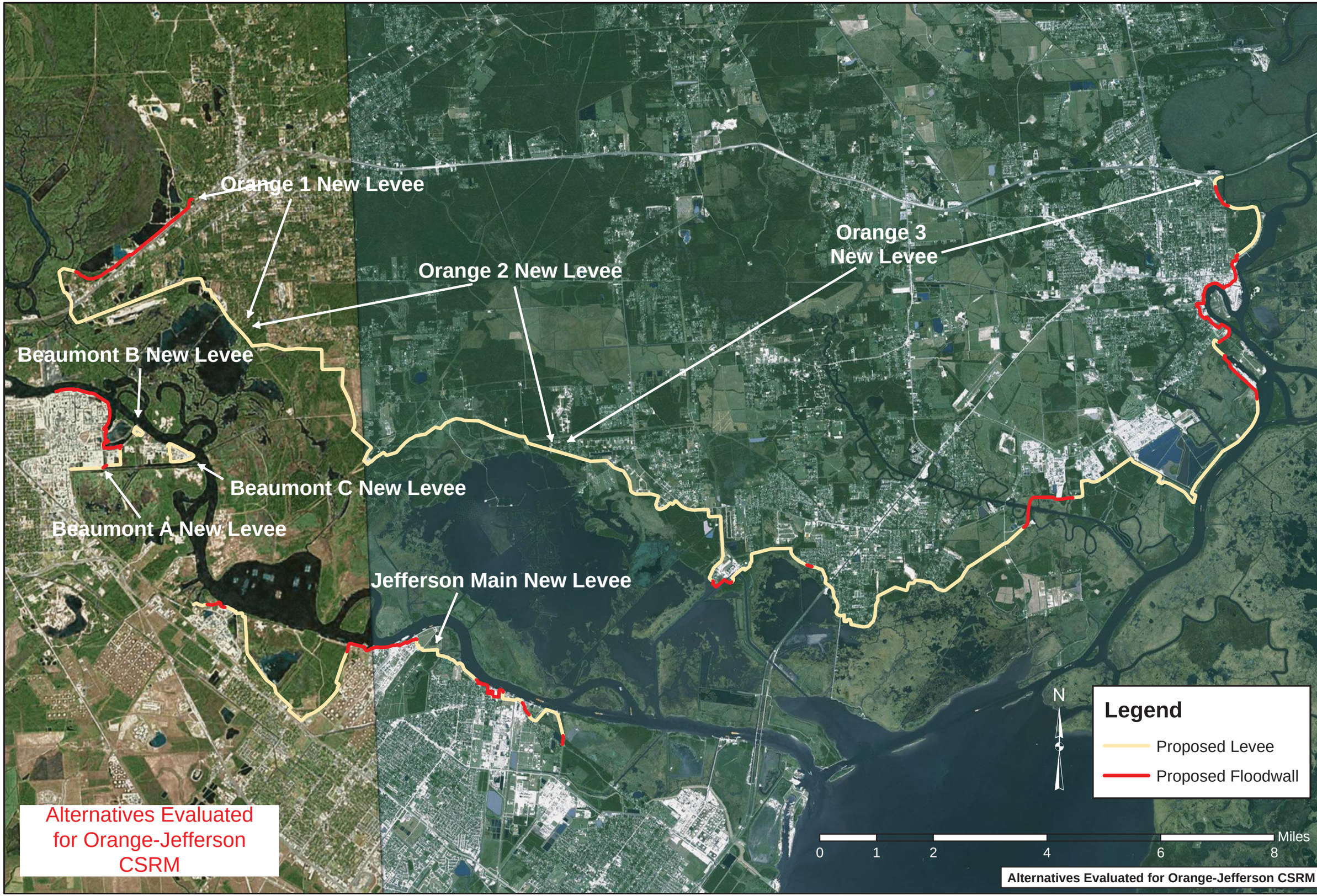

Alternatives Evaluated for Orange-Jefferson CSRM

US Army Corps of Engineers
Galveston District

Rev.	Description	Date	By

Drawn by:
Designed by:
Reviewed by:
Submitted by: Chief Geo & Structural Section
Approved by: Chief Engineering and Construction Division

Date:
Scale:
Approval Recommended: Chief Engineer Branch

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GALVESTON, TEXAS

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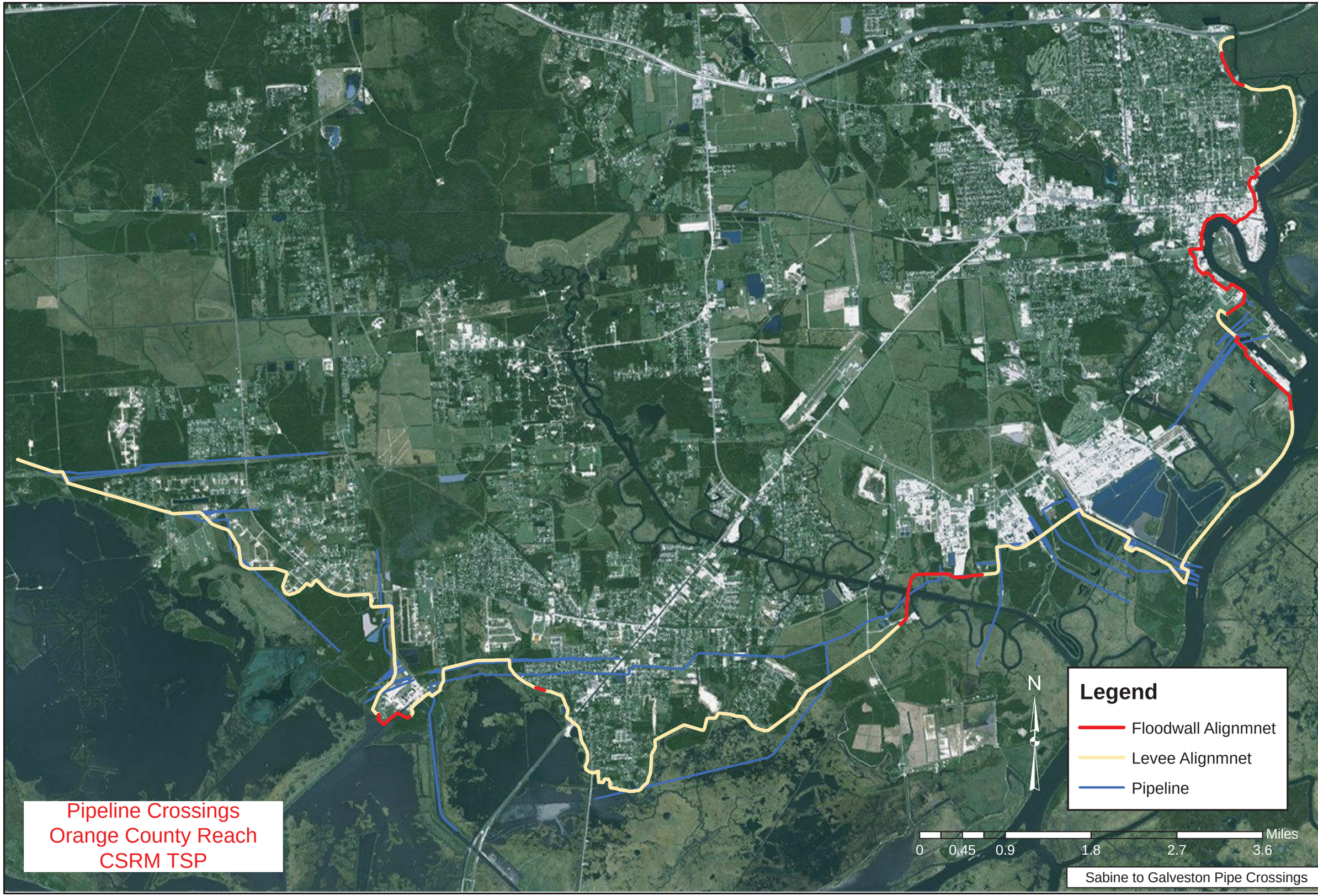
Sabine to Galveston, Texas
Orange and Jefferson County
Core Borings and CPTs

Drawing No.
C-01



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Galveston District

Rev.	Description	Date	by

Drawn by: Brad Burrows
Designed by: Brad Burrows
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Submitted by:
Chief Geo & Structal Section
Approved by:
Chief Engineering and Construction Division

Date: 31 July 2015
Scale: 1: 55,602
Approval Recommended
Chief Engineer Branch

U.S. ARMY ENGINEER DISTRICT,GALVESTON
CORPS OF ENGINEERS,
GALVESTON, TEXAS

PREPARED UNDER THE DIRECTION OF
RICHARD P. PANNELL, COL.
DISTRICT COMMANDER

Sabine to Galveston, Texas
Orange and Jefferson County
Core Borings and CPTs

Drawing No.
C-02

Pipeline Crossings
Jefferson County Main Reach
CSRM TSP

US Army Corps of Engineers
Galveston District

Rev.	Description	Date	By

Drawn by: Brad Burrows
Designed by: Brad Burrows
Reviewed by:
Submitted by:
Chief Geo & Structural Section
Approved by:
Chief Engineering and Construction Division

Date: 31 July 2015
Scale: 1:55,602
Approval Recommended
Chief Engineer Branch
Construction Division

U.S. ARMY ENGINEER DISTRICT,GALVESTON
CORPS OF ENGINEERS,
GALVESTON, TEXAS

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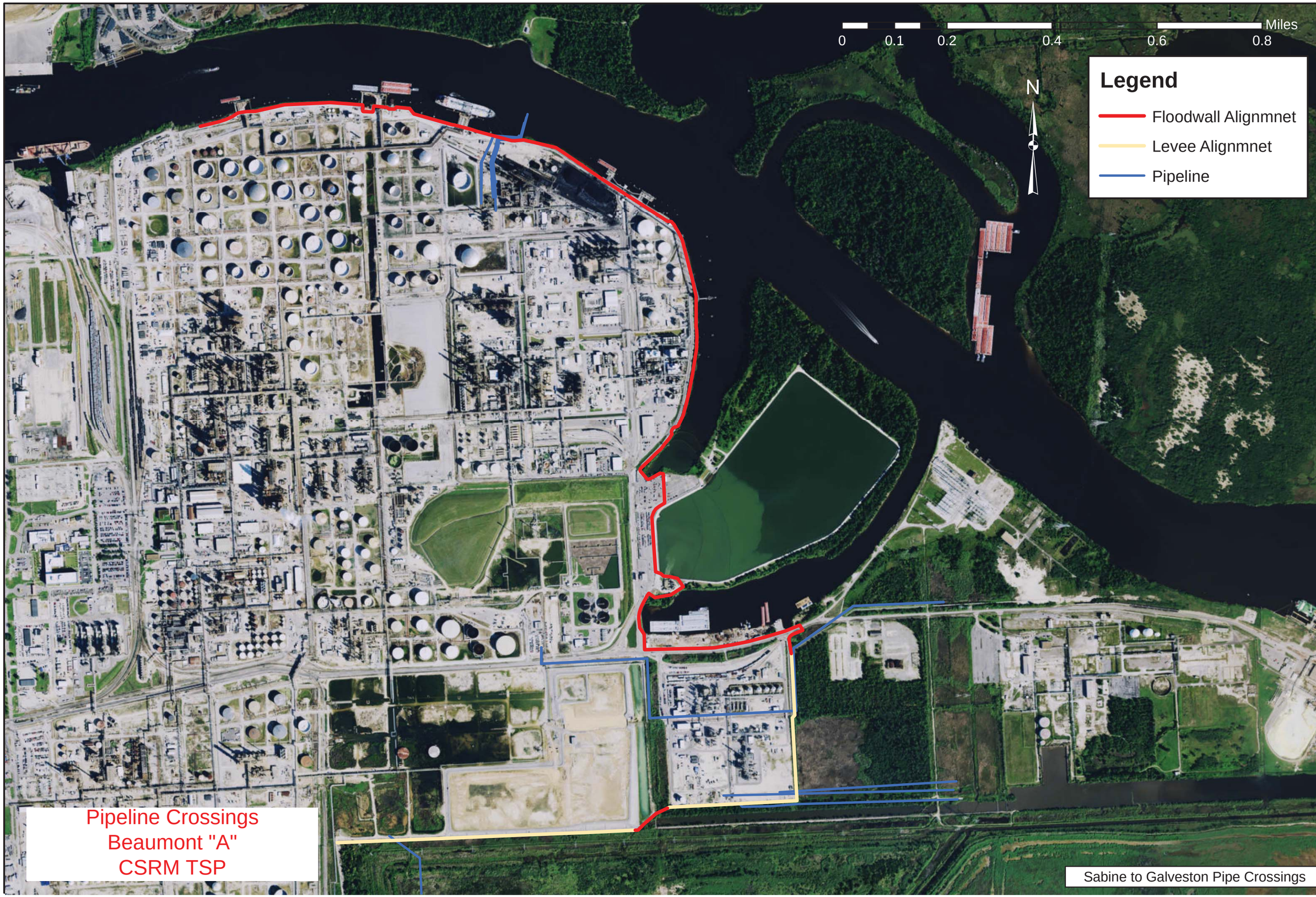
RICHARD P. PANNELL, COL.
DISTRICT COMMANDER

Sabine to Galveston, Texas
Orange and Jefferson County
Core Borings and CPTs

Drawing No.
C-03



US Army Corps of Engineers
Galveston District

Rev.	Description	Date	by

Drawn by: Brad Burrows
Designed by: Brad Burrows
Reviewed by:
Submitted by:
Chief Geo & Structal Section
Approved by:
Chief Engineering and Construction Division

Date: 31 July 2015
Scale: 1:13,521
Approval Recommended
Chief Engineer Branch

U.S. ARMY ENGINEER DISTRICT,GALVESTON
CORPS OF ENGINEERS,
GALVESTON, TEXAS

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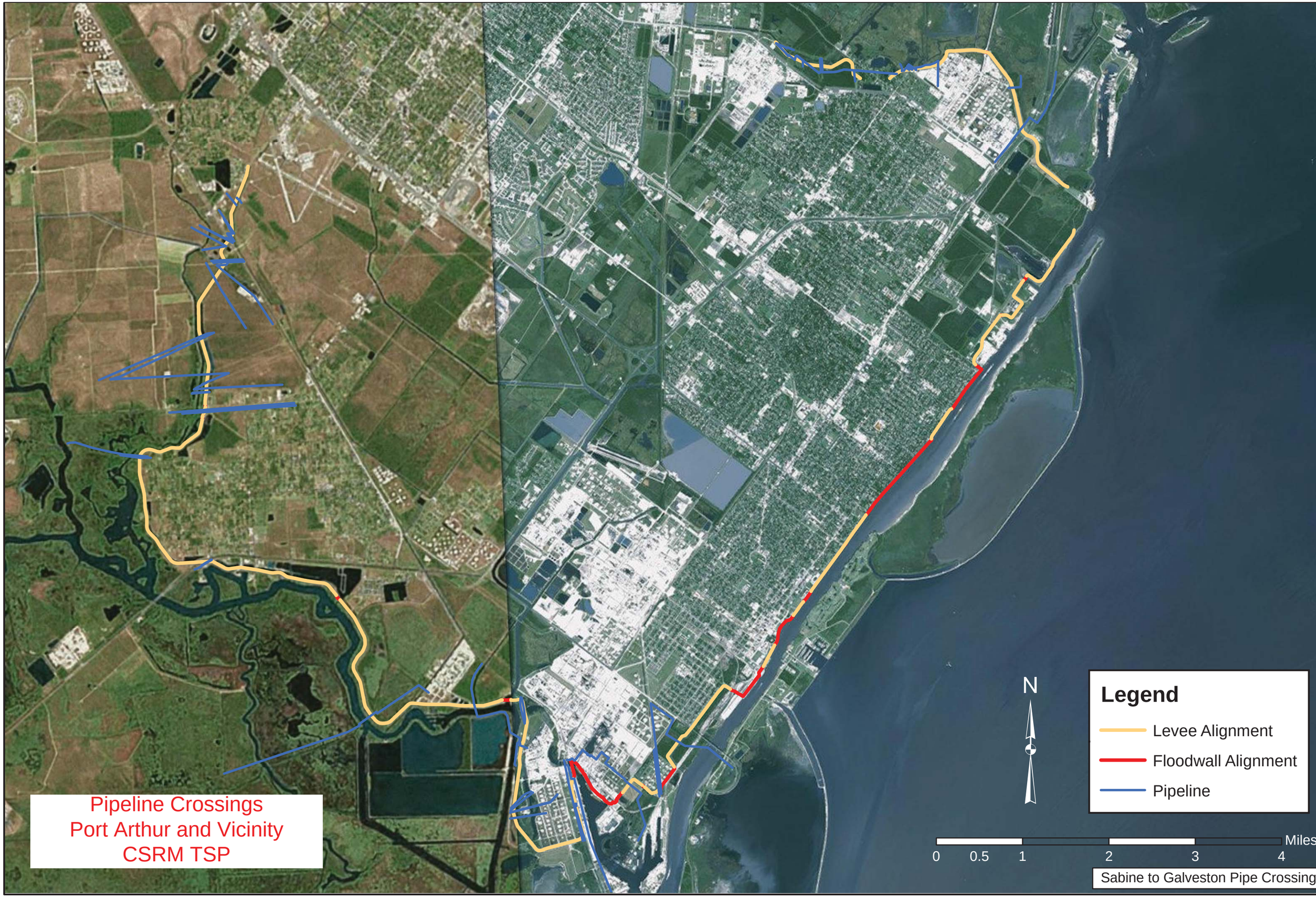
Sabine to Galveston, Texas
Orange and Jefferson County
Core Borings and CPTs

Drawing No.
C-04



US Army Corps of Engineers ®
Galveston District

Rev.	Description	Date	By

U.S. ARMY ENGINEER DISTRICT,GALVESTON
CORPS OF ENGINEERS,
GALVESTON, TEXAS

PREPARED UNDER THE DIRECTION OF
RICHARD P. PANNELL, COL.
DISTRICT COMMANDER

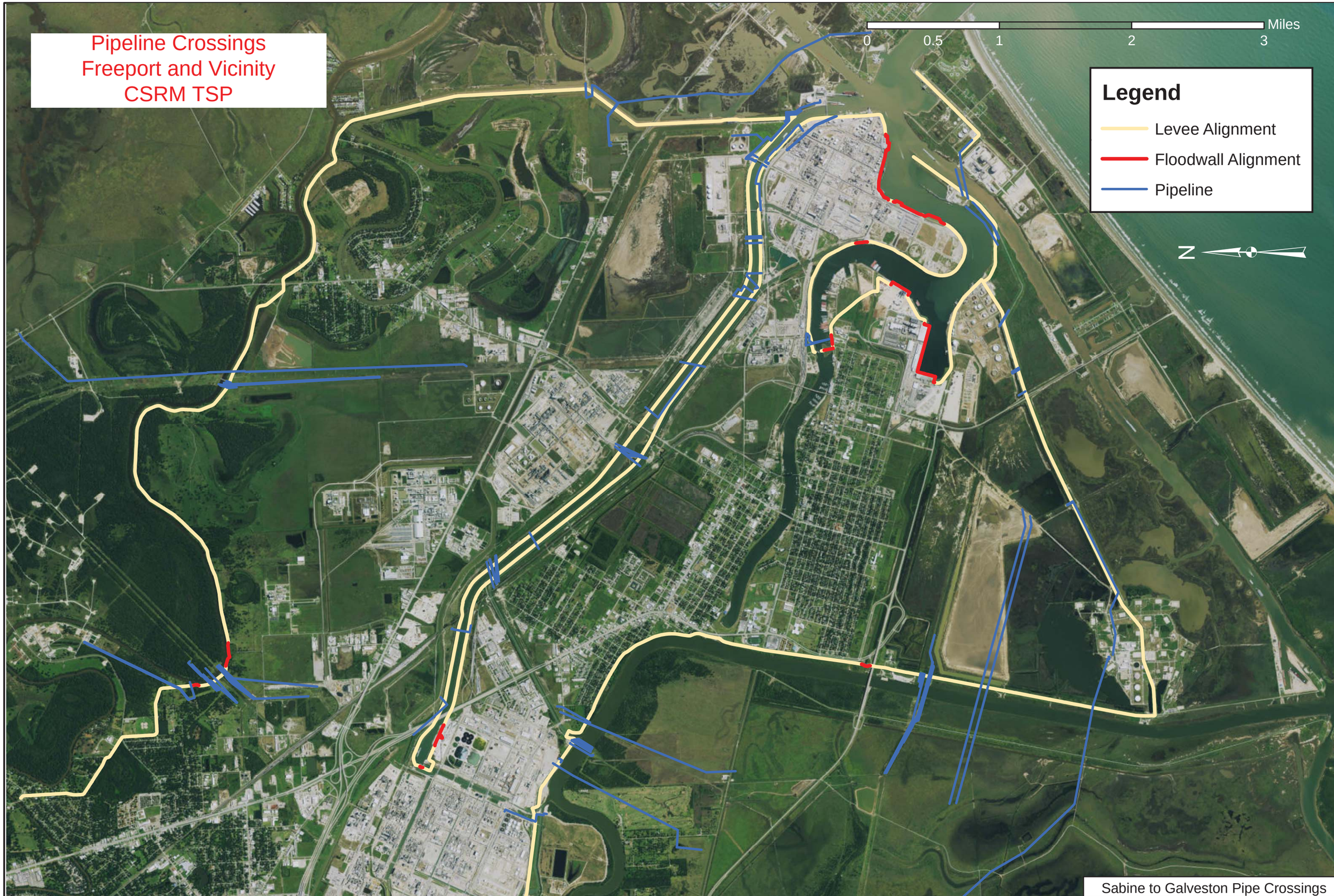
Drawn by: Brad Burrows
Designed by: Brad Burrows
Reviewed by:
Submitted by:
Chief Geo & Structal Section
Approved by:
Chief Engineering and Construction Division

Date: 3 August 2015
Scale: 1:61,406
Approval Recommended
Chief Engineer Branch

Rev.

Sabine to Galveston, Texas
Orange and Jefferson County
Core Borings and CPTs

Drawing No.
C-05



US Army Corps of Engineers®
Galveston District

Rev.	Description	Date	By

Drawn by: Brad Burrows
Designed by: Brad Burrows
Reviewed by:
Submitted by:
Chief Geo & Structural Section
Approved by:
Chief Engineering and Construction Division

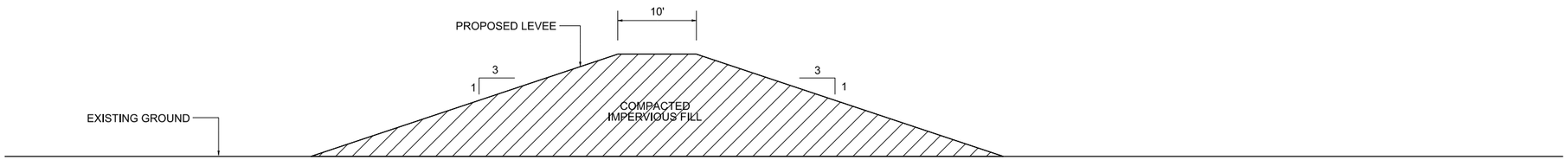
Date: 3 August 2015
Scale: 1:40,495
Approval Recommended
Chief Engineer Branch

U.S. ARMY ENGINEER DISTRICT,GALVESTON
CORPS OF ENGINEERS,
GALVESTON, TEXAS

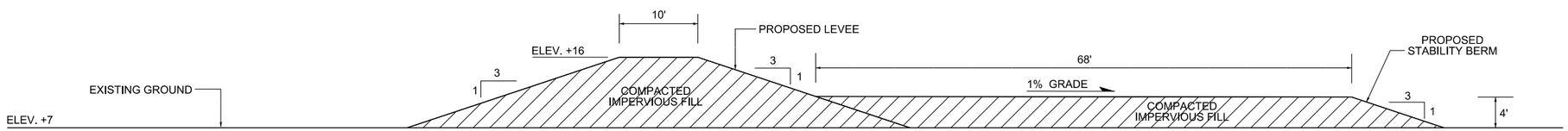
PREPARED UNDER THE DIRECTION OF
RICHARD P. PANNELL, COL.
DISTRICT COMMANDER

Sabine to Galveston, Texas
Orange and Jefferson County
Core Borings and CPTs

Drawing No.
C-06



TYPICAL



TYPICAL
ORANGE STABILITY BERM

U.S. Army Corps of Engineers
Galveston District

Rev.	Description	Date	By

Drawn by: X
Designed by: X
Checked by: X
Submitted by: _____
Approved by: _____
Chief, Engineering and Construction Division

Date: #####
Rev: ___
Scale: AS SHOWN
Approval Recommended:
Chief, Engineering Branch

U.S. ARMY ENGINEER DISTRICT, GALVESTON
CORPS OF ENGINEERS
GALVESTON, TEXAS

PREPARED UNDER THE DIRECTION OF
RICHARD P. PANNELL, COL., C.E.,
DISTRICT COMMANDER

SABINE TO GALVESTON
FEASIBILITY STUDY

TYPICALS

Sheet No.:
B-01

U.S. Army Corps of Engineers
Galveston District

Rev.	Description	Date	By

Drawn by: C.I.M.
Designed by: C.I.M.
Checked by: X
Submitted by: _____ Chief, Engineering and Construction Division
Approved by: _____ Chief, Engineering Branch

Date: ####
Scale: AS SHOWN
Approval Recommended:

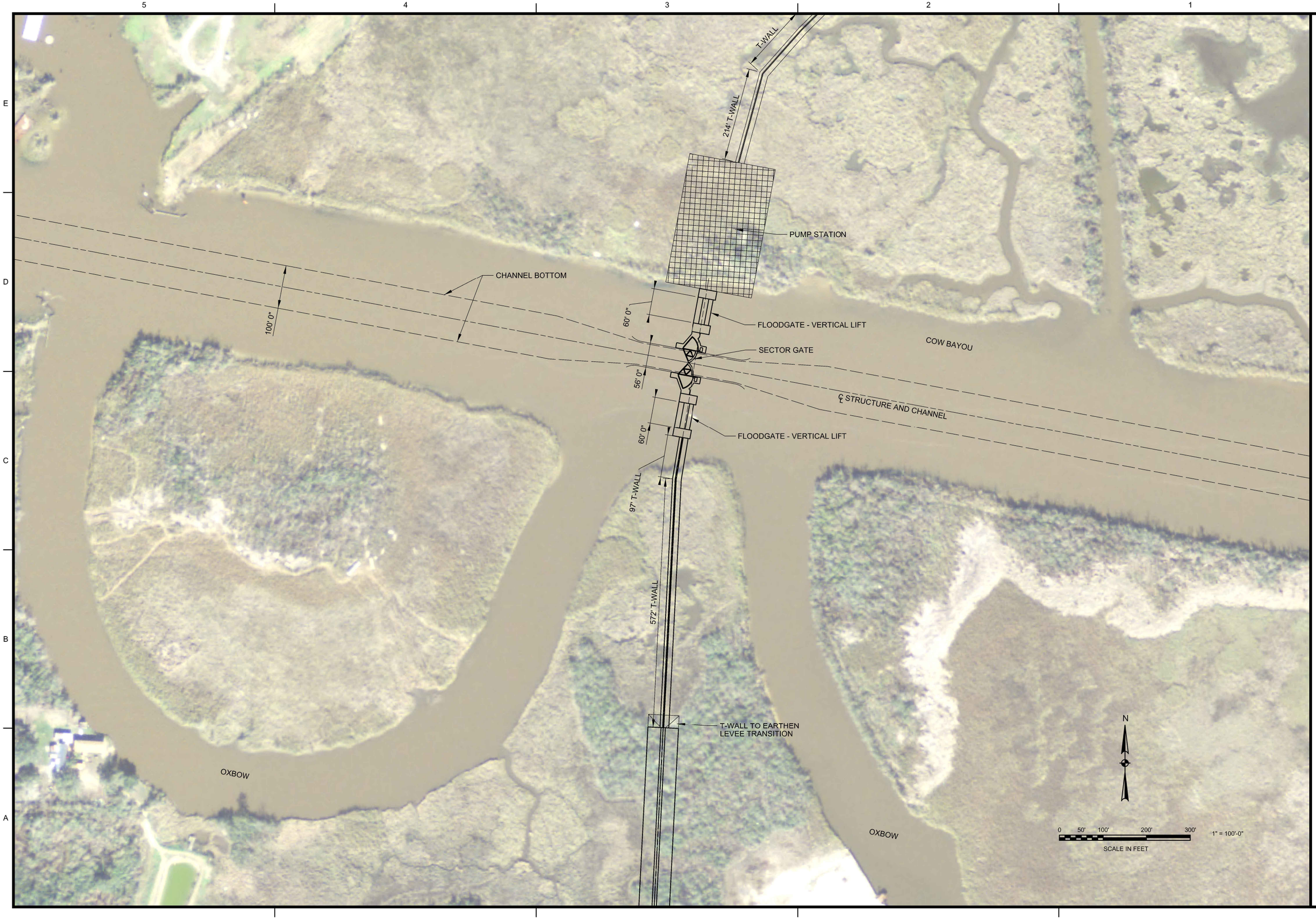
U.S. ARMY ENGINEER DISTRICT, GALVESTON
CORPS OF ENGINEERS
GALVESTON, TEXAS

PREPARED UNDER THE DIRECTION OF
RICHARD P. PANNELL, COL., C.E.,
DISTRICT COMMANDER

SABINE TO GALVESTON
FEASIBILITY STUDY

ADAMS BAYOU
GATE STRUCTURE PLAN

Sheet No.:
S-01



U.S. Army Corps of Engineers
Galveston District

Rev.	Description	Date	By

Drawn by: CJM
Designed by: CJM
Checked by:
Submitted by:
Approved by:
Date: ####
Scale: AS SHOWN
Approval Recommended:
Chief, Engineering Branch
Chief, Engineering and Construction Division

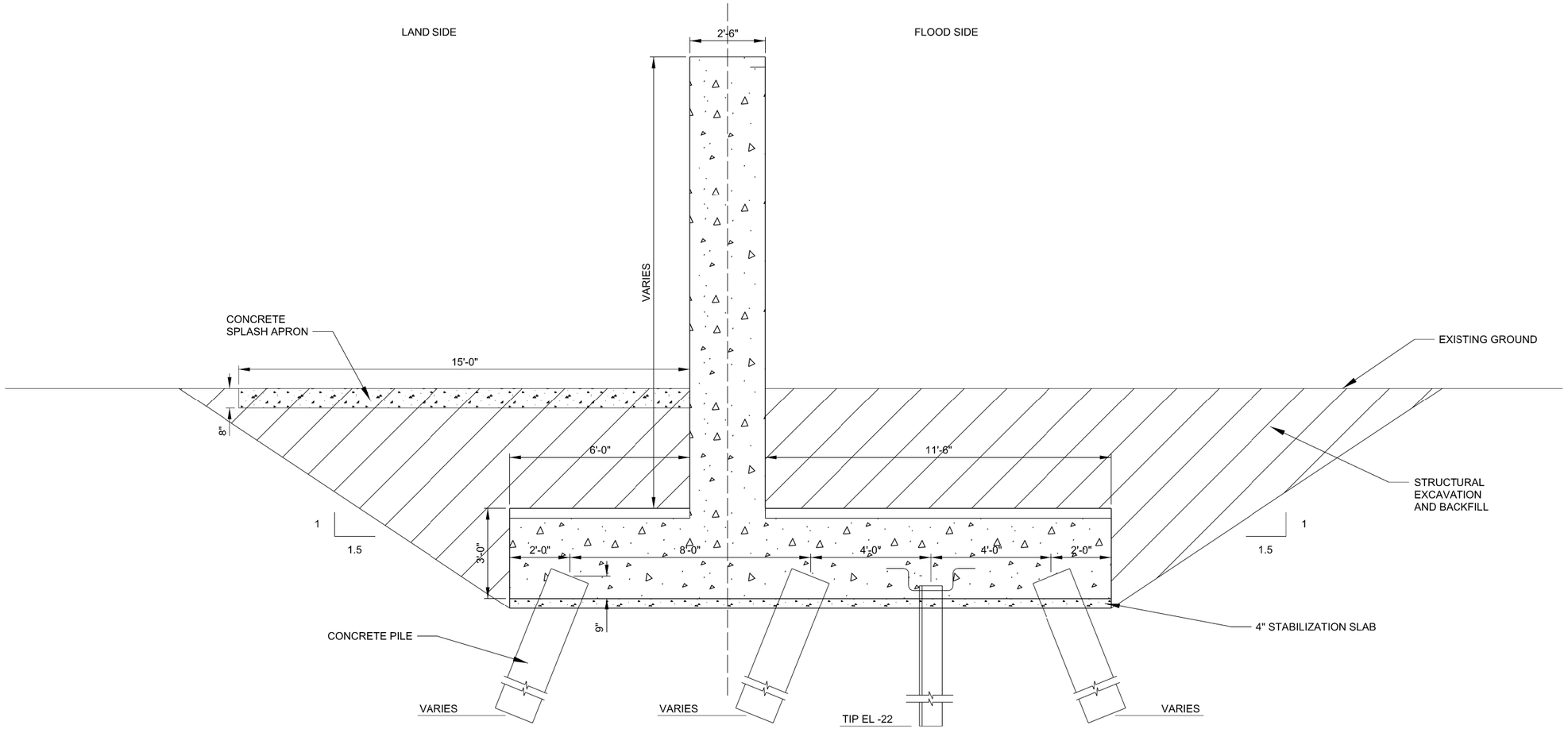
U.S. ARMY ENGINEER DISTRICT, GALVESTON
CORPS OF ENGINEERS
GALVESTON, TEXAS

PREPARED UNDER THE DIRECTION OF
RICHARD P. PANNELL, COL., C.E.,
DISTRICT COMMANDER

SABINE TO GALVESTON
FEASIBILITY STUDY

COW BAYOU
GATE STRUCTURE PLAN

Sheet No.:
S-02



ASSUMPTIONS:

1. EXISTING GROUND AT EL 5.0
2. STRUCTURAL EXCAVATION TO BOTTOM OF FLOODWALL CONSTRUCTION.
3. SIMILAR SOIL CONDITIONS EXIST IN ALL FLOODWALL LOCATIONS.
4. 16" SQUARE PRESTRESSED CONCRETE PILE. 3 PILES/ROW AT 5 FT SPACING.
   FOR COST ESTIMATING PURPOSES, PILES ARE 60' IN LENGTH.

0 1' 2' 4' 6'
SCALE IN FEET

1/2" = 1'-0"

U.S. Army Corps of Engineers
Galveston District

Rev.	Description	Date	By

Drawn by: C.J.M.
Designed by: C.J.M.
Checked by: X
Submitted by: _____
Approved by: _____
Chief, Engineering Branch
Chief, Engineering and Construction Division

Date: ####
Scale: AS SHOWN
Approval Recommended:

U.S. ARMY ENGINEER DISTRICT, GALVESTON
CORPS OF ENGINEERS
GALVESTON, TEXAS

PREPARED UNDER THE DIRECTION OF
RICHARD P. PANNELL, COL., C.E.,
DISTRICT COMMANDER

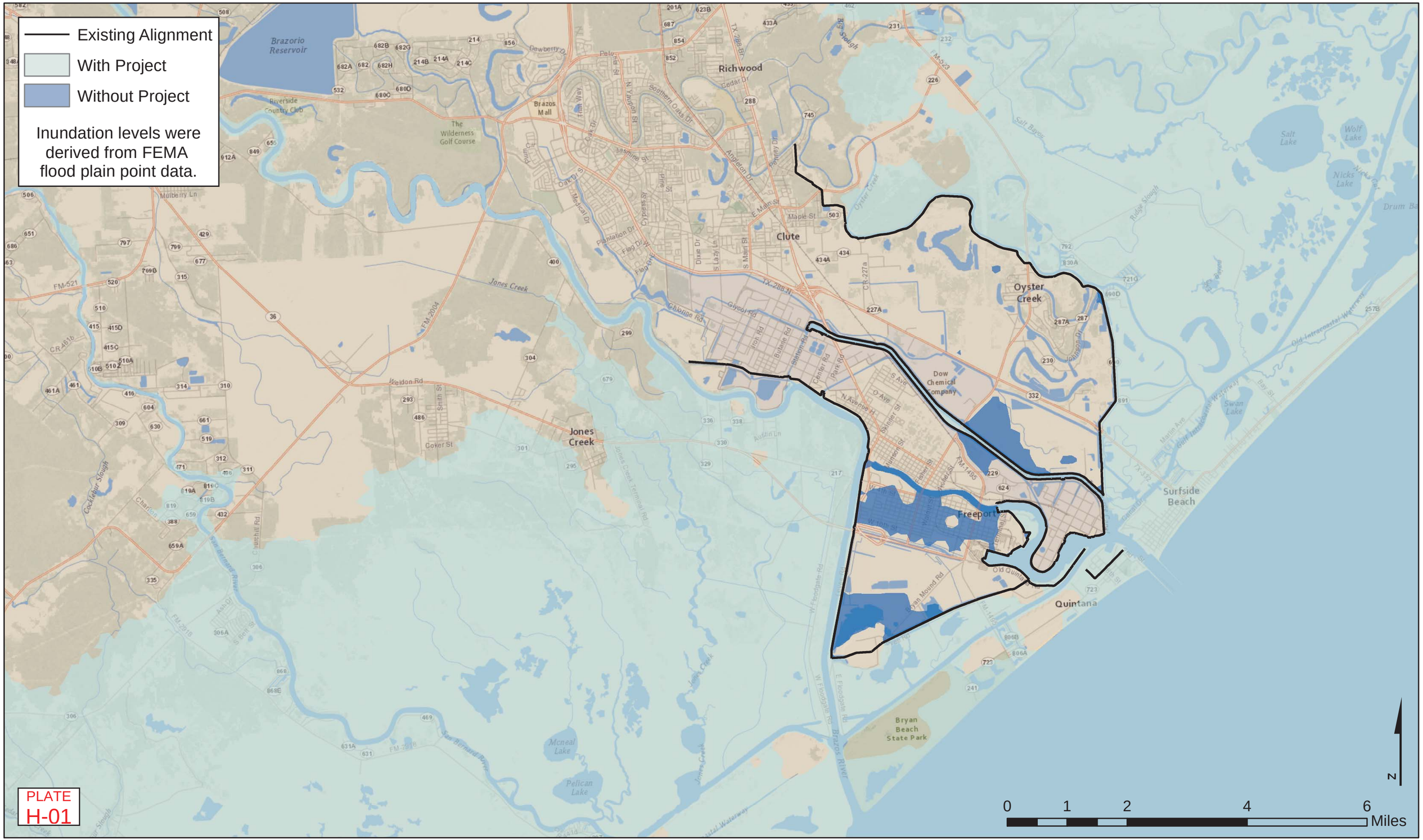
SABINE TO GALVESTON
FEASIBILITY STUDY

FLOODWALL
TYPICAL SECTION

Sheet No.:
S-03

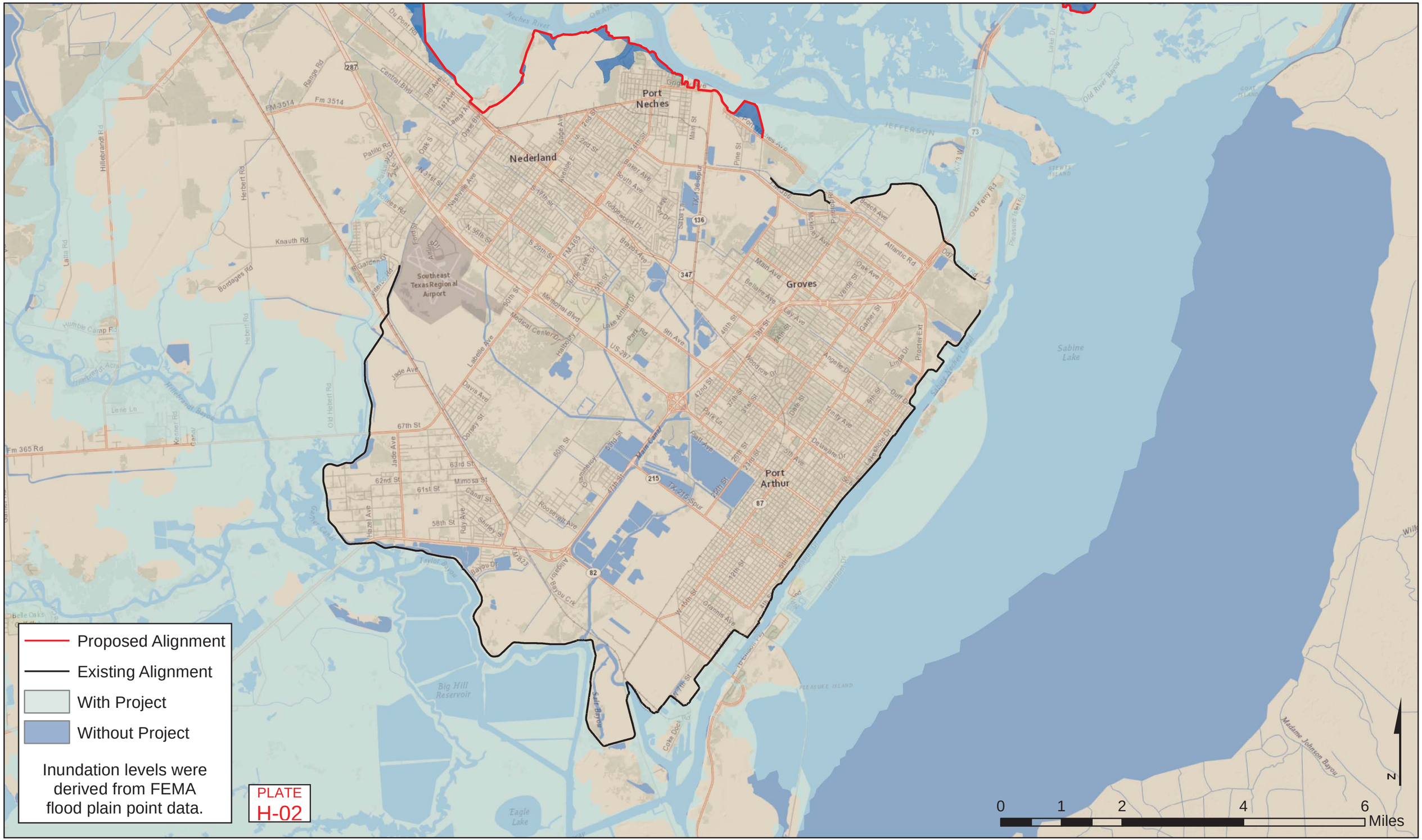
Freeport Inundation Change

at the 100 Year Flood Plain Level



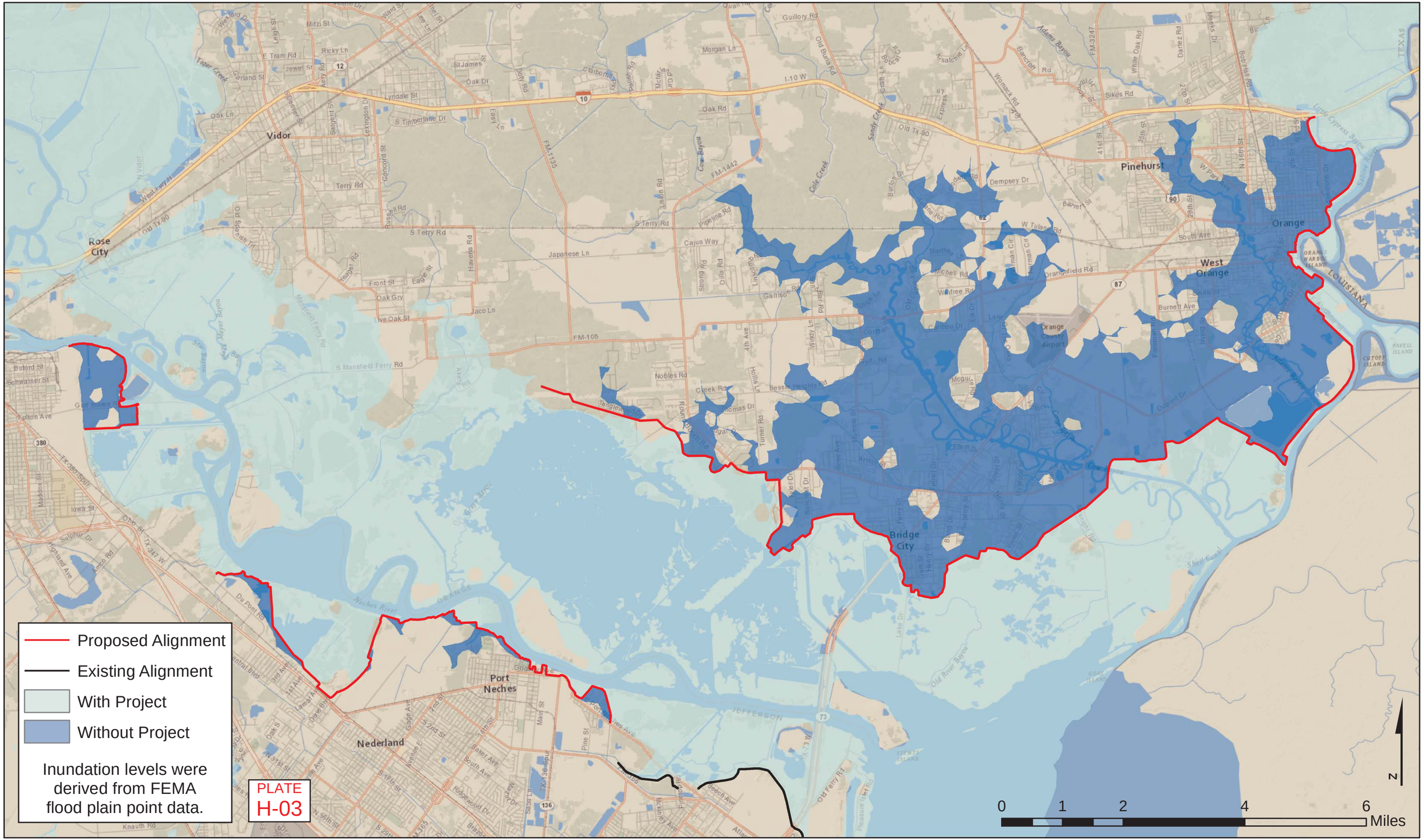
Port Arthur Inundation Map

at the 100 Year Flood Plain Level



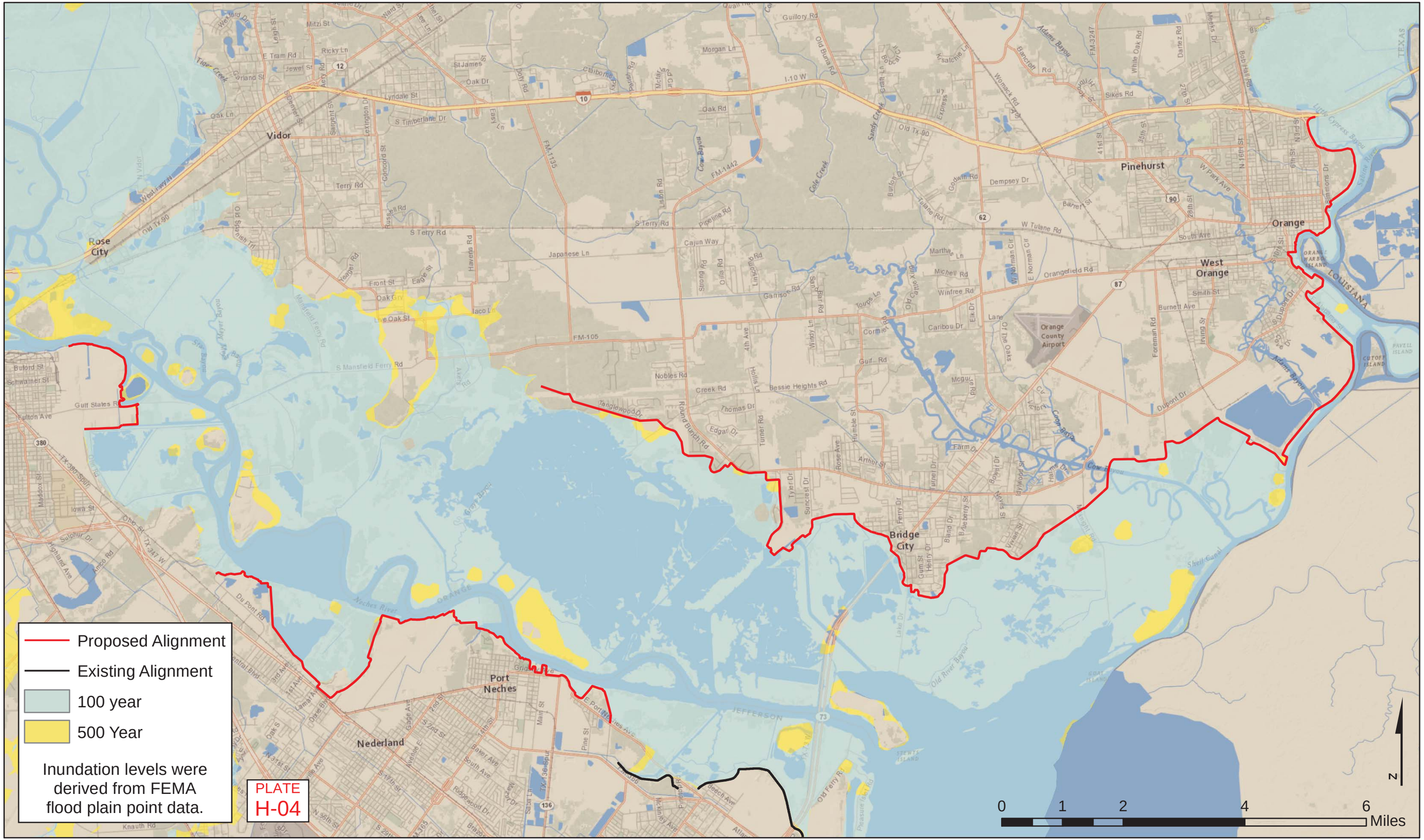
Jefferson/Orange Inundation Change

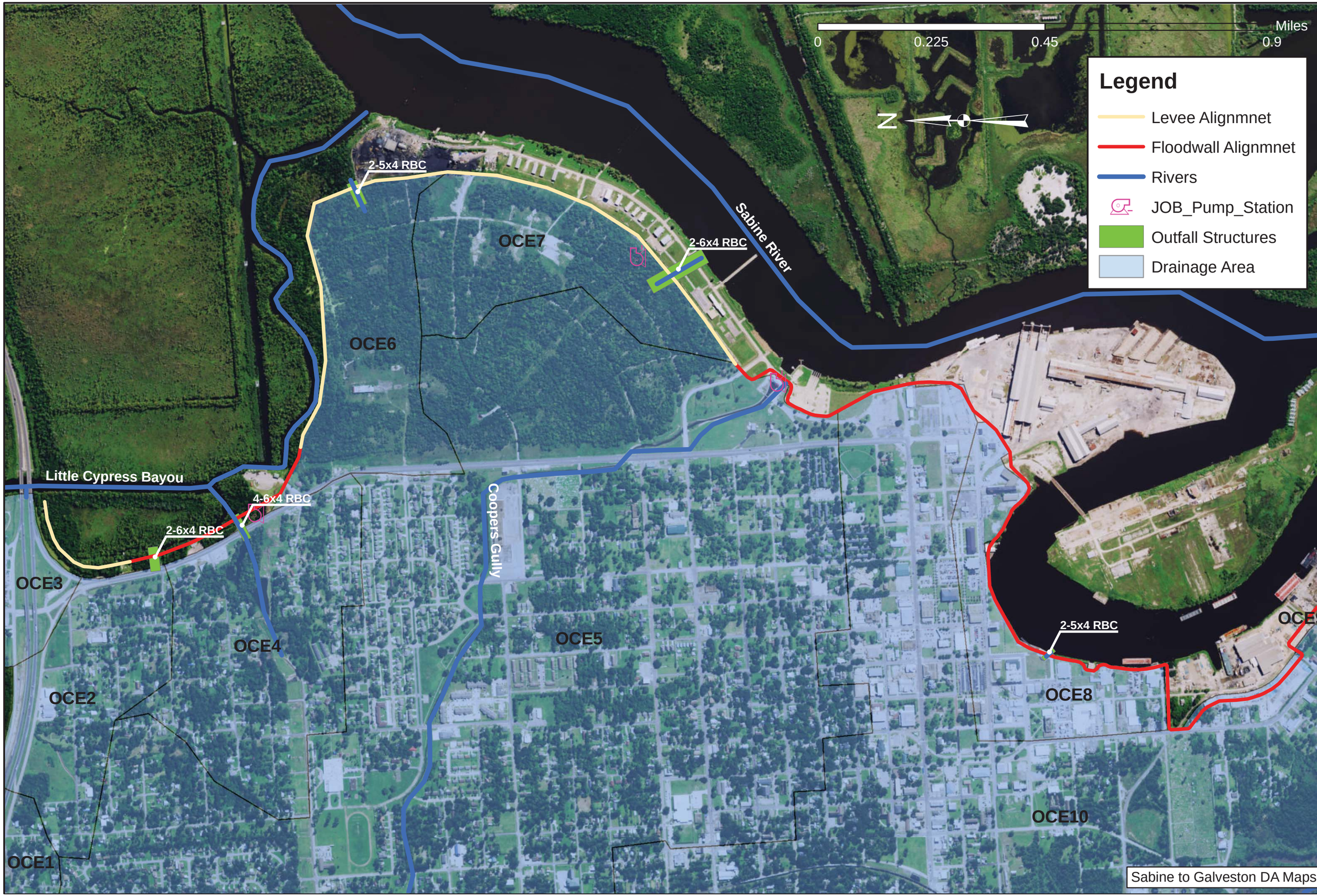
at the 100 Year Flood Plain Level



Jefferson/Orange Inundation Change

at the 500 Year Flood Plain Level





Sabine to Galveston DA Maps

US Army Corps of Engineers
Galveston District

Rev.	Description	Date	By
1	Update page 1 to better represent location of outfalls.	07/23	BB
2	Reformat alignment to show each section of levee and flood wall without stationing. Update color scheme.	07/31	BB

Drawn by: Brad Burrows
Designed by: Eric Wood
Reviewed by:
Submitted by:
Approved by:
Date: 31 July 2015
Rev: 2
Scale: 1:10,500
Approval Recommended
Chief Geo & Structural Section
Chief Engineer Branch
Chief Engineering and Construction Division

U.S. ARMY ENGINEER DISTRICT,GALVESTON
CORPS OF ENGINEERS,
GALVESTON, TEXAS

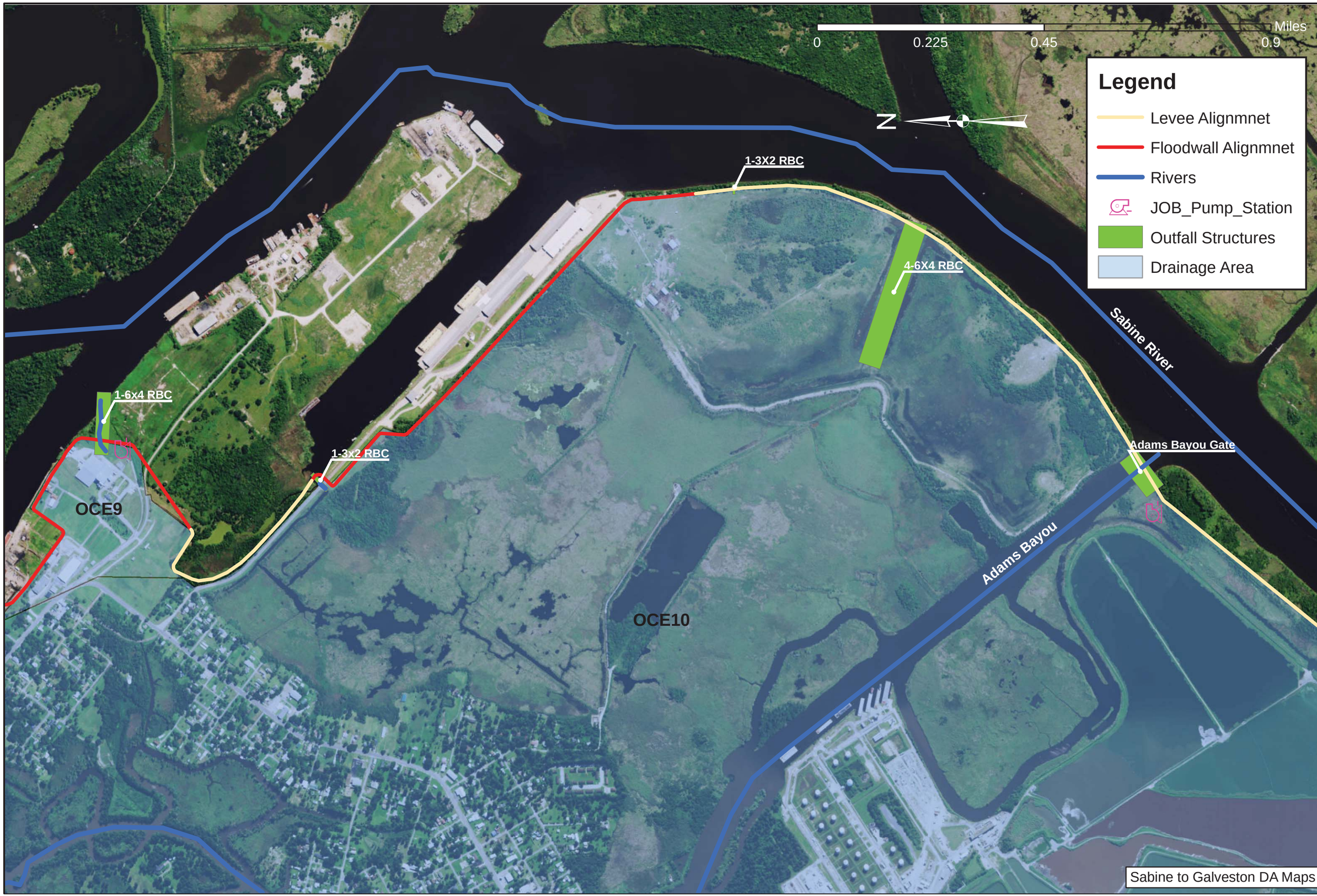
PREPARED UNDER THE DIRECTION OF
RICHARD P. PANNELL, COL.
DISTRICT COMMANDER

Sabine to Galveston, Texas
Orange and Jefferson County
Core Borings and CPTs

DRAINAGE AREA MAP ORANGE

Drawing No.

PLATE
H-05



US Army Corps of Engineers
Galveston District

Rev.	Description	Date	By
1	Update page 1 to better represent location of outfalls.	07/23	BB
2	Reformat alignment to show each section of levee and flood wall without stationing. Update color scheme.	07/31	BB

Drawn by: Brad Burrows
Designed by: Eric Wood
Reviewed by:
Submitted by:
Chief Geo & Structal Section
Approved by:
Chief Engineering and Construction Division
Date: 31 July 2015
Rev: 2
Scale: 1:10,500
Approval Recommended
Chief Engineer Branch

U.S. ARMY ENGINEER DISTRICT,GALVESTON
CORPS OF ENGINEERS,
GALVESTON, TEXAS

PREPARED UNDER THE DIRECTION OF
RICHARD P. PANNELL, COL.
DISTRICT COMMANDER

Sabine to Galveston, Texas
Orange and Jefferson County
Cove Springs and CPTs

DRAINAGE AREA MAP ORANGE

Drawing No.

PLATE
H-06

US Army Corps of Engineers®
Galveston District

Rev.	Description	Date	By
1	Update page 1 to better represent location of outfalls.	07/23	BB
2	Reformat alignment to show each section of levee and flood wall without stationing. Update color scheme.	07/31	BB

Drawn by: Brad Burrows
Designed by: Eric Wood
Reviewed by:
Submitted by:
Chief Geo & Structural Section
Approved by:
Chief Engineering and Construction Division

Date: 31 July 2015
Rev: 2
Scale: 1:10,500
Approval Recommended
Chief Engineer Branch

U.S. ARMY ENGINEER DISTRICT,GALVESTON
CORPS OF ENGINEERS,
GALVESTON, TEXAS

PREPARED UNDER THE DIRECTION OF
RICHARD P. PANNELL, COL.
DISTRICT COMMANDER

Sabine to Galveston, Texas
Orange and Jefferson County
Coastal Barrier Study

DRAINAGE AREA MAP ORANGE

Drawing No.

PLATE
H-07

Sabine to Galveston DA Maps

US Army Corps of Engineers®
Galveston District

Rev.	Description	Date	By
1	Update page 1 to better represent location of outfalls.	07/23	BB
2	Reformat alignment to show each section of levee and flood wall without stationing. Update color scheme.	07/31	BB

Drawn by: Brad Burrows
Designed by: Eric Wood
Date: 31 July 2015
Rev: 2
Scale: 1:10,500
Reviewed by:
Submitted by: Approval Recommended
Chief Geo & Structural Section: Chief Engineer Branch
Approved by:
Chief Engineering and Construction Division

U.S. ARMY ENGINEER DISTRICT,GALVESTON
CORPS OF ENGINEERS,
GALVESTON, TEXAS

PREPARED UNDER THE DIRECTION OF
RICHARD P. PANNELL, COL.
DISTRICT COMMANDER

Sabine to Galveston, Texas
Orange and Jefferson County
Cow Bayou and CPTS

DRAINAGE AREA MAP ORANGE

Drawing No.

PLATE
H-08

US Army Corps of Engineers®
Galveston District

Rev.	Description	Date	By
1	Update page 1 to better represent location of outfalls.	07/23	BB
2	Reformat alignment to show each section of levee and flood wall without stationing. Update color scheme.	07/31	BB

Drawn by: Brad Burrows
Designed by: Eric Wood
Reviewed by:
Submitted by: Chief Geo & Structural Section
Approved by: Chief Engineering and Construction Division
Date: 31 July 2015
Scale: 1:10,500
Rev: 2
Approval Recommended
Chief Engineer Branch

U.S. ARMY ENGINEER DISTRICT,GALVESTON
CORPS OF ENGINEERS,
GALVESTON, TEXAS

PREPARED UNDER THE DIRECTION OF
RICHARD P. PANNELL, COL.
DISTRICT COMMANDER

Sabine to Galveston, Texas
Orange and Jefferson County
Coastal Barrings and CFTS

DRAINAGE AREA MAP ORANGE

Drawing No.

PLATE
H-09

US Army Corps of Engineers
Galveston District

Rev.	Description	Date	By
1	Update page 1 to better represent location of outfalls.	07/23	BB
2	Reformat alignment to show each section of levee and flood wall without stationing. Update color scheme.	07/31	BB

Drawn by: Brad Burrows
Designed by: Eric Wood
Reviewed by:
Submitted by:
Chief Geo & Structural Section
Approved by:
Chief Engineering and Construction Division

Date: 31 July 2015
Scale: 1:10,500
Approval Recommended
Chief Engineer Branch

Rev. 2

U.S. ARMY ENGINEER DISTRICT,GALVESTON
CORPS OF ENGINEERS,
GALVESTON, TEXAS

PREPARED UNDER THE DIRECTION OF
RICHARD P. PANNELL, COL.
DISTRICT COMMANDER

Sabine to Galveston, Texas
Orange and Jefferson County
Coea Bayous and Cr's

DRAINAGE AREA MAP ORANGE

Drawing No.

PLATE
H-10

Sabine to Galveston DA Maps

US Army Corps of Engineers®
Galveston District

Rev.	Description	Date	By
1	Update page 1 to better represent location of outfalls.	07/23	BB
2	Reformat alignment to show each section of levee and flood wall without stationing. Update color scheme.	07/31	BB

Drawn by: Brad Burrows
Designed by: Eric Wood
Reviewed by:
Submitted by: Chief Geo & Structural Section
Approved by: Chief Engineering and Construction Division
Date: 31 July 2015
Scale: 1:10,500
Approval Recommended
Chief Engineer Branch
Rev: 2

U.S. ARMY ENGINEER DISTRICT,GALVESTON
CORPS OF ENGINEERS,
GALVESTON, TEXAS

PREPARED UNDER THE DIRECTION OF
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Sabine to Galveston, Texas
Orange and Jefferson County
Core Borings and CPTs

DRAINAGE AREA MAP ORANGE

Drawing No.

PLATE
H-11

Sabine to Galveston DA Maps

US Army Corps of Engineers®
Galveston District

Rev.	Description	Date	By
1	Update page 1 to better represent location of outfalls.	07/23	BB
2	Reformat alignment to show each section of levee and flood wall without stationing. Update color scheme.	07/31	BB

Drawn by: Brad Burrows
Designed by: Eric Wood
Date: 31 July 2015
Rev: 2
Scale: 1:10,500
Reviewed by:
Submitted by:
Approval Recommended
Chief Geo & Stucutal Section
Chief Engineer Branch
Approved by:
Chief Engineering and Construction Division

U.S. ARMY ENGINEER DISTRICT,GALVESTON
CORPS OF ENGINEERS,
GALVESTON, TEXAS

PREPARED UNDER THE DIRECTION OF
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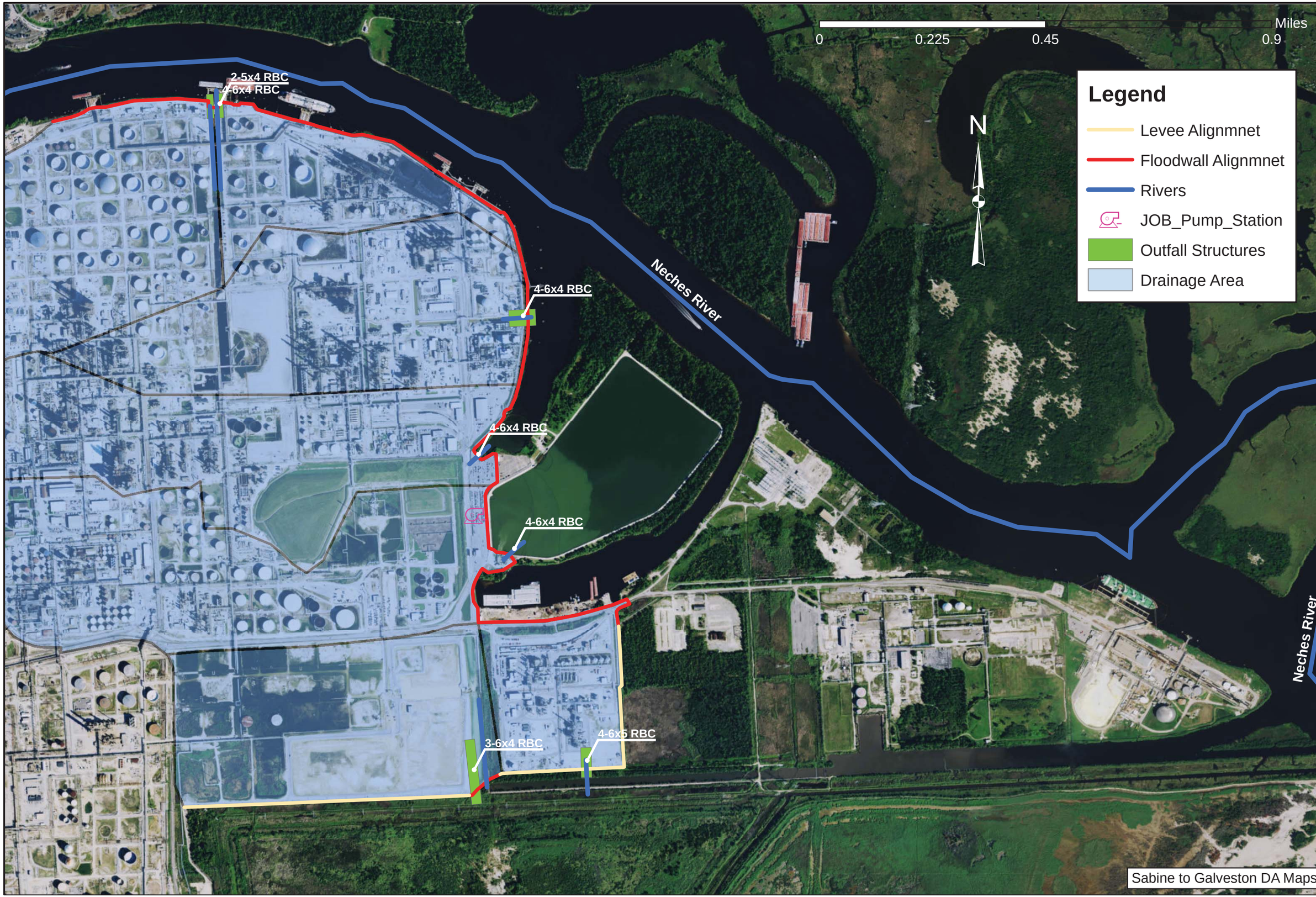
DISTRICT COMMANDER

Sabine to Galveston, Texas
Orange and Jefferson County
Case Borings and CPTs

DRAINAGE AREA MAP ORANGE

Drawing No.

PLATE
H-12



Sabine to Galveston DA Maps

US Army Corps of Engineers
Galveston District

Rev.	Description	Date	By
1	Update page 1 to better represent location of outfalls.	07/23	BB
2	Reformat alignment to show each section of levee and flood wall without stationing. Update color scheme.	07/31	BB

Drawn by: Brad Burrows
Designed by: Eric Wood
Reviewed by:
Submitted by:
Approved by:
Date: 31 July 2015
Scale: 1:10,500
Rev: 2
Approval Recommended
Chief Geo & Structal Section
Chief Engineer Branch
Chief Engineering and Construction Division

U.S. ARMY ENGINEER DISTRICT,GALVESTON
CORPS OF ENGINEERS,
GALVESTON, TEXAS

PREPARED UNDER THE DIRECTION OF
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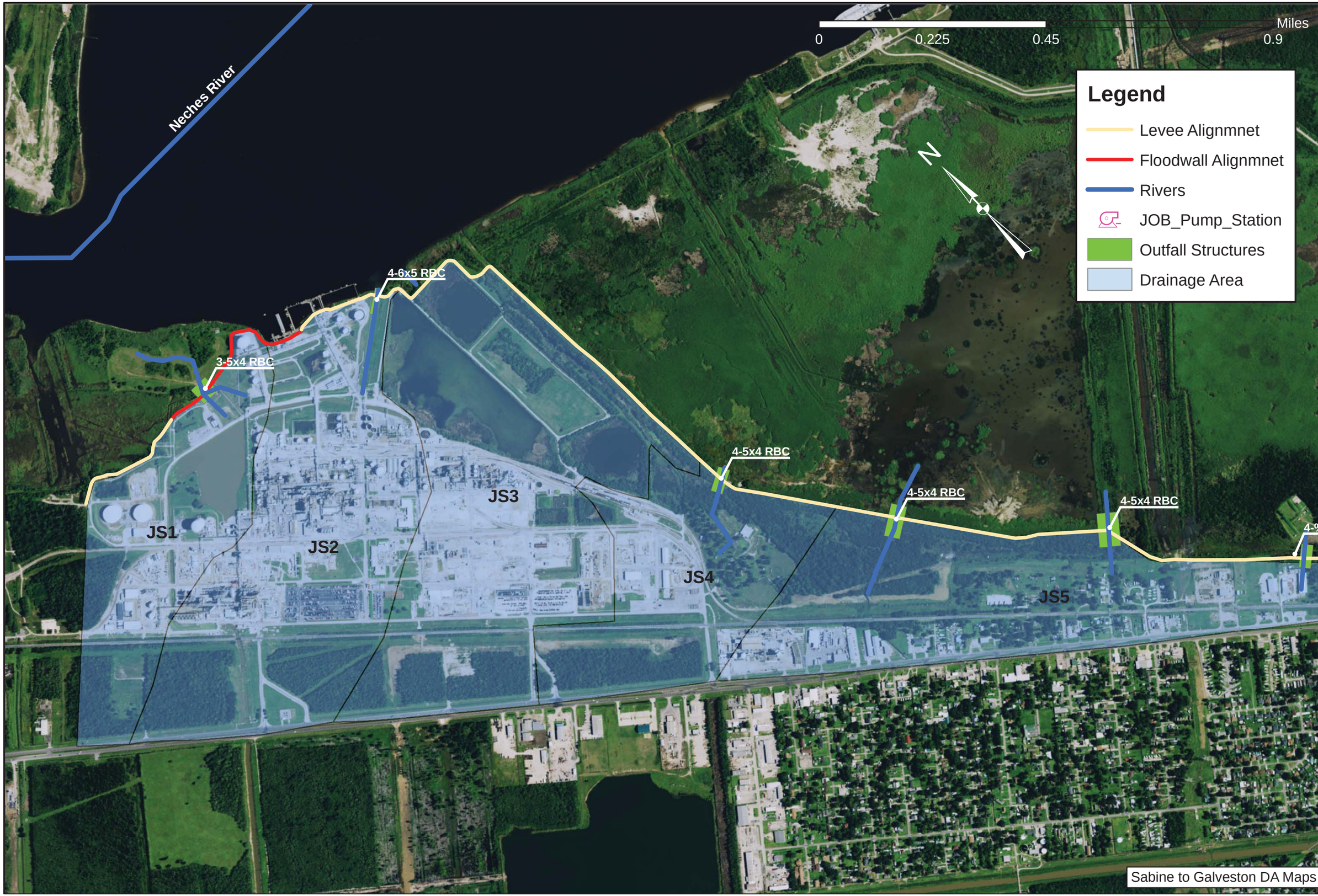
DISTRICT COMMANDER

Sabine to Galveston, Texas
Orange and Jefferson County
Cove Borings and CPTs

DRAINAGE AREA MAP BEAUMONT

Drawing No.

PLATE
H-13



US Army Corps of Engineers
Galveston District

Rev.	Description	Date	By
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2	Reformat alignment to show each section of levee and flood wall without stationing. Update color scheme.	07/31	BB

Drawn by: Brad Burrows
Designed by: Eric Wood
Reviewed by:
Submitted by: Chief Geo & Structal Section
Approved by: Chief Engineering and Construction Division
Date: 31 July 2015
Scale: 1:10,500
Approval Recommended: Chief Engineer Branch
Rev. 2

U.S. ARMY ENGINEER DISTRICT,GALVESTON
CORPS OF ENGINEERS,
GALVESTON, TEXAS

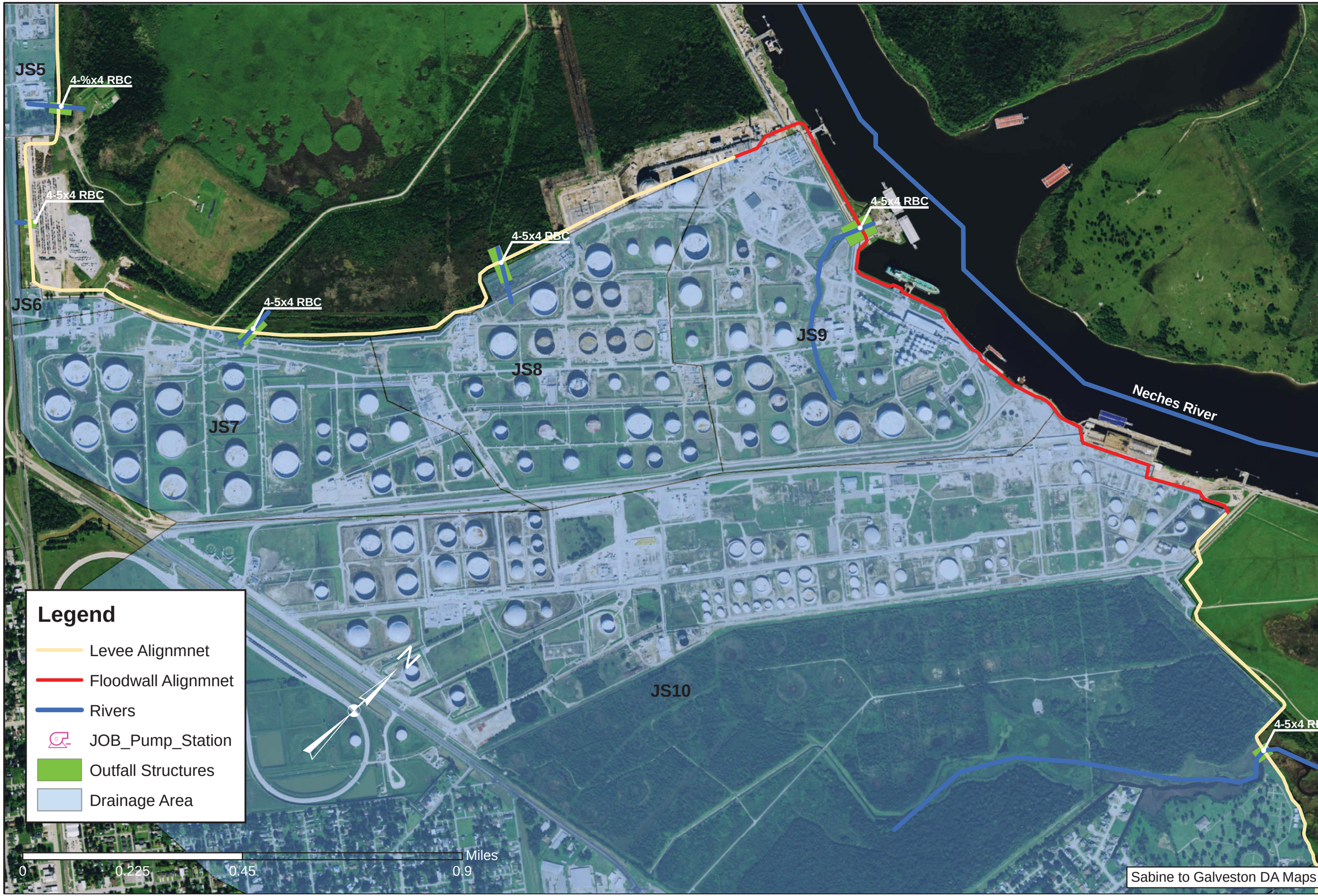
PREPARED UNDER THE DIRECTION OF
RICHARD P. PANNELL, COL.
DISTRICT COMMANDER

Sabine to Galveston, Texas
Orange and Jefferson County
Core Borings and CPTs

DRAINAGE AREA MAP JEFFERSON

Drawing No.

PLATE
H-14



Sabine to Galveston DA Maps

US Army Corps of Engineers
Galveston District

Rev.	Description	Date	By
1	Update page 1 to better represent location of outfalls.	07/23	BB
2	Reformat alignment to show each section of levee and flood wall without stationing. Update color scheme.	07/31	BB

Drawn by: Brad Burrows
Designed by: Eric Wood
Reviewed by:
Submitted by:
Chief Geo & Stucutal Section
Approved by:
Chief Engineering and Construction Division

Date: 31 July 2015
Rev: 2
Scale: 1:10,500
Approval Recommended
Chief Engineer Branch

U.S. ARMY ENGINEER DISTRICT,GALVESTON
CORPS OF ENGINEERS,
GALVESTON, TEXAS

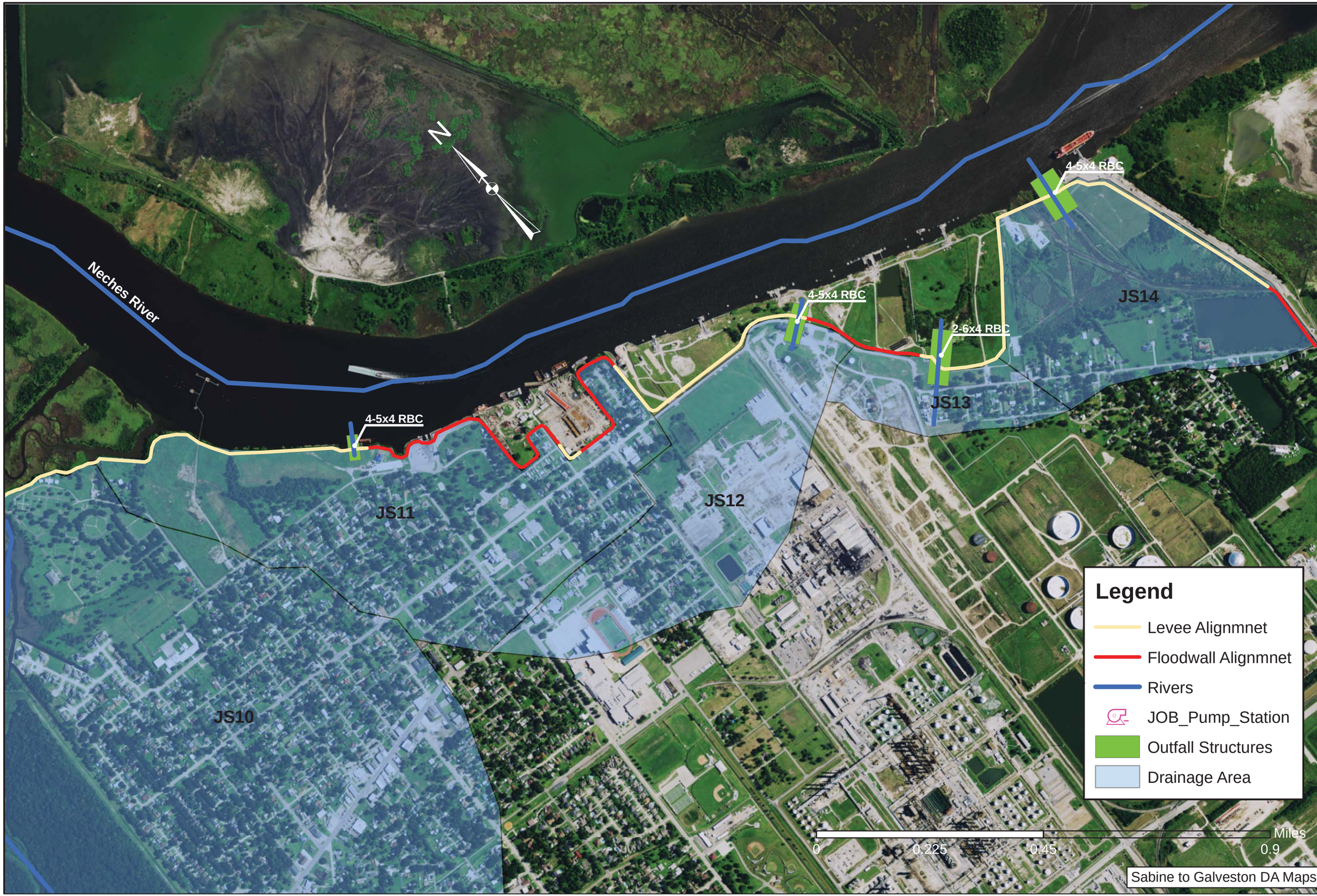
PREPARED UNDER THE DIRECTION OF
RICHARD P. PANNELL, COL.
DISTRICT COMMANDER

Sabine to Galveston, Texas
Orange and Jefferson County
Core Borings and CPTs

DRAINAGE AREA MAP JEFFERSON

Drawing No.

PLATE
H-15



US Army Corps of Engineers®
Galveston District

Rev.	Description	Date	By
1	Update page 1 to better represent location of outfalls.	07/23	BB
2	Reformat alignment to show each section of levee and flood wall without stationing. Update color scheme.	07/31	BB

Drawn by: Brad Burrows
Designed by: Eric Wood
Reviewed by:
Submitted by:
Chief Geo & Stucutal Section
Approved by:
Chief Engineering and Construction Division

Date: 31 July 2015
Rev: 2
Scale: 1:10,500
Approval Recommended
Chief Engineer Branch

U.S. ARMY ENGINEER DISTRICT,GALVESTON
CORPS OF ENGINEERS,
GALVESTON, TEXAS

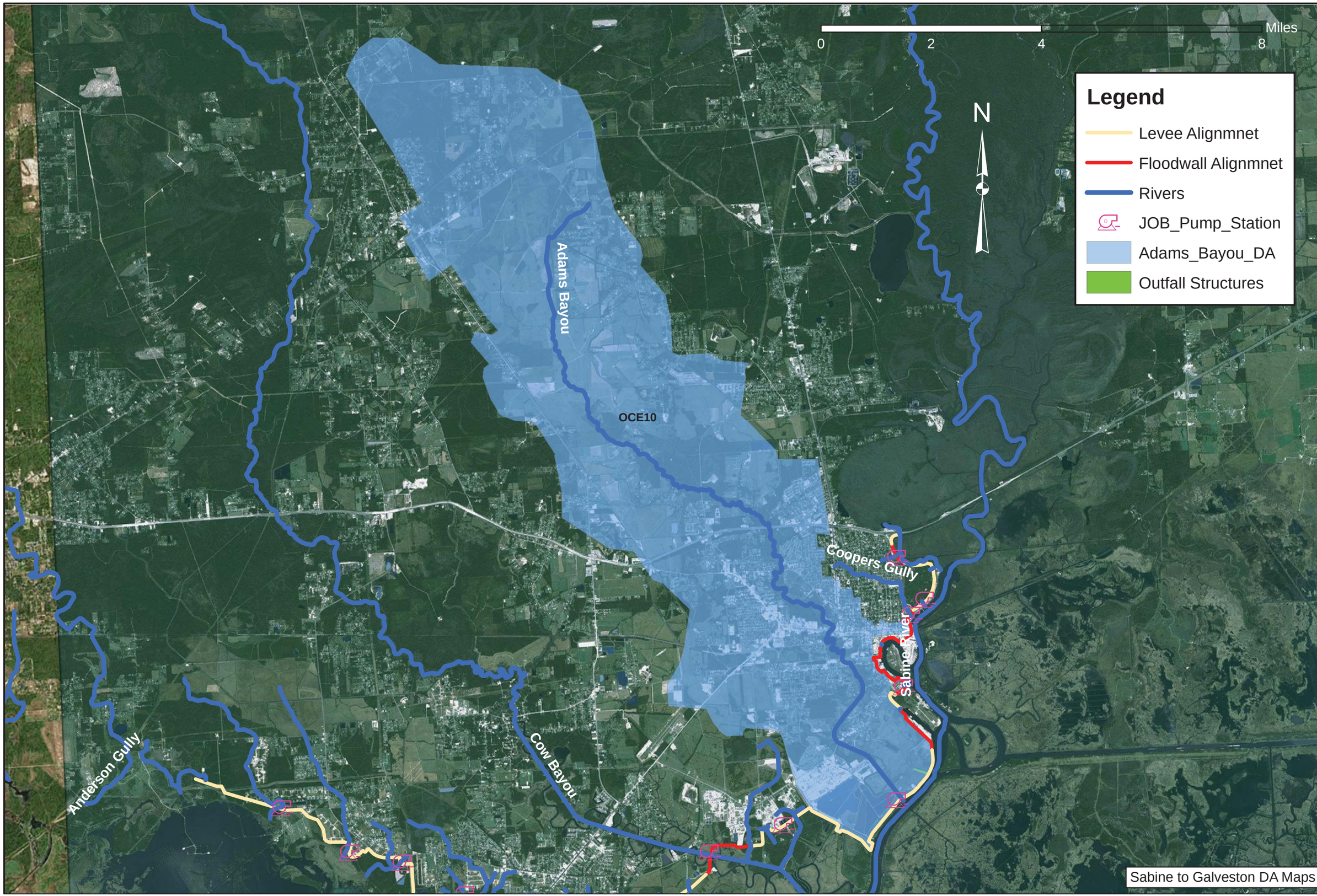
PREPARED UNDER THE DIRECTION OF
RICHARD P. PANNELL, COL.
DISTRICT COMMANDER

Sabine to Galveston, Texas
Orange and Jefferson County
Clove Savings and CPTS

DRAINAGE AREA MAP JEFFERSON

Drawing No.

PLATE
H-16



US Army Corps of Engineers
Galveston District

Rev.	Description	Date	By
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Drawn by: Brad Burrows
Designed by: Eric Wood
Reviewed by:
Submitted by:
Chief Geo & Stucural Section
Approved by:
Chief Engineering and Construction Division
Date: 31 July 2015
Scale: 1:10,500
Rev: 2
Approval Recommended
Chief Engineer Branch

U.S. ARMY ENGINEER DISTRICT,GALVESTON
CORPS OF ENGINEERS,
GALVESTON, TEXAS

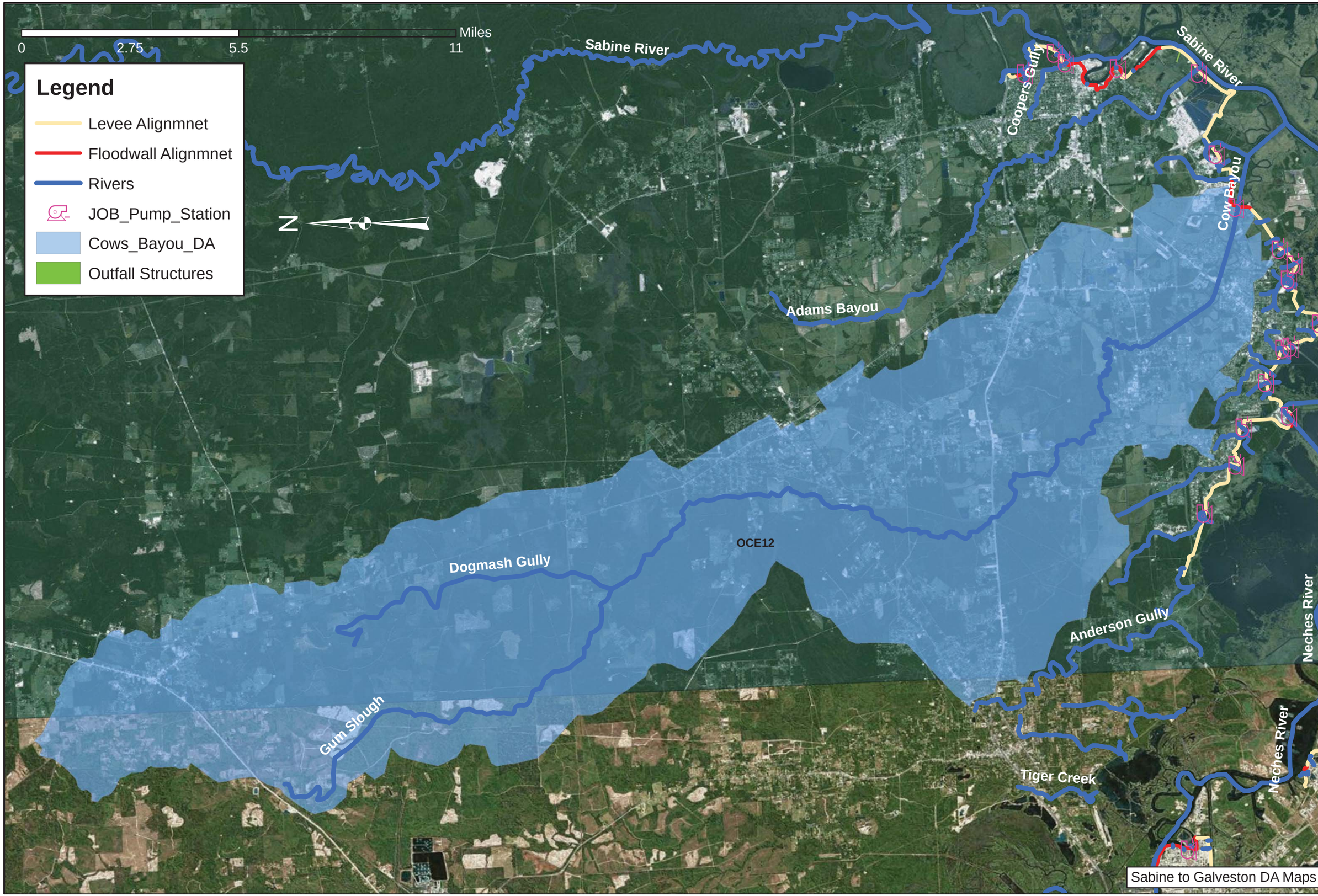
PREPARED UNDER THE DIRECTION OF
RICHARD P. PANNELL, COL.
DISTRICT COMMANDER

Sabine to Galveston, Texas
Orange and Jefferson County
Coordinates and Datums

DRAINAGE AREA MAP ADAMS BAYOU (ORANGE)

Drawing No.

PLATE
H-17



Sabine to Galveston DA Maps

US Army Corps of Engineers®
Galveston District

Rev.	Description	Date	By
1	Update page 1 to better represent location of outfalls.	07/23	BB
2	Reformat alignment to show each section of levee and flood wall without stationing. Update color scheme.	07/31	BB

Drawn by: Brad Burrows
Designed by: Eric Wood
Reviewed by:
Submitted by:
Approved by:
Chief Geo & Structural Section
Chief Engineering and Construction Division
Chief Engineer Branch
Approval Recommended
Scale: 1:10,500
Date: 31 July 2015
Rev: 2

U.S. ARMY ENGINEER DISTRICT,GALVESTON
CORPS OF ENGINEERS,
GALVESTON, TEXAS

PREPARED UNDER THE DIRECTION OF
RICHARD P. PANNELL, COL.
DISTRICT COMMANDER

Sabine to Galveston, Texas
Orange and Jefferson County
Coastal Texas Study

DRAINAGE AREA MAP COW BAYOU (ORANGE)

Drawing No.

PLATE
H-18

Sabine Pass to Galveston Bay, Texas
Coastal Storm Risk Reduction and Ecosystem Restoration
Draft Integrated Feasibility Report and Environmental Impact Study

Draft Appendix E

Real Estate

September 2015

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1 PURPOSE

This Real Estate Plan (REP) has been prepared in support of the feasibility study that describes the lands, easements, rights of way, relocation, and disposal (LERRD) required for the for the Sabine Pass to Galveston Bay, Texas, Feasibility Study. The information contained herein is tentative in nature for planning purposes only.

2 PROJECT LOCATION

The study area consists of three distinct project areas: Orange, Jefferson, and Brazoria regions. The Orange region is located about 90 miles east of the City of Houston and shares a border with the State of Louisiana. The region is approximately 356 square miles in size, 333 square miles of land and 23 square miles of water. A total of seven incorporated cities (Orange, Vidor, Bridge City, West Orange, Rose City, Pinehurst, and Pine Forest) are in this region. The Jefferson region is located about 90 miles east of the City of Houston. The region is approximately 1,111 square miles in size, 904 square miles of land and 207 square miles of water. A total of nine incorporated cities (Beaumont, Port Arthur, Nederland, Port Neches, Groves, China, Nome, Bevil Oaks, and Taylor Landing) are in this region. The Brazoria region is located about 60 miles south of the City of Houston. The region is approximately 1,597 square miles in size, 1,386 square miles of land and 211 square miles of water. A total of 20 incorporated cities (Angleton, Pearland, Lake Jackson, Brazoria, Alvin, Freeport, Clute, Rosharon, Manvel, Sweeny, West Columbia, Surfside Beach, Danbury, Richwood, Quintana, Oyster Creek, Jones Creek, Iowa Colony, Brookside Village, and Liverpool) are in the county. The study area is identified on Exhibit A.

For the purposes of this report, the Tentatively Selected Plan (TSP) project areas were renamed as Orange-Jefferson Coastal Storm Risk Management (CSRM), Port Arthur and Vicinity CSRM, and Freeport and Vicinity CSRM. Within the project area are different reaches. Reaches of project areas are listed below and are shown on Exhibits B-D.

Orange-Jefferson CSRM

- Orange 3
- Jefferson Main
- Beaumont A

Port Arthur and Vicinity CSRM

- 8- to10-foot I-Wall
- Closure Structure
- I-Wall Near Valero
- I-Wall Near Tank Farm

Freeport and Vicinity CSRM

- DOW Barge Canal
- Oyster Creek Levee
- East Storm Levee
- South Storm Levee
- Freeport Dock Floodwall
- Old River Levee at DOW Thumb
- Tide Gate I-Wall

3 PROJECT AUTHORIZATION

Authorization for the study is derived from a resolution from the Committee on Environmental and Public Works dated June 23, 2004, entitled "Coastal Texas Protection and Restoration Study".

By resolution dated June 23, 2004, entitled "Coastal Texas Protection and Restoration Study", the Committee on Environment and Public Works, U.S. Senate has requested that in accordance with Section 110 of the Rivers and Harbors Act of 1962 the Secretary of the Army develop a comprehensive plan for severe erosion along coastal Texas for the purposes of shoreline erosion and coastal storm damages, providing for environmental restoration and protection, increasing natural sediment supply to coast, restoring and preserving marshes and wetlands, improving water quality, and other related purposes to the interrelated ecosystem along the coastal Texas area.

The study fits into the overall concept of the authorization to conduct an integrated and coordinated approach to locating and implementing opportunities for CSRM. The purpose of the study is to recommend for Congressional approval a regional CSRM project that encompasses counties of the upper Texas coast between Sabine Pass and Galveston Bay.

4 NON-FEDERAL SPONSOR

The USACE Galveston District was responsible for the overall management of the study and the report preparation. As the non-Federal sponsor (NFS), the Texas General Land Office (GLO) was actively involved throughout the study process. GLO is the NFS for the study phase only.

As the project moves towards implementation, three different entities have been identified as NFS for the three different project areas. Velasco Drainage District will oversee Freeport and Vicinity CSRM, Jefferson County Drainage District #7 will oversee Port Arthur and Vicinity CSRM features, and Orange County and Jefferson County will oversee Orange-Jefferson CSRM.

4.1 LANDS, EASEMENT, AND RIGHTS-OF-WAY

The Non-Federal Sponsor is responsible for acquiring and furnishing all lands, easements, rights-of-way, relocations (i.e., P.L. 91-646 relocations and utility/facility relocations), borrow material, and dredged or excavated material disposal areas (LERRD) for the project, if required. All lands needed for this project will be acquired in fee, with the exception of the land needed for the flood protection levee easement, staging areas, a perpetual road easement, and borrow area easement. A review of LERRD requirements is set forth below. The real estate requirements for the Project must support construction, as well as the continued operation and maintenance of the Project. The majority of the acreage affected by the project consists of residential, commercial, industrial, and vacant/undeveloped and marsh land.

The real estate interests for this project are as follows. The following Corps Standard Estates are applicable:

- *<u>Fee</u> - the fee simple title to the land described, subject, however, to existing easements for public roads and highways, public utilities, railroads, and pipelines.*

- *<u>Flood Protection Levee Easement</u> - a perpetual and assignable right and easement in the land described to construct, maintain, repair, operate, patrol, and replace a flood protection levee, including all appurtenances thereto; reserving, however, to the owners, their heirs, and assigns, all such rights and privileges in the land as may be used without interfering with or abridging the rights and easement hereby acquired; subject, however, to existing easements for public roads and highways, public utilities, railroads, and pipelines.*

- *<u>Temporary Work Area Easement</u> - a temporary easement and right-of-way in, on, over, and across the land described, for a period not to exceed ___ months, beginning with the*

date possession of the land is granted to the United States, for use by the United States, its representatives, agents, and contractors as a (work area), including the right to (borrow and/or deposit fill, spoil, and waste material thereon) (move, store and remove equipment and supplies, and erect and remove temporary structures on the land and to perform any other work necessary and incident to the construction of the _____ Project, together with the right to trim, cut, fell, and remove there from all trees, underbrush, obstructions, and any other vegetation, structures, or obstacles within the limits of the right-of-way; reserving, however, to the landowners, their heirs, and assigns, all such rights and privileges as may be used without interfering with or abridging the rights and easement hereby acquired; subject, however, to existing easements for public roads and highways, public utilities, railroads, and pipelines.

- *<u>Road Easement</u> - a perpetual easement and right-of-way in, on, over, and across the land described, for the location, construction, operation, maintenance, alteration replacement of (a) road and appurtenances thereto; together with the right to trim, cut, fell, and remove therefrom all trees, underbrush, obstructions, and other vegetation, structures, or obstacles within the limits of the right-of-way; reserving, however, to the landowners, their heirs, and assigns, the right to cross over or under the right-of-way as access to their adjoining land at the locations indicated in Schedule B; subject, however, to existing easements for public roads and highways, public utilities, railroads, and pipelines.*

- *<u>Borrow Easement</u> - a perpetual and assignable right and easement to clear, borrow, excavate, and remove soil, dirt, and other materials from the land described in (Schedule A) (Tracts ____); subject, however, to existing easements for public roads and highways, public utilities, railroads, and pipelines; reserving, however, to the landowners, their heirs, and assigns, all such rights and privileges in said land as may be used without interfering with or abridging the rights and easement hereby acquired.*

5 PROJECT LEVEE AND FLOODWALL ALIGNMENT

The project will affect approximately 216 ownerships*. Project features are shown in Exhibits G, H and I.

5.1 ORANGE – JEFFERSON CSRM

Descriptions of the Orange 3, Jefferson Main, and Beaumont A reaches assume levee height at 12 feet, 12 feet, and 13 feet, respectively. A TSP meeting was held on July 29, 2015, where the PDT was directed by HQ to lower levee height design by 1 foot in the reaches referenced above. The Real Estate Plan will be revised to reflect this directive prior to ADM.

Orange 3 Reach: Current plans indicate 21.51 miles of new levee (200 feet wide) and 5.65 miles of new floodwall (60 feet wide) will be constructed. In general, the alignment for the levee and/or floodwall starts near Rose City (I-10) and meanders in a southeast direction, turning north near Bridge City, to the termini near the City of Orange and adjacent to I-10. In support of the construction activities, the following estimates were used:

- 96 acres of borrow material will be required for the construction of new levee and floodwall
- 27.16 miles of perpetual road easement (40 feet wide) for operations and maintenance
- temporary work area easement (20 feet wide by 27.16 miles in length) for 3 years, seven staging areas (2.0 acres each) for 3 years

Jefferson Main & Beaumont A Reach: Current plans indicate 8.82 miles of levee (200 feet wide) and 5.49 miles of floodwall (60 feet wide) will be constructed. In general, the alignment starts on the west bank of the Neches River, immediately north of the DuPont facility, and meanders in a southeastern direction to Port Neches Atlantic Road. In support of the construction activities, the following estimates were used:

- 28 acres of borrow material will be required for the construction of new levee and floodwall
- 14.31 miles of perpetual road easement (40 feet wide) for operations and maintenance
- temporary work area easement (20 feet wide by 14.31 miles in length) for 3 years
- three staging areas (2.0 acres each) for 3 years, and one staging area (3.0 acres - Beaumont) for 3 years

5.2 PORT ARTHUR AND VICINITY CSRM

Certain portions of the existing 29.04-mile system of levees and floodwalls and/or closure system will be improved or replaced. All work will be achieved within the existing rights-of-way. In support, the following estimates were used:

- temporary work area easement (20 feet wide by 29.04 miles in length) for 3 years
- five staging areas (2.0 acres each) for 3 years.

5.3 FREEPORT AND VICINITY CSRM

Certain portions of the existing 43.12-mile system of levees and floodwalls and/or closure system will be improved or replaced. All work will be achieved within the existing rights-of-way. In support, the following estimates were used:

- temporary work area easement (20 feet wide by 43.12 miles in length) for 3 years
- 10 staging areas (2.0 acres each) for 3 years.

5.4 BORROW MATERIAL

Borrow material will only be needed in Orange and Jefferson counties for the construction of the levee and portions of the flood wall for the Orange-Jefferson CSRM. Locations of borrow have not been determined at this phase of the report. It is assumed that a total of 124 acres will be required for the Orange – Jefferson CSRM. No borrow material will be required for Port Arthur or Freeport CSRM.

5.5 ACCESS/STAGING AREA

Access to the construction areas will be over existing public roads and navigable waters throughout the project areas. In some areas, access will be via existing levee right-of-way. However, Temporary Access Easements are proposed in areas where access is needed on privately owned lands.

5.6 RECREATION FEATURES

The proposed Project does not have any recreation features.

5.7 INDUCED FLOODING

There will be no induced flooding by virtue of the construction of the Project.

5.8 MITIGATION

A total of approximately 139.9 acres of forested wetland and 100.9 acres of coastal marsh would be indirectly impacted. Mitigation would be needed to compensate for a loss of forested wetlands and coastal wetlands. Planning for the avoidance and minimization of impacts began with the initial selection of the Orange-Jefferson levee alignment. The levee was located as close to the upland-wetland margin as possible to minimize wetland impacts, while also minimizing social effects and maximizing economic impacts. Opportunities to further avoid and minimize environmental impacts will be identified during final feasibility planning. Only a conceptual description of the mitigation plan has been developed as described in the WVA Appendix. Lands required for mitigation will be identified during final feasibility planning.

5.9 FEDERALLY OWNED LAND AND EXISTING FEDERAL PROJECT

There is no existing Federally owned land within the LERRD required for this Project

5.10 NON-FEDERAL SPONSOR-OWNED LAND

There is no existing NFS-owned land within the LERRD required for this Project

5.11 NAVIGATION SERVITUDE

Portions of the project structures lie within the navigable waters of the United States, and therefore the Federal Navigational Servitude will be invoked for those portions of the project.

Navigation servitude is the dominant right of the Government under the Commerce Clause of the U.S. Constitution (U.S. CONST. Art. I, §8, cl.3) to use, control, and regulate the navigable waters of the United States and the submerged lands hereunder for various commerce-related purposes, including navigation and flood control. In tidal areas, the servitude extends to all lands below the mean high water mark. In non-tidal areas, the servitude extends to all lands within the bed and banks of a navigable stream that lie below the ordinary high water mark (United States v. Cress, 243 U.S. 316, 37 S.Ct. 380, 61 L.Ed. 746 [1917], Kaiser Aetna v. United States, 444 U.S. 164, 100 S.Ct. 383, 62 L.Ed.2d 332 [1979]). The Government's rights under the navigation servitude exist irrespective of the ownership of the banks and bed of a stream below the ordinary high water mark and irrespective of western water rights under prior appropriation doctrine.

6 PUBLIC LAW 91-646 RELOCATION ASSISTANCE

The benefits of Title II of the Uniform Relocation Assistance and Real Property Acquisition Policy Act of 1970 (P.L. 91-646), as amended, are applicable for this project. Title II requires that persons and businesses displaced by a Federal project be given advisory services and assistance in the location of replacement dwellings and businesses.

Under Title II, displaced persons are entitled to reimbursement for actual and reasonable moving of personal property, differential housing payment, and incidental costs associated with the relocation. Differential housing payment is a payment made by the Government when the compensation paid for the property being acquired is not sufficient to cover the costs of a replacement dwelling for the displaced persons. Differential payments are capped at $34,000 for homeowners and $10,200 for tenants. Commercial businesses are entitled to receive advisory services, reimbursement for actual reasonable moving costs, re establishment costs which are capped at $10,000, and certain reasonable and necessary incidental costs associated with the relocation. For purposes of this study, the estimate of relocation for business includes all of these costs and was estimated to be approximately $100,000 per industrial business and $50,000 per commercial business.

7 ASSESSMENT OF NON-FEDERAL SPONSOR LAND ACQUISITION CAPABILITIES

GLO is the current NFS for the study phase only. As the project moves towards implementation, three different entities have been identified as a NFS for the three different project areas. Velasco Drainage District will oversee Freeport and Vicinity CSRM, Jefferson County Drainage District #7 will oversee Jefferson County features, and Orange County will oversee Orange County features.

At the point which the new NFS has been declared for each project area, an assessment of its land acquisitions capabilities will be made and updated in this REP.

8 BASELINE COST ESTIMATE FOR REAL ESTATE

Descriptions of the Orange 3, Jefferson Main, and Beaumont A reaches assume levee heights at 12 feet, 12 feet, and 13 feet, respectively. A TSP meeting was held on July 29, 2015, where the PDT was directed by HQ to lower levee height design by 1 foot in the reaches referenced above.

Refer to Exhibits E and F for the Baseline Cost Estimate/Chart of Accounts estimate for Port Arthur and Freeport CSRM project areas. Cost for the Orange-Jefferson CSRM is not shown due to the July 29 TSP meeting. The Baseline Cost Estimate for Orange-Jefferson CSRM will be revised to reflect the HQ directive prior to ADM.

Non-Federal Cost was estimated for planning purposes only. Because the NFS have not been formally declared for the construction of the project, non-Federal "Project Related Administration" and "LERRD Crediting" activity costs were determined by increasing Federal cost by 40 percent. Non-Federal costs will be updated to be more accurate as the NFS are formally identified. Land costs were obtained by a gross appraisal that was performed by a USACE appraiser.

9 ACQUISITION SCHEDULE

An acquisition schedule has not been determined at this time. The NFS will be required to acquire the land for proposed Coastal Storm Risk Management features after an amended LCA/PPA has been signed and prior to the advertisement for construction, such that the features can be constructed and available for use as scheduled. A description of acquisition milestones is listed below.

Milestones are based on the Project Partnership Agreement being signed	
Transmittal of ROW drawings & estate(s)	30 days after PPA signed
Obtain Surveys	60 days after transmittal of ROW drawings & estate(s)
Obtain Title Evidence	60 days after obtaining surveys
Obtain Appraisals & Reviews	60 days after obtaining titles
Authorization to Proceed with Offer	10 days after obtaining appraisals & reviews
Conclude Negotiations	90 days after start of negotiations
Conclude Closings	45 days after concluding closings
Conclude Condemnations	240 days after condemnation process starts
Attorney Certify Availability of LERRD	15 days after condemnations concluded
Corps Certifies Availability of LERRD	5 days after NFS Attorney Certifies LERRD
Review LERRD Credit Request	45 days after receiving LERRD documentation
Approve or Deny LERRD Credit Requests	5 days after concluding review of LERRD documentation

10 MINERALS

Extensive research has been done to verify any present or anticipated mineral activity. There are no known mineral interests or any evidence of the use of horizontal directional drilling within the proposed Project areas.

11 FACILITIES/UTILITIES/PIPELINE RELOCATION AND REMOVALS

It is known that there will be multiple pipelines that will be impacted by this project. However, relocation and modification costs were purposely not included because the relocations and modifications that will be necessary largely depend on how the feature designs evolve prior to ADM, and what the actual field conditions are when more thoroughly investigated.

12 HTRW OR OTHER ENVIRONMENTAL CONTAMINATES

Database searches were performed to identify potential sites of concern in the project area. Investigations indicate no HTRW areas are within or adjacent to the proposed project areas which could impact the project. Based on findings of the searches, the potential of encountering HTRW is considered low. A more detailed description of HTRW can be found in the HTRW Appendix.

13 LANDOWNER OPPOSITION

During the preliminary phases of this report, there was a mix of both support and opposition from landowners. Landowner concerns were due to the alignment of the levee and flood walls. It was explained that this project is only in the preliminary study phase and final design has not been determined.

14 ZONING

No application or enactment of zoning ordinances is proposed in connection with the Project.

Exhibit A. Study Area

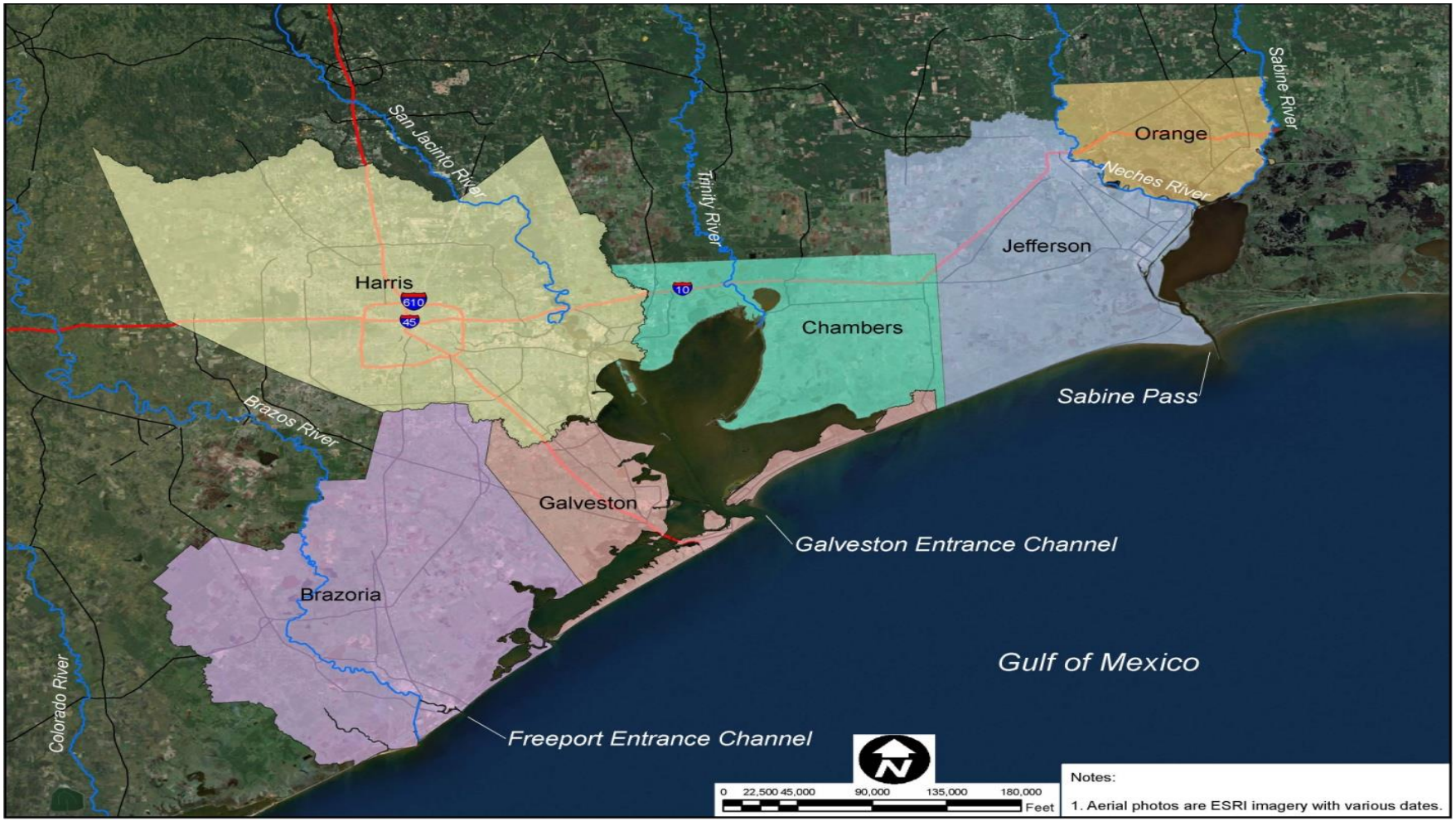

Exhibit B. TSP for Orange-Jefferson CSRM

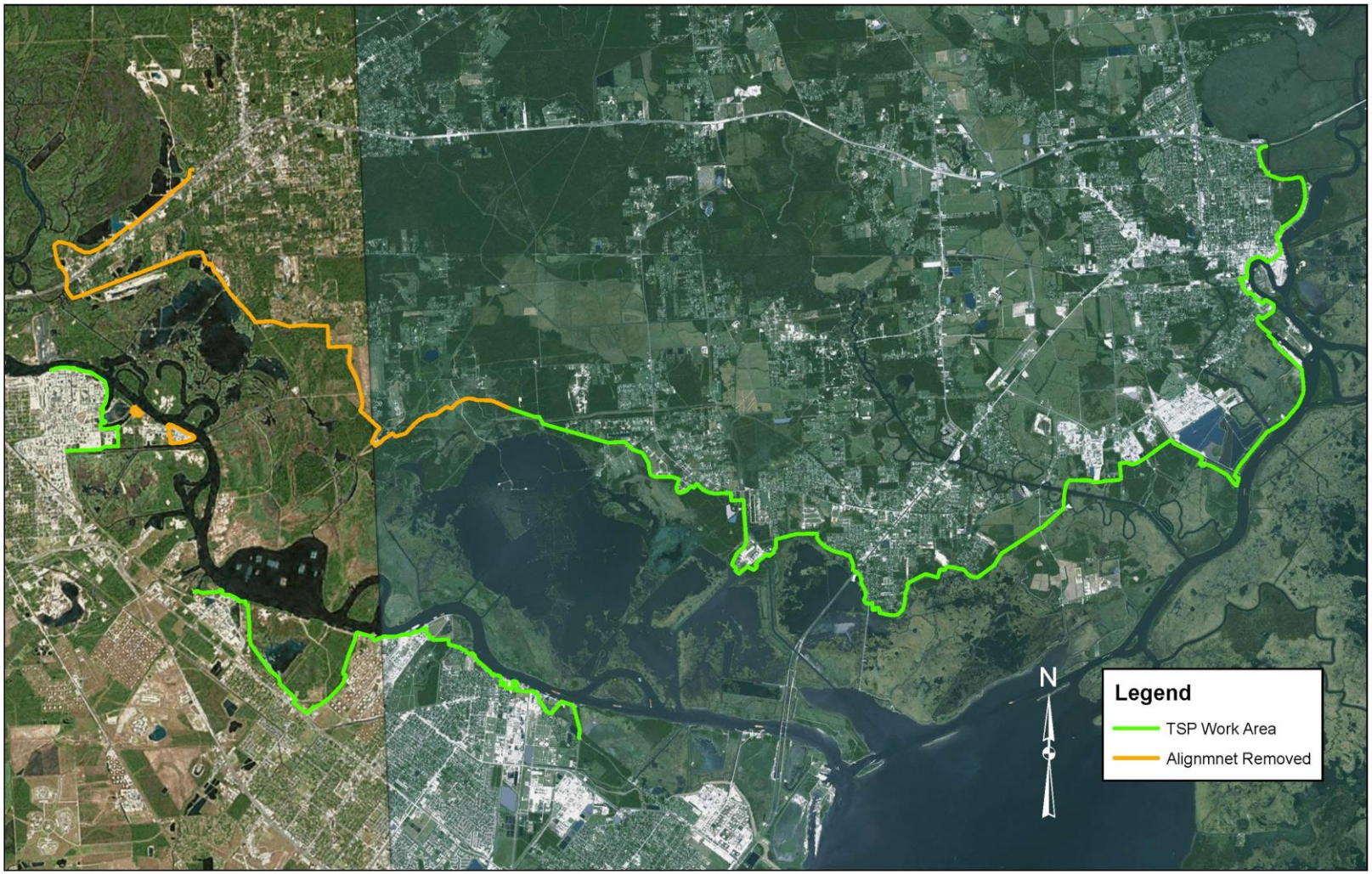

Exhibit C. TSP for Port Arthur and Vicinity CSRM

Exhibit D. TSP for Freeport and Vicinity CSRM

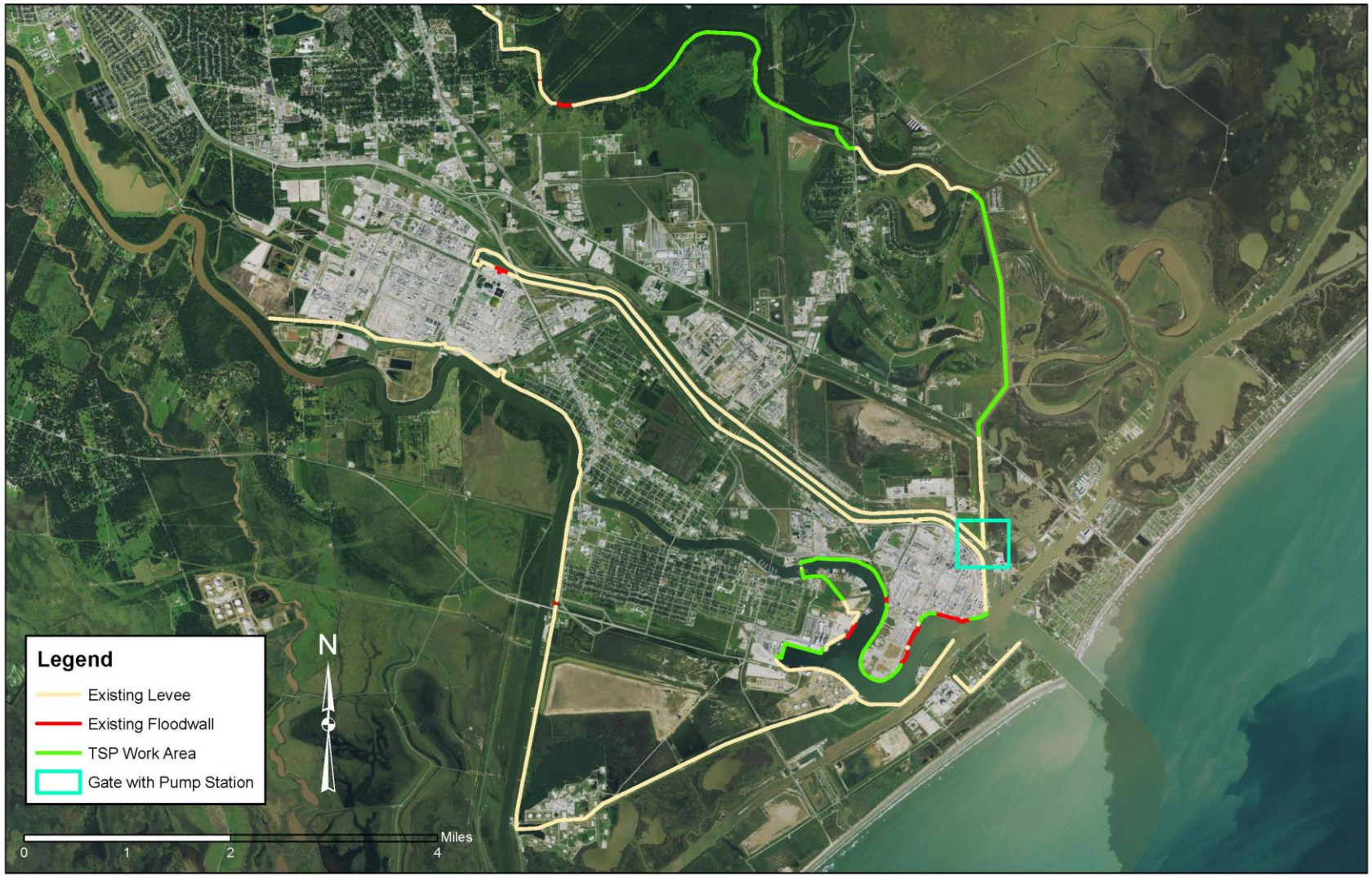

Exhibit E. Port Arthur and Vicinity – Non-Federal Costs

		Amount	Contingency
102	Acquisitions (TWE 70acres & Staging Area 5@ 2 acres)	$3,019,200.00	$603,840.00
103	Condemnations	$0.00	$0.00
104	In-leasing	$0.00	$0.00
105	Appraisals	$0.00	$0.00
106	PL 91-646 Assistance	$0.00	$0.00
107	Temporary Permits/R.O.W	$0.00	$0.00
109	Encroachments and Trespass	$0.00	$0.00
110	Disposals	$0.00	$0.00
111	Real Property Accountability	$0.00	$0.00
112	Project Related Administration	$14,000.00	$2,800.00
113	Pipeline Removal Administration	$0.00	$0.00
114	Withdrawals (Public Domain Land)	$0.00	$0.00
115	Real Estate Payments	$0.00	$0.00
1150	Land Payments	$0.00	$0.00
11502	PL 91-646 Assistance Payments	$0.00	$0.00
11503	Damage Payments	$0.00	$0.00
117	LERRD Crediting	$42,000.00	$8,400.00
	Sub Total	$3,075,200.00	$615,040.00
	Total	**$3,690,240.00**	

Exhibit E, continued

		Amount	Contingency
102	Acquisitions Reviews(TWE 70acres & Staging Area 5@ 2 acres)	$15,000.00	$3,000.00
103	Condemnations	$0.00	$0.00
104	In-leasing	$0.00	$0.00
105	Appraisals Reviews ($5,000 per tract assuming 5 tracts)	$25,000.00	$6,250.00
106	PL 91-646 Assistance	$0.00	$0.00
107	Temporary Permits/R.O.W	$10,000.00	$2,500.00
109	Encroachments and Trespass	$0.00	$0.00
110	Disposals	$0.00	$0.00
111	Real Property Accountability	$1,000.00	$250.00
112	Project Related Administration	$10,000.00	$2,000.00
113	Pipeline Removal Administration	$0.00	$0.00
114	Withdrawals (Public Domain Land)	$0.00	$0.00
115	Real Estate Payments	$0.00	$0.00
1150	Land Payments	$0.00	$0.00
11502	PL 91-646 Assistance Payments	$0.00	$0.00
11503	Damage Payments	$0.00	$0.00
117	LERRD Crediting ($6,000 per tract assuming 5 tracts)	$30,000.00	$6,000.00
	Sub Total	$91,000.00	$20,000.00
	Total	**$111,000.00**	

*Temp Work Easement and Staging Area were all assumed for planning purposes.

*Pipeline Removal Administration Cost will be determined prior to ADM.

Exhibit F. Freeport – Non-Federal Costs

		Amount	Contingency
102	Acquisitions (TWE 105 acres & Staging Area 10@ 2 acres)	$2,187,000.00	$437,400.00
103	Condemnations	$0.00	$0.00
104	In-leasing	$0.00	$0.00
105	Appraisals	$0.00	$0.00
106	PL 91-646 Assistance	$0.00	$0.00
107	Temporary Permits/Licenses/R.O.W	$0.00	$0.00
109	Encroachments and Trespass	$0.00	$0.00
110	Disposals	$0.00	$0.00
111	Real Property Accountability	$0.00	$0.00
112	Project Related Administration	$21,000.00	$4,200.00
113	Pipeline Removal Administration	$0.00	$0.00
114	Withdrawals (Public Domain Land)	$0.00	$0.00
115	Real Estate Payments	$0.00	$0.00
1150	Land Payments	$0.00	$0.00
11502	PL 91-646 Assistance Payments	$0.00	$0.00
11503	Damage Payments	$0.00	$0.00
117	LERRD Crediting	$84,000.00	$16,800.00
	Sub Total	$2,292,000.00	$458,400.00
	Total	**$2,750,400**	

Exhibit F (continued)

		Amount	Contingency
102	Acquisitions Review (TWE 105 acres & Staging Area 10@ 2 acres)	$30,000.00	$6,000.00
103	Condemnations	$0.00	$0.00
104	In-leasing	$0.00	$0.00
105	Appraisal Review ($5,000 per tract assuming 10 tracts)	$50,000.00	$12,500.00
106	PL 91-646 Assistance	$0.00	$0.00
107	Temporary Permits/Licenses/R.O.W	$20,000.00	$0.00
109	Encroachments and Trespass	$0.00	$0.00
110	Disposals	$0.00	$0.00
111	Real Property Accountability	$1,000.00	$0.00
112	Project Related Administration	$15,000.00	$3,000.00
113	Pipeline Removal Administration	$0.00	$0.00
114	Withdrawals (Public Domain Land)	$0.00	$0.00
115	Real Estate Payments	$0.00	$0.00
1150	Land Payments	$0.00	$0.00
11502	PL 91-646 Assistance Payments	$0.00	$0.00
11503	Damage Payments	$0.00	$0.00
117	LERRD Crediting ($6,000 per tract assuming 10 tracts)	$60,000.00	$12,000.00
	Sub Total	$176,000.00	$33,500.00
	Total	**$209,500.00**	

*Temp Work Easement and Staging Area were all assumed for planning purposes.
*Pipeline Removal Administration Cost will be determined prior to ADM.

Sabine Pass to Galveston Bay, Texas
Coastal Storm Risk Reduction and Ecosystem Restoration
Draft Integrated Feasibility Report and Environmental Impact Study

DRAFT APPENDIX F

PUBLIC COORDINATION

September 2015

PART I

SCOPING COMMENTS

Sabine Pass to Galveston Bay, Texas
Coastal Storm Risk Reduction and Ecosystem Restoration
Draft Integrated Feasibility Report-Environmental Impact Statement
Public Scoping Summary

Extensive public scoping, stakeholder communication, and resource agency coordination have been maintained throughout development of the Tentatively Selected Plan (TSP). Four scoping meetings were held in early 2012 which resulted in the identification of over 250 ideas addressing Coastal Storm Risk Management (CSRM) problems and Ecosystem Restoration (ER) opportunities in the six-county study area. The February 6, 2012 invitation to participate in meetings held in Beaumont, Seabrook, Galveston and Freeport, Texas, was published in local newspapers and on the U.S. Army Corps of Engineers - Galveston District (USACE) website, in addition to an extensive public mailing. The published announcement is Attachment 1.

Two stakeholder briefings were held in the spring of 2014 that focused primarily on communicating the goals and progress of the study with local governments and agencies. Continuous contact has been maintained with outside organizations that have been working to address the same problems as those addressed by this study. In particular, close communication has been maintained with the team at Texas A&M Galveston which has been working to develop the Ike Dike proposal, the Severe Storm Prediction, Education and Evacuation from Disasters Center (a consortium of several universities headquartered at Rice University in Houston) which has been assessing a number of other CSRM, ER and recreation initiatives for the Galveston Bay region, and the Gulf Coast Community Protection and Restoration District which is preparing a report evaluating CSRM opportunities in the six-county study area.

USACE published the Notice of Intent (NOI) to prepare an Environmental Impact Statement in the Federal Register on November 24, 2014. A copy of that notice is Attachment 2. Written comments were accepted for a 30-day period following that notice. In total, about 20 written comments were received following the public meetings and NOI. These comments are provided in Attachment 3. Comments made at the public meetings and in the written comments are summarized below.

The majority of the original public and agency comments received pertained to the Galveston Bay Region and to ecosystem restoration opportunities in general. The Audubon Society expressed concerns regarding Colonial Waterbird rookeries and piping plover critical habitat areas. Several rookery and critical habitat areas are within the project area, which provide nesting and feeding habitat, and are currently subject to erosion from storm damage, ship traffic and sand mining activities. Areas where critical habitat exists, especially along southwestern

coast of Galveston Island, need to be considered prior to any beach nourishment or armoring activities occur. Port of Houston Authority (PHA) advised that solutions will need to reflect industry participation or sponsorship of projects considering that public and private interests coexist along the coast. In addition, PHA expressed concerns regarding current infrastructure and industries in the study area, and specifically, along the Houston Ship Channel. Feasibility of structural solutions need to be considered prior to implementation as most of the current transportation systems that serve the HSC cannot appropriately accommodate proposed flood control structures without causing a disruption in the transportation of commerce. Weighting of nationally significant industries along HSC prior to project implementation will also need to be addressed to prioritize project need and timeline. The City of Galveston and the general public also expressed interest in public and private partnerships where open communication can address and reduce the financial burden on tax payers, and provide a forum where alternative options can be investigated. The City of Galveston recommended that a sediment management plan be considered that encourages beneficial use of dredge materials for public and private projects. This could utilize maintenance material from inlets, outlets, and harbors, while also mitigating impacts from maintenance activities and hard structures through beach preservation, beach nourishment, and establishment of a natural sand dune defense system. Local citizens and municipalities would also like to see conservation and enhancement of wetlands, in combination with responsible development, to prevent and mitigate impacts from severe weather and flood damage, specifically on Bolivar Peninsula and west end of Galveston Island. Multiple comments referenced flood control projects, greenspace, and conservations areas utilized by city Metro Parks and foreign countries as practicable and effective examples.

In the Sabine region, Orange County expressed strong support for an evaluation of surge protection for that county, including protection for Chemical Row and the Entergy Power Plant. The Corps was urged to evaluate levee and surge gate alternatives, and to utilize the Orange County study which evaluated several potential alternatives. Industrial facilities and the general public emphasized the need to protect petro-chemical facilities in the area, one of which is the largest refinery in the U.S. The general public was also concerned about maintaining or improving evacuation routes during storm emergencies. Jefferson County and Ducks Unlimited supported shoreline erosion control for the GIWW; this would prevent the loss of interior marshes that serve as storm buffers for inland communities. Comments from resource agencies focused on the need for marsh restoration on the lower Neches River and marshes near Sabine Pass, and dune and shoreline restoration of the Jefferson county shoreline, again as a means for buffering surge impacts. GIWW erosion, marsh, dune and shoreline restoration will be addressed as part of the new Jefferson County ER study.

In the Brazoria region, the local sponsor of the Freeport Hurricane Flood Protection Project (HFPP) supported evaluation of storm surge impacts on the existing system. This would strengthen existing protection of the dense petrochemical and residential development within the

Freeport HFPP. Maintaining or improving evacuation routes were important to local citizens. Local interest groups and the general public expressed concern with maintaining a tidal connection with the Gulf at the San Bernard River, and the effect of altered circulation created by the GIWW intersection with the Brazos River Diversion Channel. Local citizens also expressed concern regarding the effect of the Brazos River Diversion Channel on sediment delivery to the Surfside area. Beach restoration in the Surfside area would protect nearby residences and help attenuate storm surge. Resource agencies recommended restoration of Follets Island, a barrier peninsula, as a means of buffering storm surge impacts to the Freeport mainland. Tidal circulation, sediment supply, beach and marsh restoration will be addressed as part of the upcoming Coastal Texas study.

The Sierra Club provided comprehensive comments which applied to the six-county study area. In general, they urged restoring natural coastal shoreline system features and urged restraint in the construction of structural systems that would encourage more development. They supported structural measures that are limited in size and focused on vulnerable, developed areas, and recommended targeted buyouts rather than structural alternatives in areas such as Surfside in the Brazoria Region. They urged working with nature and natural processes, as well as protecting shoreline features that provide natural erosion protection.

The Draft Integrated Feasibility Report (DIFR)-EIS will be released for public review and comment. All comments received and USACE responses will be included in the Final IFR-EIS.

Attachment 1

DEPARTMENT OF THE ARMY
GALVESTON DISTRICT, CORPS OF ENGINEERS
P. O. BOX 1229
GALVESTON, TEXAS 77553-1229

February 6, 2012

INVITATION TO PARTICIPATE IN PUBLIC WORKSHOP AND NEPA SCOPING MEETING FOR

IDENTIFICATION OF STORM DAMAGE REDUCTION, ECOSYSTEM RESTORATION, AND FLOOD RISK MANAGEMENT OPPORTUNITIES IN ORANGE, JEFFERSON, CHAMBERS, HARRIS, GALVESTON, BRAZORIA COUNTIES

The U.S. Army Corps of Engineers, Galveston District and the Texas General Land Office along with their Regional County partners, are seeking individuals, groups or organizations interested in participating in public workshops for the purpose of gathering ideas for hurricane / tropical storm damage reduction, ecosystem restoration, and flood risk management opportunities in Orange, Jefferson, Chambers, Galveston, Harris, and Brazoria Counties. This outreach effort is being conducted in conjunction with the Sabine Pass to Galveston Bay, Texas Study. The meeting will also serve as a scoping meeting for the purposes of identifying significant issues to be addressed in accordance with requirements of the National Environmental Policy Act (NEPA).

The workshops will take place at the following locations:

February 28, 6:30 to 8:30 PM - Seabrook Community House, 1210 Anders Ave, Seabrook, TX

February 29, 6:30 to 8:30 PM - Jefferson County Agri-Life Auditorium, 1225 Pearl Street, Beaumont, TX (Enter on Franklin St., north side of bldg.)

March 6, 6:30 to 8:30 PM - Freeport Riverplace, 420 N. Brazosport Blvd., Freeport, TX

March 7, 6:30 to 8:30 PM - Galveston County Courthouse, 722 Moody Ave., Galveston, TX

If you would like to receive information or submit comments please notify us in writing at: SabinePassToGalvestonBay@usace.army.mil or at the following address:

U.S. ARMY ENGINEER DISTRICT, GALVESTON
ATTENTION: Sabine Pass to Galveston Bay, TX, Study
CESWG-PE-PL
P.O. BOX 1229
GALVESTON, TEXAS 77553-1229

For additional information please visit the project website at:
http://www.swg.usace.army.mil/sabinepasstogalvestonbay/

Attachment 2

to the location listed (see **ADDRESSES**). In order to be considered, each application must include:

1. The name of the applicant and the primary stakeholder interest category that person is qualified to represent;

2. A written statement describing the applicant's area of expertise and why the applicant believes he or she should be appointed to represent that area of expertise on the MRRIC;

3. A written statement describing how the applicant's participation as a Stakeholder Representative will fulfill the roles and responsibilities of MRRIC;

4. A written description of the applicant's past experience(s) working collaboratively with a group of individuals representing varied interests towards achieving a mutual goal, and the outcome of the effort(s);

5. A written description of the communication network that the applicant plans to use to inform his or her constituents and to gather their feedback, and

6. A written endorsement letter from an organization, local government body, or formal constituency, which demonstrates that the applicant represents an interest group(s) in the Missouri River basin.

To be considered, the application must be complete and received by the close of business on December 29, 2014, at the location indicated (see **ADDRESSES**). Applications must include an endorsement letter to be considered complete. Full consideration will be given to all complete applications received by the specified due date.

Application Review Process. Committee stakeholder applications will be forwarded to the current members of the MRRIC. The MRRIC will provide membership recommendations to the Corps as described in Attachment A of the *Process for Filling MRRIC Stakeholder Vacancies* document (*www.MRRIC.org*). The Corps is responsible for appointing stakeholder members. The Corps will consider applications using the following criteria:

- Ability to commit the time required.
- Commitment to make a good faith (as defined in the Charter) effort to seek balanced solutions that address multiple interests and concerns.
- Agreement to support and adhere to the approved MRRIC Charter and Operating Procedures.
- Demonstration of a formal designation or endorsement by an organization, local government, or constituency as its preferred representative.
- Demonstration of an established communication network to keep constituents informed and efficiently seek their input when needed.
- Agreement to participate in collaboration training as a condition of membership.

All applicants will be notified in writing as to the final decision about their application.

Certification. I hereby certify that the establishment of the MRRIC is necessary and in the public interest in connection with the performance of duties imposed on the Corps by the Endangered Species Act and other statutes.

Dated: November 13, 2014.

Brad Thompson,

Chief of Planning, Omaha District.

[FR Doc. 2014–27718 Filed 11–21–14; 8:45 am]

BILLING CODE 3720–58–P

DEPARTMENT OF DEFENSE

Department of the Army; Corps of Engineers

Intent To Prepare a Draft Environmental Impact Statement for the Sabine Pass to Galveston Bay, TX, Coastal Storm Risk Management and Ecosystem Restoration Feasibility Study

AGENCY: Department of the Army, U.S. Army Corps of Engineers, DoD.

ACTION: Notice of Intent.

SUMMARY: The Sabine Pass to Galveston Bay, Texas, study area encompasses six coastal counties on the upper Texas Gulf coast—Orange, Jefferson, Chambers, Harris, Galveston and Brazoria. The Draft Integrated Feasibility Report and Environmental Impact Statement (DIFR–EIS) will evaluate structural and non-structural alternatives which address coastal storm risk management (CSRM) and ecosystem restoration (ER) impacts in the study area. The environmental impact study will focus on environmental and social conditions currently present and those likely to be affected by potential future impacts of storm surge and ecosystem restoration opportunities. Several major historical surge events have occurred in the study area in the past 120 years. The most notable is perhaps the 1900 Storm, which inundated most of the island city of Galveston, TX, and adjacent areas on the mainland. The storm was responsible for over eight thousand deaths and up to $30 million in property damage. Hurricane Rita in 2005 resulted in storm surge of 9.2 feet in Port Arthur, TX, and just over 8 feet in Sabine Pass. Most recently, Hurricane Ike in 2008 produced storm surges of 14 feet near Sabine Pass and 11 to 12 feet across Sabine Lake. The City of Port Arthur was spared from the impacts of storm surge thanks to its existing 14- to 17-foot hurricane flood protection system. However, the remaining southern half of Jefferson County was inundated, with estimated high water marks reaching 18 to19 feet to the south and east of High Island. The City of Galveston was protected from Hurricane Ike's high energy surge impacts by the Galveston Seawall, but much of the City of Galveston was later flooded by about 6 to 10 feet of surge coming from the bay. The City of Texas City was protected from Ike's surge impacts by its existing hurricane flood protection system. At risk within the study area are approximately 2.26 million people living within the storm-surge inundation zone, three of the nine largest oil refineries in the world, 40 percent of the nation's petrochemical industry, 25 percent of the nation's petroleum-refining capacity, and three of the ten largest U.S. seaports.

DATES: Comments on proposed DIFR–EIS will be accepted through December 24, 2014.

ADDRESSES: U.S. Army Corps of Engineers, Galveston District, P.O. Box 1229, Galveston, TX 77553–1229. Emails may be sent to *Janelle.S.Stokes@usace.army.mil.*

FOR FURTHER INFORMATION CONTACT: Ms. Sheridan Willey, (409) 766–3917, Planning Lead, Plan Formulation Section, Regional Planning and Environmental Center; or Ms. Janelle Stokes, (409) 766–3039, Environmental Lead, NEPA/Cultural Resources Section, Regional Planning and Environmental Center.

SUPPLEMENTARY INFORMATION:

(1) *Background.* In 2011, the Corps of Engineers and non-Federal sponsor, the Texas General Land Office, agreed to rescope an earlier study to evaluate plans to develop CSRM and ER features over the entire six-county region covering the upper Texas coast. The study is authorized under Section 4091, Water Resources Development Act of 2007 Public Law 110–114.

(2) *Alternatives.* Structural alternatives that will be evaluated are: (1) A new surge protection system in Orange and Jefferson Counties, including small, navigable surge gates on Cow and Adams Bayous; (2) a large navigable surge gate in the Neches River near the Rainbow Bridge; and (3) reevaluation of the existing Port Arthur and Freeport Hurricane Flood Protection Systems. Non-structural measures such as targeted buy-outs, will also be evaluated. Structural and non-structural alternatives to address storm

surge impacts in the Galveston Bay system, as well as ER measures throughout the six-county study area will be evaluated programmatically, with recommendations being made for future detailed analyses of feasible alternatives.

(3) *Scoping.* In February and March of 2012, four scoping meetings were held in the cities of Beaumont, Seabrook, Galveston and Freeport, TX. The scoping process involved Federal, State and local agencies, Federally-recognized Indian tribes, and other interested persons and organizations. Comments were received for 30 days following each scoping meeting. A total of 285 ideas were collected and these were collated and screened into a detailed list of structural and non-structural CSRM and ER measures that are being considered during this study. At this time, there are no plans for an additional scoping meeting. However, input from affected Federal, state and local agencies, affected Indian tribes, and other interested private organizations and parties is being solicited with this notice.

(4) *Coordination.* Further coordination with environmental agencies will be conducted under the National Environmental Policy Act, the Fish and Wildlife Coordination Act, the Endangered Species Act, the Clean Water Act, the Clean Air Act, the National Historic Preservation Act, the Magnuson-Stevens Fishery Conservation and Management Act, and the Coastal Zone Management Act under the Texas Coastal Management Program.

(5) *DIFR–EIS Preparation.* It is estimated that the DIFR–EIS will be available to the public for review and comment in August, 2015.

Brenda S. Bowen,

Army Federal Register Liaison Officer.

[FR Doc. 2014–27723 Filed 11–21–14; 8:45 am]

BILLING CODE 3720–58–P

DEPARTMENT OF ENERGY

Commission To Review the Effectiveness of the National Energy Laboratories

AGENCY: Department of Energy.

ACTION: Notice of open meeting.

SUMMARY: This notice announces an open meeting of the Commission to Review the Effectiveness of the National Energy Laboratories (Commission). The Commission was created pursuant section 319 of the Consolidated Appropriations Act, 2014, Public Law 113–76, and in accordance with the provisions of the Federal Advisory Committee Act (FACA), as amended, 5 U.S.C. App. 2. This notice is provided in accordance with the Act.

DATES: Monday, December 15, 2014, 10:00 a.m.–3:30 p.m.

ADDRESSES: Institute for Defense Analyses, 4850 Mark Center Drive, Room 1301, Alexandria, VA 22311.

FOR FURTHER INFORMATION CONTACT: Karen Gibson, Designated Federal Officer, U.S. Department of Energy, 1000 Independence Avenue SW., Washington, DC 20585; telephone (202) 586–3787; email *crenel@hq.doe.gov*.

SUPPLEMENTARY INFORMATION:

Background: The Commission was established to provide advice to the Secretary on the Department's national laboratories. The Commission will review the DOE national laboratories for alignment with the Department's strategic priorities, clear and balanced missions, unique capabilities to meet current energy and national security challenges, appropriate size to meet the Department's energy and national security missions, and support of other Federal agencies. The Commission will also look for opportunities to more effectively and efficiently use the capabilities of the national laboratories and review the use of laboratory directed research and development (LDRD) to meet the Department's science, energy, and national security goals.

Purpose of the Meeting: This meeting is the fourth meeting of the Commission.

Tentative Agenda: The meeting will start at 10:00 a.m. on December 15. The tentative meeting agenda includes discussion on how the DOE Labs impact the national science and technology enterprise and further discussions on their relationship with industry. Key presenters will address and discuss these topics with comments from the public. The meeting will conclude at 3:30 p.m. The agenda will be posted when finalized and in advance of the meeting on the Lab Commission Web site: (*http://energy.gov/labcommission/commission-review-effectiveness-national-energy-laboratories*).

Public Participation: The meeting is open to the public. Individuals who would like to attend must RSVP to Karen Gibson no later than 5:00 p.m. on Wednesday, December 10, 2014 at email *crenel@hq.doe.gov*. Please provide your name, organization, citizenship, and contact information. Anyone attending the meeting will be required to present government issued identification. Individuals and representatives of organizations who would like to offer comments and suggestions may do so at the end of the meeting. Approximately 30 minutes will be reserved for public comments. Time allotted per speaker will depend on the number who wish to speak but will not exceed 5 minutes. The Designated Federal Officer is empowered to conduct the meeting in a fashion that will facilitate the orderly conduct of business. Those wishing to speak should register to do so beginning at 10:00 a.m. on December 15.

Those not able to attend the meeting or who have insufficient time to address the committee are invited to send a written statement to Karen Gibson, U.S. Department of Energy, 1000 Independence Avenue SW., Washington DC 20585, or to email: *crenel@hq.doe.gov*.

Minutes: The minutes of the meeting will be available on the Commission Web site at: *http://energy.gov/labcommission*.

Issued in Washington, DC, on November 18, 2014.

LaTanya R. Butler,

Deputy Committee Management Officer.

[FR Doc. 2014–27742 Filed 11–21–14; 8:45 am]

BILLING CODE 6450–01–P

ENVIRONMENTAL PROTECTION AGENCY

[FRL–9919–53–OAR]

California State Nonroad Engine Pollution Control Standards; Diesel Engines on Commercial Harbor Craft; Request for Within-the-Scope and Full Authorization; Opportunity for Public Hearing and Comment

AGENCY: Environmental Protection Agency (EPA).

ACTION: Notice.

SUMMARY: The California Air Resources Board (CARB) has notified the Environmental Protection Agency (EPA) that it has adopted amendments to its Commercial Harbor Craft regulation (CHC amendments). By letter dated May 28, 2014, CARB asked that EPA authorize these amendments pursuant to section 209(e) of the Clean Air Act (CAA or Act). CARB seeks confirmation that certain of the amendments are within the scope of a prior authorization issued by EPA, and that certain of the amendments require and merit a full authorization. This notice announces that EPA has tentatively scheduled a public hearing to consider California's request for authorization of the CHC amendments, and that EPA is now

Attachment 3

Audubon TEXAS

901 S. Mopac, Bldg 2, #410
Austin, TX 78746
Tel: 512-306-0225
Fax: 512-306-0235
www.audubon.org
ipena@audubon.org

March 16, 2012

Colonel Christopher W. Sallese
District Engineer, Galveston District
U.S. Army Corps of Engineers
CESWG-PE-PL
P.O. Box 1229
Galveston, TX 77553-1229

RE: Sabine Pass to Galveston Bay, TX Study

Dear Colonel Sallese:

The eastern coast of Texas is vital habitat for a number of bird species, both resident and migratory. Audubon Texas has a long history of coastal stewardship and avian research in the region and would like to act as one of the regional contacts during the re-scoping effort stakeholder meetings.

Audubon owns, leases, and manages several islands within the proposed study area. These islands are critical to nesting colonial waterbirds including egrets, herons, spoonbills, skimmers, gulls and terns. Many of our islands are shrinking due to erosion caused by storm damage, subsidence and local ship traffic thus reducing the amount of available habitat for these and other waterbird species. We would be very interested in working with the USACE to find a solution to the degradation of several islands we oversee in West, East, and Galveston Bay as well as the Smith Point area. We would also like to avoid the problems of the past. A previous USACE project on Smith Point Island was completed but ineffective due to poor project oversight and miscommunication by contractors.

We are also very interested in the potential sand mining for beach nourishment from the west end of Galveston Island and dredging of San Luis Pass. The west end of Galveston Island supports a rich variety of habitat for both wintering and breeding shorebirds. The flats to the northeast of San Luis Pass offer foraging habitat for a number of herons, egrets, and gull species, as well as the endangered piping plover. Many of these birds depend on foraging areas on the Texas coast to replenish their fat reserves during migrations from wintering areas in South America to breeding habitat in Canada and the Artic. If major dredging work in San Luis Pass alters the hydrology and sediment behavior of these flats, many species would lose a vital patch of habitat. Wintering piping plover are also using the beaches along the southwestern coast of Galveston Island for foraging and need to be considered during any beach nourishment or armoring that may occur in these areas.

Please feel free to contact Iliana Pena, Director of Conservation or Bob Benson, Executive Director for Audubon Texas for additional information.

Sincerely,

Iliana A. Peña
Director of Conservation
Audubon Texas

From:	Leslie Barras
To:	Stokes, Janelle S SWG
Subject:	[EXTERNAL] DEIS for the Sabine Pass to Galveston Bay, TX, Coastal Storm Risk Management and Ecosystem Restoration Feasibility Study
Date:	Saturday, November 22, 2014 6:36:49 PM

Dear Ms. Stokes:

Please include me in the email list regarding the DEIS and FEIS for the above-referenced study. I understand, from Monday's Federal Register notice, that the DEIS may be issued in Aug. 2015.

Also, I am interested in the Section 106 consultation on the proposed undertaking and major federal action. When would you anticipate beginning the process of involving consulting parties?

Thank you,
Ms. Leslie Barras
912 W. Cypress Avenue
Orange, TX 7630

PUBLIC WORKSHOP
AND NEPA SCOPING MEETING FOR
IDENTIFICATION OF
STORM DAMAGE REDUCTION, ECOSYSTEM RESTORATION,
AND FLOOD RISK MANAGEMENT OPPORTUNITIES
IN
ORANGE, JEFFERSON, CHAMBERS, HARRIS,
GALVESTON, BRAZORIA COUNTIES

Comment Form

This form is provided for your comments regarding the U. S. Army Corps of Engineers, Galveston District Sabine Pass to Galveston Bay, Texas Study Project. Please use the space below, attaching additional pages if necessary. The form may be deposited in the comment box, mailed to the address provided below, or emailed to SabinePassToGalvestonBay@usace.army.mil. Future information will be posted to our website. http://www.swg.usace.army.mil/sabinepasstogalvestonbay/

We appreciate your interest in and contributions towards this project.

Comments:

Thank you for the opportunity to comment on this issue.

We've lived on Robinson Bayou for 25 years. We see wonderful wildlife and destructive flooding. I believe that conservation and enhancement of wetlands combined with responsible development and drainage can mitigate the effects of severe storms on those of us in inland tidal areas. We get slammed doubly:

- by storm surge pushing "upstream"
- by runoff pushing "downstream" (in surge-swollen bayous). We have seen larger waterways become dikes that block the flow of smaller ones.

My suggestions:

a) Conservation- I support your interest in protecting estuaries. I would like you to also consider parkways. They are narrow parks along waterways that are prone to flooding. They accommodate flood waters, support wildlife, and are popular with the public. They may have trails, recreation facilities, gardens, fish hatcheries, etc. Sometimes the land is donated by utilities. Maintenance may be supported by community groups.

b) Development- Neighborhoods, private and public buildings, sports fields, roads-- they are all on high ground that was not there 100 years ago. The volume and speed of runoff is more than waterways can hold. Some communities are trying to slow the volume of runoff but we also need some wider/deeper spots in the waterways that will slow the velocity of the water.

Comments due by March 16, 2012 to:

District Engineer, Galveston District
U.S. Army Corps of Engineers
Attn: Sabine Pass to Galveston Bay, TX Study
CESWG-PE-PL
P.O. Box 1229
Galveston, Texas 77553-1229

Please Print:

Your Name Kathleen Barth
Your Company/Org.
Address 2211 Bayou Drive
League City, TX 77573
email: Katy.Barth@hotmail.com

From: Boyers, Amy [mailto:Amy.Boyers@h-gac.com]
Sent: Wednesday, March 14, 2012 1:38 PM
To: SabinePassToGalvestonBay
Subject: Comments on the Sabine Pass to Galveston Bay Project

Thanks to the USACE and GLO for taking on the Sabine Pass to Galveston Bay Project. We appreciate the opportunity to provide comments. H-GAC urges the USACE and GLO to fully explore all structural and non-structural options and also to determine an equitable cost-benefit analysis for coastal wetlands and barrier island dune systems (non-structural) to include not only environmental benefits but also economic benefits.

Thank you,

Amy

Amy Boyers

Resiliency Coordinator

From: Michael W. Kovacs [mailto:KovacsMic@cityofgalveston.org]
Sent: Friday, March 16, 2012 8:26 AM
To: SabinePassToGalvestonBay
Cc: Kelly De Schaun
Subject: Comments on Galveston Area Study Project

Thank you for the opportunity to comment on the Corps of Engineer's study of the Storm Damage Reduction, ecosystem restoration, and flood risk management opportunities for the upper Texas coast. I would encourage the scoping plan to focus on more detailed reviews of the following:

Top Priority:

Comprehensive sediment management plan that encourages partnerships on the beneficial use of dredge materials wherever possible, and the maintenance of not only inlets and harbors, which is done very well as part of the current mission, but also including mitigating impacts of those activities and existing hard structures (jetties for example) by planning to address beach preservation, periodic beach nourishment, and a natural dune defensive system. A plan that acknowledges the responsibility of federal, state, and local governments in the management of passes, beaches, and dunes and seeks to form partnerships for addressing the missing pieces of natural beach and dune protection of shorelines on Galveston Island is critical.

Secondary Priorities:

Surge protection plan reviews of costs/benefits of concepts including a ring levee on the back of Galveston Island and the Ike Dike are of significant interest to our citizens and businesses.

Thanks again. Good luck in your endeavors to improve the upper Texas Coast. We are interested in being a major partner with you.

Michael W. Kovacs

City Manager

City of Galveston

From: Garrett Dolan [mailto:garrettdolan@earthlink.net]
Sent: Saturday, March 03, 2012 2:01 PM
To: SabinePassToGalvestonBay
Cc: bedient@rice.edu
Subject: Comments for the Sabine to Galveston Bay

Dear USACE/GLO.

Please find below my comments regarding the Sabine Pass to Galveston Bay, Texas re-scoping process that will result in a new Feasibility Cost Sharing Agreement.

Most of my comments are targeted at how and why decisions should be made for protecting the coast. There are two articles attached that will provide insight into my comments. I offer them as resources to help the management team. Thank you.

Recommendations:
• Understand the true natural process at work
Approach any analysis with the understanding that coastlines are dynamic environments that are in a constant state of flux. Further, coastal erosion, floods, hurricanes, etc…. are natural processes that have occurred for thousands of years and will continue to occur into the next century. Public health problems and property destruction occur when humans try to impose their will over these natural processes. Sustainability requires human involvement and interventions that align with nature's natural process.

• Make decisions based on science
The upper Texas coast is geologically, meteorologically, and hydrologically in a dynamic state of flux. All four of the major natural processes shaping the coast—subsidence, sediment supply and transport, global sea level rise, and tropical cyclones—are pro¬jected to continue transforming the shore¬line. Structural mitigation efforts that try to prevent these natural processes from occurring are a sure-fire way to create an extremely expensive program dependent upon constant infusions of taxpayer money. Further, it has been scientifically proven that structural mitigation efforts can in fact, speed up the change process. Please read the attached article "A Foundation for Developing a Coastal Sustainability Program in the Houston-Galveston Region" for a short synopsis the natural processes shaping the coast.

• Correct public policy "moral hazards" before any infrastructure is built
Along the Upper Texas coast, public policy intended to protect and make life more viable is actually creating "moral hazards" and escalating the financial burdens on government. There are several public policies at the local, state and federal levels of government that are working at cross purposes by allowing risky investment decisions that put people's livelihoods in jeopardy. If not addressed first, these policies will negate any benefit added by USACE mitigation efforts. The attached article "Policy and management hazards along the Upper Texas coast" explains the hazards in detail.

• Only use tax payer money to protect structures of national interest and security

The use of taxpayer money for the development of mitigation interventions should be exclusively reserved for those projects that are of national interest (i.e. Houston Ship Channel). Using federal money to protect the lifestyles of a very small minority of people is inequitable, unsustainable and ultimately, increases the number of people vulnerable to the adverse consequences of severe storms.

• Create a hierarchy of coastal protection measures
Conduct an analysis of coastal protection measures that prioritizes the prevention, reduction and hardening options available. Prevention measures are those actions that remove people and their structures from potential harm (i.e. buyouts). Reduction measures are those actions and public policies that seek to minimize the scope and scale of harm (i.e. changing National Flood Insurance Program). Finally, hardening, are capital improvement projects that seek to defend against harm (i.e. levee).

- Leverage financial resources of the project by financially supporting the modeling and impact analyses already underway by the SSPEED Center.

Thank you.

Garrett Dolan, Ph.D.
2106 Amber Glen Lane
Katy, TX 77494
281-395-2158
garrettdolan@earthlink.net

From: Nick Fratila [mailto:nfratila@brazoriainet.com]
Sent: Sunday, March 11, 2012 9:13 PM
To: SabinePassToGalvestonBay
Cc: ttaylor@computer.org; 'Mike Goodson'; linda@yellowstoneboat.com; 'Marie Breakiron'
Subject: San Bernard River

I attended the March 6 public COE/GLO meeting in Freeport as the co-chairman of the River Mouth Committee of the Friends of the River San Bernard non-profit organization.

For a long term solution for the San Bernard River water flow, I had suggested building a jetty at the mouth. Today, I received a very interesting photo of the intersection of the river and the Intracoastal Waterway (ICW) taken this month. Due to a strong current from Brazos River, the San Bernard flow looks like it is going into the ICW moving toward Sargent. Taking a good look at this intersection, doesn't it show that this is happening because some of the land is extending too far into the river? Wouldn’t this cause another problem in the water flow to the mouth? I am not sure who is the owner of that land, but a correction of the river banks may improve the river flow to the Gulf. I attached also a photo with my suggested correction of the river banks.

Best Regards,

Nick Fratila, P.E.
1126 County Road 432
Brazoria, TX 77422
(979) 964-4549
(409) 284-7862 Cell
nfratila@brazoriainet.com <mailto:nfratila@brazoriainet.com>

PUBLIC WORKSHOP
AND NEPA SCOPING MEETING FOR
IDENTIFICATION OF
STORM DAMAGE REDUCTION, ECOSYSTEM RESTORATION,
AND FLOOD RISK MANAGEMENT OPPORTUNITIES
IN
ORANGE, JEFFERSON, CHAMBERS, HARRIS,
GALVESTON, BRAZORIA COUNTIES

Comment Form

This form is provided for your comments regarding the U. S. Army Corps of Engineers, Galveston District Sabine Pass to Galveston Bay, Texas Study Project. Please use the space below, attaching additional pages if necessary. The form may be deposited in the comment box, mailed to the address provided below, or emailed to SabinePassToGalvestonBay@usace.army.mil. Future information will be posted to our website. http://www.swg.usace.army.mil/sabinepasstogalvestonbay/

We appreciate your interesting and contributions towards this project.

Comments:

Thank you for coming to Beaumont and taking our input.

We believe the construction of rock breakwaters along the Gulf Intracoastal Waterway in Jefferson County should have a high priority, since it is an economical solution to day-to-day silting, as well as storm surge erosion of the banks, which threatens precious wetlands and marsh ecosystems.

Hurricane Ike caused 30 feet of erosion along the banks of the G.I.W.W., which could have been prevented by rock breakwaters.

Included herein are aerial photographs taken to 1-ft resolution by the Jefferson County Appraisal District before and after Hurricane Ike. These photographs prove the effectiveness of these breakwaters, which not only prevent erosion, but encourage ground and vegetation buildup between the breakwaters and the shoreline. These breakwaters cost $130 per linear foot.

Such severe erosion has occurred along the G.I.W.W. in Jefferson County, that the placement of these breakwaters in no way restricts navigation. Construction of the rock breakwaters is easily permitted through the COE's regulatory branch.

Examples and details of the breakwaters are included herein.

Comments due by March 16, 2012 to:

District Engineer, Galveston District
U.S. Army Corps of Engineers
Attn: Sabine Pass to Galveston Bay, TX Study
CESWG-PE-PL
P.O. Box 1229
Galveston, Texas 77553-1229

Please Print:

Your Name **Doug S. Canant, P.E., R.P.L.S., C.F.M.**
Your Company/Org. **Jefferson County Drainage District No. 6**
Address **6550 Walden Road**
Beaumont, Texas 77707

email: **dscanant@dd6.org**

The following six aerial photographs illustrate the erosion of the shoreline along the Gulf Intracoastal Waterway, primarily during Hurricane Ike.

Hurricane Ike occurred in September of 2008, and included record breaking storm surge levels covering the coast in Jefferson County and 22 miles inland. The storm surge reached elevation 21' above sea level near the coast. Most of the ground along the G.I.W.W. in Jefferson County is at elevation 5' above sea level or lower.

Aerial photos were taken to a 1-ft resolution in 2006 and in 2009. We traced the shoreline in three locations on the 2006 aerials. One of these locations had rock breakwater in place during Hurricane Ike. We then superimposed the shoreline on the 2009 aerial to show the amount of shore that was lost in each instance. The areas with no breakwater protection in place during the hurricanes showed significant shoreline erosion; that is 12 to 30 feet. The areas with rock breakwater in place showed no erosion, and actually showed a gain of ground between the shoreline and the breakwater, as well as signification vegetation growth.

From: William Kiene [mailto:william.kiene@noaa.gov]
Sent: Tuesday, April 09, 2013 4:40 PM
To: SabinePassToGalvestonBay
Subject: Status of Sabine Pass to Galveston Bay Study

As someone who participated in the public workshops regarding this study, I am wondering what has happened to this effort by the ACOE to study the options for protecting the region from storm-surge flooding. I strongly believe that all options should be investigated to ensure that an effective, affordable and practical solution is found. The only option that seems to so far be under investigation (not by the ACOE) is the Ike Dike proposal. Has the ACOE study been completed or was it terminated?

Regards,

William E. Kiene, Ph.D.
NOAA's Office of National Marine Sanctuaries
Southeast, Gulf of Mexico and Caribbean Region
4700 Avenue U, Building 216
Galveston, Texas 77551
Tel: (409) 621-5151 x109
Fax: (409) 621-1316
Mobile: (409) 550-6214

William.Kiene@noaa.gov

Statement for Delivery
At Corps of Engineers Scoping Meeting
March 6, 2012

My name is Craig Sherlock and I am representing LaBelle General, Inc, LaBelle Properties LLC and the Broussard family. We own approximately 6,000 acres, consisting primarily of wetlands, in the Salt Bayou Basin in southern Jefferson County near Sabine Pass.

During recent years, we have become aware of the conversion of a substantial surface acreage of our property to open water as a result of substrate erosion, subsidence, mortality of native vegetation, increases in water salinity, and acceleration of beach erosion. The loss of surface acreage is ongoing.

We believe that these proximate causes are associated with or result from a number of government-implemented actions which collectively resulted in the conversion of at least the lower portion of the Salt Bayou Basin from a historic freshwater wetland to a much more saline condition. These actions include, but may not be limited to the construction of the Gulf Intracoastal Waterway, the Sabine Pass Jetty, and the Keith Lake Fish Pass.

Construction of the Intracoastal Waterway isolated the existing Salt Bayou drainage basin from approximately 60 percent of its historic freshwater watershed, and served as a source for introduction of more saline water to the Salt Bayou basin. The construction of the Sabine Jetty system interrupted longshore flow of materials which historically nourished the beaches west of Sabine Pass, contributing to the erosion of the beach ridge and increasing the frequency of salt water overwash from the Gulf of Mexico into the middle portion of the Salt Bayou Basin. The construction of the Keith Lake Fish Pass has resulted in a dramatic increase in tidal exchange between the Salt Bayou Basin and the Sabine Neches Waterway.

Collectively, these projects have decreased the amount of freshwater entering the Salt Bayou Basin, increased tidal exchange, introduced large volumes of saline water, and caused mortality of freshwater wetlands vegetation and erosion of surface features. The resulting conditions effectively result in the change in the character of and loss of surface features on our property, diminishing and ultimately depriving us of the beneficial use of our property and effectively taking our land. Additionally, the conversion of emergent wetlands to open water compromises the ability of the wetlands in the Salt Bayou Basin to attenuate storm surge, increasing the likelihood of flooding in residential and industrial areas lying to the north.

We understand that the Corps of Engineers has developed a plan to mitigate these adverse impacts on the Salt Bayou basin. The plan reportedly includes beach renourishment to attenuate breaching of the beach ridge by high-tides and storm events in the Gulf, reduction in the capacity of the Fish Pass to deliver saline water

to the system, and reconnection of the system to that portion of the portion of the watershed lying north of the Intracoastal Waterway through construction of a system of inverted siphons. Collectively, these actions would minimize the ongoing taking of our land and its beneficial use, restore the Salt Bayou Basin to a less saline condition, restore a measure of the Salt Bayou Basin's traditional ecological function, improve wildlife habitat and improve the capacity of the Salt Bayou wetlands to attenuate storm surge damage to residential and industrial lands lying to the north.

We respectfully request your priority implementation of these measures. Thank you for your consideration.

Sincerely,

Craig J. Sherlock

From: Susan [mailto:dolphints@erfw.net]
Sent: Tuesday, March 06, 2012 3:15 PM
To: SabinePassToGalvestonBay
Subject: Freeport Meeting Tonight - Question

Thank you for hosting these type of events. I did not know these informational events occurred until last night and just received the letter of announcement which indicates questions may be submitted. I plan to attend this evening and hope I am not too late to ask a question?

Background: There is a 500 acre tract of land located along County Road (CR) 792, just off of FM 523 near the City of Oyster Creek. The property is not located in the jurisdiction of any municipality but is under Brazoria County's jurisdiction. This tract of land backs up to the Brazoria National Wildlife Refuge. There is over 300 acres of wetland on this property. It is my understanding the the owner intends to elevate 22 acres 16 feet above natural grade, and construct a retention pond of 22 acres with elevated berms/sides. I also understand that 80 acres will be used for equipment and supplies. The 16 foot change in natural grade appears like it would have a significant impact on the lands natural drainage not only to the refuge but the remaining wetlands acreage. Question: What impact will a Hurricane Ike type storm surge have not only to the wetlands but to the surrounding properties in your knowledgeable opinion?

Thank you for your time.

Susan Luycx
1557 Blue Water Drive
Freeport, Texas 77541

From: McAlister, Gay [mailto:gmcalist@mail.smu.edu]
Sent: Wednesday, February 29, 2012 4:35 PM
To: SabinePassToGalvestonBay
Subject: Storm Damage Reduction, Environmental Restoration, and Flood Risk in Galveston County

I own property in Galveston County (995 Alicia, Gilchrist 77617 and 1044 Waco, Gilchrist, 77617) on Bolivar Peninsula and I strongly request consideration of a beach renourishment project on Bolivar Peninsula. Highway 87 runs the length of the peninsula and the only land access to the peninsula. This land transportation route needs to be protected, as well as serious erosion that occurred as a result of Hurricane Ike 9/13/2008. Please give this request strong consideration as I believe it merits approval as service to the permanent home owners on the peninsula as well as the thousands of summer tourists.
Thank you,
Gay McAlister

Gay McAlister, Ph.D., LPC-S
Associate Director of Supervision
Southern Methodist University
5228 Tennyson, Ste. 102G
Plano, Texas 75024
972-473-3452 (Office)
972-473-3490 (Fax)

From: Tyler Ortego [mailto:tyler@oratechnologies.com]
Sent: Tuesday, April 24, 2012 9:49 AM
To: SabinePassToGalvestonBay
Subject: OysterBreak Shoreline Protection

Dear project team,

We developed the OysterBreak Shoreline Protection system for the purpose of delivering engineered shoreline protection while enhancing the health of our estuaries. I think you will find the OysterBreak an interesting alternative that is consistent with the comprehensive approach planned for the Sabine Pass to Galveston study.

The OysterBreak Shoreline Protection System uses the gregarious nature of oysters to create engineered shoreline protection structures. The OysterBreak design consists of interlocking concrete armor units that can be configured in any number of ways. The individual armor units are made of OysterKrete, a proprietary concrete developed specifically for growing oysters. Key benefits of the OysterBreak over rock structures are the ecological enhancements, low bearing pressure and ease of construction. We designed the OysterBreak as an engineered alternative to rock breakwaters, so you can use it in similar applications. More information can be found at http://www.wayfarertech.com/oysterbreak or at www.oratechnologies.com.

Would you recommend a point of contact, either at the Galveston District or with your consultants?

Thank you,

Tyler Ortego, PE
ORA Engineering, LLC
www.ora-eng.com
ORA Technologies, LLC
www.Oratechnologies.com <http://www.oratechnologies.com/>
Mobile: (225) 229-2539
http://www.linkedin.com/in/tylerortego
Twitter: @TylerOrtego

From: Mark Vincent [mailto:mvincent@poha.com]
Sent: Wednesday, March 14, 2012 3:08 PM
To: SabinePassToGalvestonBay
Cc: James Jackson
Subject: Sabine Pass to Galveston Bay, Tx Regional Risk Reduction Study

The Port of Houston Authority offers the following general comments, as the District prepares the rescoped project:

1. Public and private interests are intermingled along the coast. Proposed solutions need to consider industry participation or sponsorship of various projects during project execution phases.

2. The national significance of certain industries along the Houston Ship Channel needs to be appropriately weighted in project prioritization.

3. Structural solutions need to carefully consider impacts on transportation systems that serve industry along the channel, particularly rail. Many of the industries rely on railroad access, which cannot easily accommodate levees, flood gates, or other protective features.

4. Structural solutions that involve gates within the water system itself have the potential to significantly impact commerce, through use (closures), or indirectly through increased silitation or siltation patterns—both of which can disrupt maritime commerce for extended periods.

5. The potential scope of the project (including geographic extent) may tax the ability of the Corps to produce a viable and defendable plan under limited time and cost (3 years, $3 mil). Subdivision of the scope into smaller, mutually supported projects should be considered.

The scoping meeting presentation includes the comment, “USCG estimates that a one month closure of a major port like Houston would cost the national economy $60 billion”. If possible, PHA respectfully requests that the study managers informally share the source of that comment, so PHA can better support funding priorities for channel maintenance and operation, region wide.

Sincerely,

Mark Vincent, P.E.

Channel Development Director
Port of Houston Authority
111 East Loop North
Houston, Texas 77029
(713) 670-2605 Office
(713) 670-2427 Fax
mvincent@poha.com <mailto:ajames@poha.com>
www.poha.com <http://www.poha.com/>

DEPARTMENT OF THE ARMY
GALVESTON DISTRICT, CORPS OF ENGINEERS
P. O. BOX 1229
GALVESTON, TEXAS 77553-1229

February 6, 2012

INVITATION TO PARTICIPATE IN PUBLIC WORKSHOP AND NEPA SCOPING MEETING FOR

IDENTIFICATION OF STORM DAMAGE REDUCTION, ECOSYSTEM RESTORATION, AND FLOOD RISK MANAGEMENT OPPORTUNITIES IN ORANGE, JEFFERSON, CHAMBERS, HARRIS, GALVESTON, BRAZORIA COUNTIES

The U.S. Army Corps of Engineers, Galveston District and the Texas General Land Office along with their Regional County partners, are seeking individuals, groups or organizations interested in participating in public workshops for the purpose of gathering ideas for hurricane / tropical storm damage reduction, ecosystem restoration, and flood risk management opportunities in Orange, Jefferson, Chambers, Galveston, Harris, and Brazoria Counties. This outreach effort is being conducted in conjunction with the Sabine Pass to Galveston Bay, Texas Study. The meeting will also serve as a scoping meeting for the purposes of identifying significant issues to be addressed in accordance with requirements of the National Environmental Policy Act (NEPA).

The workshops will take place at the following locations:

February 28, 6:30 to 8:30 PM - Seabrook Community House, 1210 Anders Ave, Seabrook, TX

February 29, 6:30 to 8:30 PM - Jefferson County Agri-Life Auditorium, 1225 Pearl Street, Beaumont, TX (Enter on Franklin St., north side of bldg.)

March 6, 6:30 to 8:30 PM - Freeport Riverplace, 420 N. Brazosport Blvd., Freeport, TX

March 7, 6:30 to 8:30 PM - Galveston County Courthouse, 722 Moody Ave., Galveston, TX

If you would like to receive information or submit comments please notify us in writing at: SabinePassToGalvestonBay@usace.army.mil or at the following address:

U.S. ARMY ENGINEER DISTRICT, GALVESTON
ATTENTION: Sabine Pass to Galveston Bay, TX, Study
CESWG-PE-PL
P.O. BOX 1229
GALVESTON, TEXAS 77553-1229

For additional information please visit the project website at:
http://www.swg.usace.army.mil/sabinepasstogalvestonbay/

From: Terren & Karen [mailto:tkroark@earthlink.net]
Sent: Friday, March 16, 2012 11:05 AM
To: SabinePassToGalvestonBay
Subject: Comments to the Sabine Pass to Galveston Bay project

I attended the public meeting that was held Wednesday, March 7, 2012 in Galveston. I would like to suggest that a long term solution be addressed. With the prospect of 9 million people populating the area in the next 50 years; something needs to be done to protect the land, erosion and life. I heard things like using things that were done in Louisiana. Why? They had a heavy rainstorm just this past week and 2 parishes were flooded. You need to start thinking outside the box. Look at the dike system in Holland. I lived in Europe for over 3 years and I have been to Holland. Europe spends money on protecting their land. Why? Because land is precious to them since the population of many of those countries exceeds the amount of land available to them so they protect it. Holland is a little country; yet they knew the value of their land was worth protecting and put in a large dike system. Europe has been around a long time and the people there have learned a lot from their years of habitation. Whereas the United States, who is young in relation to Europe, seems to think that "we" can only have the good ideas. I have lived there. Europe actually has some very good ideas and we need to really embrace their knowledge and history. They learned what happens when you take things for granted which is what we do especially here in Texas. Protect our seashores. I spent many a summer vacation on the beaches in Texas. That was all my family could afford. If we don't take care of them now, there won't be anything left for future generations. We need to think outside the usual box. Some of those ideas are only good for a short period of time. Do something that will be lasting. Use our tax money, both state and national, for something that is going to preserve our seashore and life itself. The millions of dollars that are lost every time a hurricane comes our way, will be reduced greatly if we spend the money on something that will protect us for many, many years to come. Don't use Louisiana as a model-please! Go somewhere that they know how to protect their precious land and people. Think outside the box-please!

Thank you,

Karen Roark

2214 Merrill Hills Circle

Katy, TX 77450

Own property on the West End of Galveston

tkroark@earthlink.net

PUBLIC WORKSHOP
AND NEPA SCOPING MEETING FOR
IDENTIFICATION OF
STORM DAMAGE REDUCTION, ECOSYSTEM RESTORATION,
AND FLOOD RISK MANAGEMENT OPPORTUNITIES
IN
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Comment Form

This form is provided for your comments regarding the U. S. Army Corps of Engineers, Galveston District Sabine Pass to Galveston Bay, Texas Study Project. Please use the space below, attaching additional pages if necessary. The form may be deposited in the comment box, mailed to the address provided below, or emailedtoSabinePassToGalvestonBay@usace.army.mil. Future information will be posted to our website. http://www.swg.usace.army.mil/sabinepasstogalvestonbay/

We appreciate your interest in and contributions towards this project.

Comments:

After attending your 2/28 Meeting, it was quite obvious that you are preparing to tackle a big problem. Although I suffered significant damage from IKE, my damages were minimal compared to those of many of my neighbors here in Nassau Bay. Since IKE, I have attended several meetings @ Rice & other venues where different solutions were discussed. Some of this effort was made possible by grants from private organizations like Houston Endowment.
Although not as grand as the "IKE DIKE", the solutions offered in the SSPEED Study certainly look like they should be looked at closely by your workshop. It seemed like you gave the SSPEED effort only a cursory mention in your presentation. In this time of deficits and excess spending, it would be terrible not to take full advantage of the excellent works already completed. The SSPEED study had input from at least 6 major Universities. I was especially impressed with the hydraulic modeling and computer work done at The University of Texas. This modeling showed that had IKE come ashore @ San Luis Pass, I probably wouldn't be sitting here @ my desk writing this note
Certainly there is a lot of Engineering work left; but, please assure me that we are going to take full advantage of the good works that have already been completed. Too many times it seems like our Government Projects waste a lot of time and tax money.
Good luck
Joseph Wayne Roberts
18530 Barbuda Ln
Houston, TX 77058
waynerob@comcast.net

Comments **due by March** 16, **2012** to:

District Engineer, Galveston District
U.S. Army Corps of Engineers
Attn: Sabine Pass to Galveston Bay, TX Study
CESWG-PE-PL
P.O. Box 1229
Galveston, Texas 77553-1229

Please Print:

Your Name _____

YourCompany/O~. _____

Address _____

_____

_____

email: _____

SIERRA CLUB
FOUNDED 1892

Houston Regional Group
P. O. Box 3021
Houston, Texas 77253-3021
713-895-9309
http://texas.sierraclub.org/houston/

February 28, 2012

Colonel Christopher W. Sallese
District Commander
U.S. Army Engineer District
Galveston
Attention: Sabine Pass to Galveston Bay, Texas, Study
CESWG-PE-PL
P.O. Box 1229
Galveston, Texas 77553-1229

Dear Colonel Sallese,

Enclosed are the scoping comments of the Houston Regional Group of the Sierra Club (Sierra Club) for the U.S. Army Corps of Engineers (Corps) National Environmental Policy Act (NEPA) process for the "Identification of Storm Damage Reduction, Ecosystem Restoration, and Flood Risk Management Opportunities in Orange, Jefferson, Chambers, Harris, Galveston, and Brazoria Counties Study," also known as the "Sabine Pass to Galveston Bay, Texas Study (SPGBTS)."

1) The Corps should ensure that an environmental impact statement (EIS) accompany the SPGBT so that a programmatic landscape-scale picture is provided to citizens and decision-makers about the environmental impacts of the study recommendations. The public needs this information so that it can review, comment on, and understand the full environmental impacts of the study and any proposals and projects that are considered and result from the study.

2) To guide the Sierra Club with regard to this issue the Lone Star Chapter of the Sierra Club Executive Committee passed on July 18, 2009 the following resolution:

Resolution on Upper Texas Coast Protection

Whereas, the Upper Texas Coast (including Galveston Island and Bolivar Peninsula) provides important historic, recreational, ecologic, economic, scenic, other values and benefits, and places for people to live;

Whereas, 95% of marine organisms in the Gulf of Mexico, at some point in their life cycle, depend upon access to healthy bays and estuaries;

Whereas, the Upper Texas Coast has longtime natural shoreline erosion and accretion, exacerbated by human causes;

Whereas, the Upper Texas Coast has many important natural areas including shallow water areas; shallow water mud and sand bottoms; beaches; sand dunes; coastal

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prairie; freshwater marsh; brackish water marsh; salt water marsh; mud flats; coves, bays, and estuaries; riparian or bottomland hardwood forested wetlands; and other important habitats;

Whereas, the beaches of Galveston County are now providing habitat for recovering endangered species, specifically the head-started Kemp's Ridley Sea Turtle and the Piping Plover;

Whereas, climate change is exacerbating existing flooding, subsidence, and rising sea level, thus increasing the potential for hurricane and storm damage problems on the Upper Texas Coast;

Whereas, it is important to recognize the goals of removing people and structures from harm's way, since hurricanes and flooding threaten our coast, while protecting natural ecosystems and functioning ecological processes on the Upper Texas Coast;

Be it therefore resolved, that the Sierra Club supports careful consideration of the protection of the Upper Texas coast and communities on Galveston Island and Bolivar Peninsula using the following principles:

1. The protection of Galveston Island and Bolivar Peninsula should be part of an Upper Texas Coast Erosion and Accretion Regional Plan (UTCEARP) which addresses coastal erosion and accretion; restoration and protection of natural coastal erosion and accretion processes so that they function naturally or more naturally than currently; protection of natural ecosystems; steers development away from more vulnerable natural coastal areas and those areas that are more vulnerable to hurricane and storm damage; and is implemented from Sabine Lake to Matagorda Bay.

2. The UTCEARP should focus any hard erosion solutions, considered compatible with the UTCEARP, on developed areas near the seawall in the City of Galveston proper, and allow no artificial structures that would impede the natural currents and salinity of Galveston Bay, or impede access to the bay of those marine organisms that depend upon it.

3. The UTCEARP must protect shoreline features that provide natural erosion protection like beaches, sand dunes, offshore sand replenishment areas, freshwater inflows that provide new sediment to the coastal shoreline system, and habitat for endangered species.

4. The UTCEARP must restore natural coastal shoreline system features like current sediment movement processes and remove obstacles to sediment movement and transport along the Upper Texas Coast.

5. The UTCEARP must ensure that adjacent and nearby areas do not have their shoreline erosion and accretion negatively impacted or their risk increased by implementation of the UTCEARP.

6. The UTCEARP must ensure that the Texas Open Beaches Act public "rolling easement" and access for public recreation, protection of existing public lands, and other purposes is not diminished.

7. The UTCEARP must assess and determine the environmental impacts and mitigation of these impacts due to any encouragement of additional development in flood and storm prone areas along the Upper Texas Coast caused by the implementation of the UTCEARP.

8. The UTCEARP must protect the scenic beauty of Galveston Island, Bolivar Peninsula, and the Upper Texas Coast.

9. Any UTCEARP must not encourage further development on more vulnerable natural coastal areas and areas that are more flood and storm prone (like West Galveston Island) and thus put more people; property; and sensitive areas in danger.

The principles embedded in this resolution guide these comments and the Sierra Club requests that the Corps consider this resolution when conducting the SPGBTS.

3) These Sierra Club scoping comments use the term "large structures" to describe any single storm damage reduction structural measure or system of storm damage reduction structural measures like dikes, gates, seawalls, and similar hard structural measures.

4) The Corps should, via the SPGBTS, make land acquisition one of the priority strategies to provide restoration for the Upper Texas Gulf Coast (UTGC) in the EIS. Land acquisition is permanent (fee title acquisition and conservation easements in perpetuity). Fee title acquisition allows restoration without other owners to modify or impede restoration.

The Sierra Club favors on the UTGC, from the Texas – Louisiana border to the end of Matagorda County, acquisition of areas (priority ecosystems) to be restored and added to existing public or land trust lands. Some of these priority ecosystem areas include:

1. The Katy Prairie, in western Harris County and eastern Waller County, particularly additions to and adjoining to existing conservation lands that have been protected by the Katy Prairie Conservancy. This includes coastal prairies and prairie wetlands like prairie pothole wetlands, pimple mounds, and gilgai.

2. The Eastern Chenier Plain, from Interstate (I) 45 east to the Texas – Louisiana border which includes coastal prairies and marshes in Anahuac National Wildlife Refuge, McFaddin National Wildlife Refuge, J.D. Murphree Wildlife Management Area, Candy Cain Abshier Wildlife Management Area, Nature Conservancy Texas City Prairie Preserve, Texas Point National Wildlife Refuge, Sea Rim State Park, and Scenic Galveston lands on Galveston Bay.

3. The Western Chenier Plain, from I-45 west to the end of Matagorda County and includes coastal prairies, marshes, and the important Columbia Bottomlands habitat in Brazoria National Wildlife Refuge, San Bernard National Wildlife Refuge, Big Boggy National Wildlife Refuge, Brazos Bend State Park, Stephen F. Austin State Park, Nannie M. Stringfellow Wildlife Management Area, Christmas Bay Preserve, Galveston Island State Park, and Scenic Galveston lands on Galveston Bay.

4. The Trinity River Floodplain and Delta, which includes bottomland hardwood forested wetlands in the Trinity River National Wildlife Refuge and U.S. Army Corps of Engineers Wallisville Lake Project.

5. Farther inland, but still mostly in or near the coastal zone, Sam Houston National Forest and Big Thicket National Preserve which include upland, slope, and bottomland hardwood forests, wetlands, and aquifer recharge areas.

5) The Corps should, via the SPGBTS, make climate change an issue in the EIS. The SPGBTS must analyze climate change and its impacts on the coast and any alternatives for shoreline protection. With current climate change, we can expect a sea level rise of three feet over the next hundred years.

Climate change will alter existing ecosystems and human inhabited areas and make it more difficult for plants/animals and humans to adapt successfully to these changed ecosystems. The Corps must address questions like:

1. How will the UTGC be affected by climate change?

2. What can be done to create more resilient and resistant habitats/ecosystems?

3. What can the Corps do to reduce carbon dioxide (CO2) or other greenhouse gas emissions on the UTGC?

4. What can be done to assist plants/animals and humans so they can adapt to climate change?

The Corps should prepare and include in the draft EIS, a climate change ecological resilience and resistance plan (CCERRP). The CCERRP will assess the biological and ecological elements in the UTGC and the effects that climate change has had and will have on them. The CCERRP will assist plants, animals, and ecosystems in adapting to climate change and would require monitoring of changes and mitigation measure effectiveness. The CCERRP would be based on:

1. Protection of the existing ecosystems functions on the UTGC.
2. Reduction of stressors on the ecosystems on the UTGC.

3. Restoration of natural functioning ecological processes on the UTGC.

4. Use natural recovery on the UTGC, in most instances.

5. Acquisition of buffers/corridors to expand and ensure connectivity of ecosystems on the UTGC.

6. Intervention to manipulate (manage) ecosystems on the UTGC only as a last resort.

7. Reduction of greenhouse gas emissions on the UTGC.

6) The Corps should, via the SPGBTS, make restoration that is done via habitat mitigation and is maintained in perpetuity an issue in the EIS.

7) The Corps should, via the SPGBTS, make the restoration of adequate freshwater inflows and instream flows for bays and estuaries on the UTGC an issue in the EIS. This action supports this natural mechanism that delivers sediments to the coast for shoreline accretion and stability.

8) The Corps should, via the SPGBTS, make the perpetual monitoring of restoration work done an issue in the EIS to ensure that the restoration is maintained and continues to provide the natural functioning ecological processes, values, and benefits that were envisioned it would.

9) The Corps should, via the SPGBTS, work with the Environmental Protection Agency (EPA), U.S. Fish and Wildlife Service, and the National Marine Fisheries Service via an agreement to ensure that a more focused Section 404 process provides mitigation for priority ecosystems. This should be an issue in the EIS. In addition, existing public lands or private lands that are already protected should be used as the foundation for building a natural coastal protection system.

10) The Corps should, via the SPGBTS, make a buy-out program with a perpetually ready to use fund an issue in the EIS. Such a fund would be established so that when natural or human disasters occur, impacted properties can be bought immediately and the land turned back into natural functioning ecosystems, allow retreat from the coast, and provide natural buffers for the protection of land and people.

11) The Corps should, via the SPGBTS, make the level of enforcement and compliance for coastal protection an issue in the EIS. Currently, the level of enforcement and compliance for coastal protection is not sufficient to ensure long-term and maintenance of natural ecological processes, values, and benefits. More resources are needed (money, people, equipment) for enforcement and compliance for the long-term. A fund that provides money for long-term enforcement, monitoring, and compliance would help provide protection in perpetuity.

12) The Corps should, via the SPGBTS, make prevention of the widening of the Gulf Intracoastal Waterway (GIWW) due to boat wake erosion an issue in the EIS. The

GIWW should be restored to its approved width and damages that have occurred to natural lands should be mitigated. Not only does the widening cause loss of coastal prairie and marshes but it cuts off freshwater flows across the land and changes the type of marsh, based on salinity, so the actual natural wetlands community changes or is extinguished.

13) The Corps should, via the SPGBTS, within Brazoria County, have an alternative that buys out as many residences/businesses as possible along County Road (CR) 257 (Blue Water Highway, a 10 mile stretch of coastal road) in the EIS. Such a program would ensure that people are permanently protected and out of harm's way.

Follets Island is one of the most vulnerable barrier islands (really a barrier peninsula like Bolivar Peninsula) on the Texas Coast. This is due to its narrowness, low elevation, and the number of storm overwashes or breaches that have occurred across Follets Island or beyond the road on the existing right-of-way (ROW).

Part of CR 257 would remain on Follets Island and allow fishers, hunters, and birders access. However, with a buyout people and their property would not be at risk to erosion, flooding, or storm surge because structures and the land they are on would be bought up wherever there are willing sellers. This is a low maintenance alternative that could rely on gravel and other relatively low cost materials to keep part of CR 257 open. This is an attractive alternative since Brazoria County does not have the funds to maintain CR 257 when it is damaged by erosion, flooding, or storms.

The Sierra Club is concerned that storm surge from a significant hurricane will undermine the revetment structure along CR 257 and daily tidal erosion will reduce the energy absorbing soil that is placed over the revetment.

The construction costs of the revetment were estimated to be $29 million. Because beach re-nourishment (a part of the proposal), once started will have to be continued in perpetuity and because beach grade sand is in short supply in the Galveston Bay area this will result in additional costs. Even if the revetment withstands storms and every day tidal erosion (which averages 10 feet of beach loss/year on Follets Island according to the Bureau of Economic Geology) only 3.5 miles of the 10 mile stretch have had the revetment installed. This means additional breaches will occur which will require revetment or other structural solutions to save the road. It therefore is not outrageous to estimate that construction costs and environmental impacts of shoreline protection for CR 257 may be $100 million or more.

Even this may underestimate the costs and environmental impacts of protection of CR 257 since offshore berms may also be needed to catch enough sand for beach re-nourishment. Due to the minimal sand in the system (the sandy shore-face is only a few 100 feet wide before mud and a steep drop-off are encountered) most of which is within the long-shore transport system (refer to Rice University sediment core studies from the summer of 2007) the result would be robbing current shorelines to acquire sand where CR 257 exists, if there is enough sand in the system to make a difference.

The Sierra Club has similar concerns about Bolivar Peninsula. A buy-out program for willing sellers there also should be considered in the SPGBTS.

14) The Corps should, via the SPGBTS, make the effect that shoreline protection projects have on erosion an issue in the EIS. Shoreline protection projects must not make erosion worse somewhere else or reduce long-shore current sediment loads downstream from project locations.

15) The Corps should, via the SPGBTS, make Highway 87 and other projects that destroy or alter beaches, dunes, and wetlands an issue in the EIS. Highway 87 cannot be justified in the location it is currently in. Any movement inward will destroy significant wetlands and alter wetland hydrology for a non-water dependent action.

16) The Corps should, via the SPGBTS, make hard structures like seawalls, extensive rock groins, jetties, or similar projects an issue in the EIS. These projects often cause further losses of shoreline and beaches and require even more shoreline erosion control.

17) The Corps should, via the SPGBTS, make the use of natural or soft erosion control methods like marsh planting, **some** beach re-nourishment, and the offshore insertion of flexible materials that assist in sediment dropout an issue in the EIS. These projects can have environmental impacts if not located properly or if sources of beach re-nourishment sand are in biologically important areas.

18) The Corps should, via the SPGBTS, make the impacts that trapping of sediments in inland reservoirs an issue in the EIS. The trapping of sediments in inland reservoirs have impacts on shoreline erosion and the EIS should analyze how these trapped sediments could be released in an environmentally safe manner and returned to the coast.

19) The Corps should, via the SPGBTS, make impacts that trapping of sediments by port projects and waterway improvements have an issue in the EIS. These projects have impacts on shoreline erosion and the EIS should analyze how these trapped sediments can be released in an environmentally safe manner and be returned to the coast.

20) The Corps should, via the SPGBTS, make the free operation of natural shoreline erosion process an issue in the EIS.

21) The Corps should, via the SPGBTS, make the protection of existing natural sand dunes an issue in the EIS.

22) The Corps should, via the SPGBTS, make continued building in 100-year floodplains, the hurricane zones, dunes, beaches, and marshes an issue in the EIS.

The Corps must ensure that this study does not encourage shoreline erosion producing developments.

23) The Corps should, via the SPGBTS, make the protection of existing riparian wetlands, freshwater wetlands, and all non-jurisdictional wetlands which naturally assist in control of shoreline erosion, an issue in the EIS.

24) The Corps should, via the SPGBTS, make the proposed bridge from Galveston to Bolivar an issue in the EIS. This bridge would exacerbate shoreline erosion directly, by its design and operation, and particularly indirectly due its impetus for development in coastal prairie, rangeland, wetlands, and marshes on Bolivar Peninsula. This new development will result in the loss of an important way of life and destroy natural erosion control features like beaches, dunes, marshes, prairies, wetlands, and vegetated areas.

25) The Corps should, via the SPGBTS, make resort/second homes and commercial properties for persons who have built in hurricane and flood prone areas an issue in the EIS. The risk of living near the Gulf of Mexico is well-known. Public works projects that protect the few, many of who can afford to protect themselves or move elsewhere, and require that the many pay for irresponsible lifestyles are not in the public interest. These actions ensure further destruction of the natural flood protection and erosion control features of the land including beaches, marshes, prairies, dunes, wetlands, riparian zones, and other vegetated areas.

26) **Technical Questions and Concerns About Large Structures**

The Corps should, via the SPGBTS, make large structures an issue in the EIS. Some of the questions/concerns about large structures and their associated facilities for storm surge protection and erosion control include:

1. **For Large Structures at Bolivar Roads**

a. Will this alter Galveston Bay salinity by adversely impacting marine spawning productivity (shrimp, oysters, fish species) if the width of Bolivar Roads is reduced from 10,000 feet to a lesser width (as narrow as 1,000 feet)?

b. Will this block the ingress/egress of marine organisms using flapper/guillotine gates and fill islands to provide an anchored framework?

c. Will scouring at Bolivar Roads lead to increased erosion at or near gates?

d. Could construction of large structures lead to the dredging of the Houston Ship Channel to 65-75 feet? If so would this be cost prohibitive since the Gulf of Mexico is shallow for about 20 miles out from the proposed gates at Bolivar Roads?

e. Will dredge material deposited in Galveston Bay means the loss of bay bottom and other habitats?

2. **For Large Structures Built Along All of Bolivar Peninsula, Galveston Island, and Other Areas**

a. Will this result in the loss of open beaches/dunes?

b. Will this result in the loss of federally endangered Kemp's Ridley sea turtle nesting habitat?

c. Will this result in the loss of federally endangered piping plover resting/feeding habitats or the resting/feeding habitats of other shorebirds and other birds?

d. Will this result in the loss of other land/marine organisms' feeding/nesting/shelter habitats?

e. Is there too little sand available to re-nourish beaches and is most of that sand economically prohibitive to dredge/use?

f. What will the maintenance costs, including beach re-nourishment, of large structures be?

g. Will this result in the loss of wetlands because sand will no longer be pushed across the barrier island to its backside to nourish wetland creation?

h. What will the air quality (carbon monoxide, CO2, nitrogen oxides, particulate matter, volatile organic compounds, sulfur dioxide, ozone, and air toxics) impacts be due to the construction, maintenance, repair, and operation (diesel trucks, dredge boats, etc) of large structures?

i. Will this result in the loss of all or a large portion of Houston Audubon Society's sanctuaries and other protected areas on Bolivar Peninsula or Galveston Island?

j. How much private/public property must be acquired for construction of large structures?

k. Will the beneficial effects and functions of hurricanes be reduced (flushing and deposition of sediments and nutrients) due to the use of large structures?

l. What will be the total costs, over 30 years, to finance, construct, maintain, repair, and operate large structures?

m. Will Bolivar Peninsula and other areas still be subject to large inside-the-bay storm surges after large structures are constructed?

n. Will the construction of large structures result in a false sense of security and encourage development to increase due to perceived protection provided by large

structures? Will more wetlands and other habitats be destroyed and more people and property put at risk due to this new development?

o. Will large structures encourage the ricochet of internal storm surge in Galveston Bay that occurs when a hurricane passes over?

p. Will large structures obscure or mar the natural ocean view of the wild Texas coast?

q. Will taxpayer dollars be used to benefit and subsidize private interests in a way that the public cannot afford?

r. Will Bolivar Peninsula, unless massive dredging is conducted (with its own environmental impacts) to raise portions of the Peninsula where people live, still be subject to large within the bay storm surges?

3. **For Side Dikes/Gates/ and Other Large Structures**

a. What will the erosion and habitat loss impacts be for San Luis Pass from the construction, maintenance, repair, and operation of a dike?

b. Will this interfere with the passage of water/salinity/marine organisms into and out of bays?

c. Will this interfere with currents, accretion/deposition patterns, and sand budgets?

d. Will sensitive habitats, like Christmas Bay, be harmed?

e. For those areas of the coast that are outside where large structures have been constructed, during storms and hurricanes, will there will be increased water, wave, and erosion effects? Will this result in areas without large structures subsidizing areas with large structures and paying a higher price in environmental, social, and economic costs?

27) The Corps should, via the SPGBTS, make protection of communities and beaches, sand dunes, bays, and wetlands an issue in the EIS. This includes:

1. The protection of Galveston Island and Bolivar Peninsula should be part of a coastal erosion and accretion plan (Plan). This Plan would address coastal erosion and accretion; restoration and protection of natural coastal erosion and accretion processes so that they function naturally or more naturally than currently; protection of natural ecosystems; steer development away from more vulnerable natural coastal areas and those areas that are more vulnerable to hurricane and storm damage.

2. The Plan should focus any compatible, hard structure solutions in developed areas near the seawall in the City of Galveston proper, and allow no artificial structures to

impede the natural currents, sediments, and salinities of Galveston Bay, or access to the bay of marine organisms that depend upon these features.

3. The Plan must protect shoreline features that provide natural erosion protection like beaches, sand dunes, offshore sand replenishment areas, wetlands, freshwater inflows that bring new sediment, and habitat for endangered species (like Kemp's Ridley Sea Turtles and Piping Plovers).

4. The Plan must restore natural coastal shoreline features and remove obstacles to sediment movement and transport along our coast.

5. The Plan must ensure that adjacent and nearby areas do not have their shoreline negatively impacted by the Plan.

6. The Plan must ensure that the public's Texas Open Beaches Act "rolling easement," access for public recreation, and protection of existing public lands are not diminished.

7. The Plan must assess and determine the environmental impacts and mitigation of these impacts due to any encouraged additional development in flood and storm prone areas along the coast caused by the implementation of the Plan.

8. The Plan must protect the scenic beauty of the UTGC.

9. The Plan must not encourage further development on more vulnerable natural coastal areas that are more flood and storm prone (like West Galveston Island) which puts more people; property; and sensitive areas in danger.

28) The Corps should, via the SPGBTS, make the concentration of development where residents live and work an issue in the EIS. Currently, much development has occurred or is planned for West Galveston Island and Bolivar Peninsula. Unfortunately, these areas are the most vulnerable to hurricane and storm effects. It makes sense to step back and look for a new way.

Concentrating development on East Galveston Island, where existing seawall, harbor, and city infrastructure exists makes good economic, environmental, and safety sense. Completing the sea wall around the City of Galveston; in some way protecting the Houston Ship Channel; and concentrating development in this area will do much to protect most residents of Galveston Island. Some sensitive areas, like wave buffering wetlands need protection on East Galveston Island. This can be accomplished with much less damage to Galveston's important beaches, dunes, coastal prairie, wetlands, and bays than allowing development on West Galveston Island.

29) The Corps should, via the SPGBTS, make working with existing natural features that protect the UTGC an issue in the EIS. The first line of defense against the power of hurricanes and storms are the natural features that already protect the UTGC. These natural features include beaches, dunes, wetlands, and coastal prairie ridges. Beaches

and dunes absorb tremendous amounts of wave energy during storms. They actually move shoreward as sands and sediment are pushed across coastal ridges to the back bays. This natural sand transport system feeds the maintenance of wave protecting wetlands, beaches, and dunes. Large structures destroy beaches and dunes and interrupt this natural sand transport system. Beach re-nourishment, if adequate sands can be found close by, enhances this natural sand transport system.

30) The Corps should, via the SPGBTS, make the protection of natural amenities an issue in the EIS. People visit the UTGC for the beaches, open vistas, and wildlife and sea life. People love walking the beach, watching birds, fishing, and just hanging out in the wind, sun, and water. Who doesn't like to see a porpoise cruise or a mullet jump in the Gulf of Mexico? The rare Kemp's Ridley Sea Turtle and Piping Plover nest or visit our beaches. By protecting these natural amenities the people of Galveston, Bolivar, and other coastal communities ensure their quality of life. Any solution must conserve, protect, and preserve these natural amenities or surely the UPGC will suffer over the short and long-term. Destroying beaches to protect houses means coastal communities would not be themselves.

31) The Corps should, via the SPGBTS, make the implementation of solutions in a sustainable and economic manner an issue in the EIS. Long-term protection of Galveston Island, Bolivar Peninsula, and other parts of the UTGC requires sustainable and economic solutions. Working with Nature, and not against it surely is the best way to go. For example, San Luis Pass is one of the few natural passes left that is able to function with the existing sediment supplies on the coast. Interrupting this natural system so that replenishing sand it reduced or sent elsewhere will create a further erosion problem and degrade the incredible marsh, mudflat, and shallow water areas that make this place so irresistible to beach combers, fishers, and boaters.

32) The Corps should, via the SPGBTS, make it clear that the SPGBTS is a plan for the future in the EIS. What is needed is a Coastal Protection Plan. This Plan would give everyone from Sabine Pass to Matagorda County a way to provide a vision for the future. All interested people could participate and at the end of the process all would be united going in the same direction for funding and implementation.

33) The Corps should, via the SPGBTS, ensure that the SPGBTS is the where people work together to determine how they can effectively reduce the impacts of hurricanes on humans and the environment in the EIS. The SPGBTS must make things safer and not continue to increase the risk to lives, property, and ways of life. It's our choice to make. Some of the policies that could be implemented right now by local, state, and federal governments to better protect people and the environment include:

1. All levels of government adopt the foundation policy that we all must work with Our Mother Nature, and not against her.

2. All levels of local government adopt the policy which maximally protects wetlands, which store and filter water during rain and storm events. All levels of government will

intercede in the wetlands dredge/fill permit process on behalf wetlands protection and the avoidance, minimization, and mitigation of all wetlands losses.

3. All levels of government adopt the policy of moving from an insurance and disaster relief process, in the 100-year floodplain or storm zone, to a buyout and environmental protection process.

4. All levels of government adopt the policy which requires immediate clean-up of existing hazardous waste and superfund sites or requires the owner of the waste site to build levees that will not be breached by a Category 5 Hurricane.

5. All levels of government adopt the policy which removes all governmental incentives to develop in the 100-year floodplain or storm zone.

6. All levels of government adopt the policy to support protection and expansion of existing and additional natural areas along our coasts and floodplains.

34) The Corps should, via the SPGBTS, ensure that:

1. The SPGBTS must learn from past mistakes. Years ago there was a proposal to build a ring levee all the way around the City of Galveston. Only the seawall was built. We know what happened to the City of Galveston in Hurricane Ike. A ring levee makes sense for very developed and densely populated areas like the built-up portion of the City of Galveston because storm surge does not just come from the Gulf of Mexico. Winds generate storm surges on both Galveston Bay and the Gulf of Mexico. A large structure on the Gulf of Mexico coast will not protect the City of Galveston from any storm surge that comes from Galveston Bay. We have to learn from our mistakes!

2. The SPBGTS must embrace local solutions that require local responsibility. Since the focus is on local shoreline protection for the UTGC the economic, social, and environmental responsibility to solve these problems must come from and be paid for by local sources. Our local governments and developers did not heed the call that we should not develop in vulnerable floodplains and hurricane surge areas. We must take responsibility for having encouraged development in harm's way. This misguided policy requires vast public subsidies so that people and their private property are kept somewhat safe in these vulnerable areas.

Therefore land development, where it is appropriate, must be done in a more sensible manner including set-backs, stronger building codes, reduction in public subsidized hurricane related insurance, storm surge easements, and other local solutions that make good economic, social, and environmental sense. But first we must take responsibility for the actions that got us into this mess.

3. The SPGBTS must work with Nature. The more humans oppose Nature and take a "we shall conquer" attitude the more we endanger ourselves and those we love. Much of the UTGC is not densely populated. Examples include parts of Bolivar Peninsula, the

coast between Sabine Pass and Winnie, the northern shoreline of West Galveston Bay, and Follets Island near Freeport. In these areas, it makes sense to keep people out of harm's way by protection and restoration of natural landscapes and ecosystems including beaches, sand dunes, coastal prairies, and marshes. National wildlife refuges, a national seashore, and state wildlife management areas make the most sense for these areas.

4. The SPGBTS must address the issue in the EIS that those who benefit must pay. Yes, the Houston Ship Channel is important and needs to be protected. The responsibility for that lies with channel companies who are publicly traded and privately-owned. These companies are supposed to spend **their money** to protect **their investments.** Should public money be privatized to subsidize channel companies' risk and responsibility? Channel companies, either separately or together, can afford to build new levees or strengthen existing ones. It may make more sense to construct a gate at the entrance of the Houston Ship Channel to Galveston Bay near Morgans Point. We should use the Port of Houston as the sponsor and channel companies should pay much of the cost.

35) The Corps should, via the SPGBTS, make the analysis of all types of alternatives an issue in the EIS. For instance, varied alternatives that should be analyzed include:

1. Ring levee around all of Galveston Island's East End.

2. Higher levees around Houston Ship Channel industries.

3. Levees around some job centers, like National Aeronautic and Space Administration (NASA) and University of Texas Medical Branch at Galveston (UTMBG).

4. Retreat from the coast in certain areas.

5. Buyouts on the coast and in floodplains in repetitive flood loss areas.

6. Expand existing national wildlife refuges.

7. Create a national seashore on Bolivar Peninsula and other coastal areas.

8. Increase structure elevation for new and old buildings.

9. Enforce stricter building codes and implement Federal Emergency Management Agency (FEMA) advisories.

10. Pay landowners for the use of their land as flood easements.

36) The Corps should, via the SPGBTS, emphasize natural protection and make this an issue in the EIS. Nature is a great protector against hurricane damage. Many natural areas were hard hit by Hurricane Ike, but nature is designed to take this stress. Certain

habitats are meant to take the brunt of severe storms to protect habitats inland. Nature has been able to fine tune its own protection system for a long time, and we should use what it already provides to us – dunes, beaches, and wetlands.

The beach and dunes act as a buffer between the mainland and the worst of a storm's energy. These habitats absorb the energy of storm surge by allowing waves to crash onto them and decrease the force of waves' impact on structures. The edge of dunes creates a line in front of which we should not build any manmade structures. If we build in front of, or on top of, dunes there will be nothing standing between these structures and the storm's force. A lack of dunes means that if we develop on the coastline, there will be no natural defense between us and the storm. Dunes keep smaller storm surges at bay because they function as a small natural hill between the water and the land.

What beaches and dunes are to the energy of a storm, wetlands are to storm surge. Wetlands can be immensely helpful in diverting floodwaters away from developed areas. On average an acre of wetland can hold 3 acre feet, or 1 million gallons, of water (http://www.epa.gov/owow/wetlands/pdf/Flooding.pdf).

There are currently about 120,000 acres of wetlands in Galveston Bay. Since the 1950's over 20% of natural wetland areas in Galveston have been lost (http://74.125.47.132/search?q=cache:Y4YEnlgbOvoJ:www.betterbay.org/html/media/WetlandsOfGalvestonBay.DOC+galveston+wetlands+acres&cd=5&hl=en&ct=clnk&gl=us).

37) The Corps should, via the SPGBTS, make analysis of community development an issue in the EIS. One of the best ways to protect people and property from hurricanes is to carefully select areas where development occurs. Hurricane Ike showed which areas will be hard hit by a storm and which areas remain relatively unharmed. By using Hurricane Ike as an example, the SPGBTS can analyze if development should be concentrated in areas that are more naturally protected from storms. For example, people could be encouraged to build behind the existing sea wall on the east end of Galveston Island.

Places harder hit by Hurricane Ike are good places to turn into natural areas. Properties that were destroyed or severely damaged can be bought and turned into wild areas. Preventing rebuilding in hard hit areas would decrease the risk of property damage and increase the number of natural areas that protect us from the storms.

The amount of concrete that is used in construction contributes to flood problems. When it rains some of the water is absorbed in the ground. Large concrete slabs (parking lots, roads, building foundations) do not absorb water. Water concentrates and causes flooding or water is flushed at a faster rate which floods those who live downstream.

38) The Corps should, via the SPGBTS, make analysis of the environmental impacts of large structures an issue in the EIS. The aesthetics of large structures can cause unanticipated problems. Many people, tourists and residents alike, are drawn to

Galveston for its natural beauty. Beaches and natural areas create a haven for people to get away and relax. However, large structures destroy the natural ecosystems in the area directly and indirectly.

Another problem with large structures is the time that it takes to build them and their cost. It is estimated that a large structure system could take ten to thirty years to construct. Another hurricane could hit the coast while construction is in progress. A storm could wipe out the unfinished construction. The SPGBTS should determine how to protect large structures that are being constructed from hurricanes and what this would cost.

Directly, the dune system and beaches will disappear due to the presence of large structures. Beaches will have to be re-nourished using expensive and hard to come by sand. The ecosystems around the bay area will change with the presence of large structures which could change water flow and salinity. By providing a false sense of security large structures encourage further development in more sensitive areas, like wetlands, around Galveston Bay. All of these problems combined should be analyzed in the SPGBTS. If much of the natural beauty of coastal areas is destroyed how many people will still be interested in visiting and spending their money?

39) The Corps should, via the SPGBTS, make the analysis of the false sense of security that the construction of large structures engender and make this an issue in the EIS. For example, construction of large structures along the Texas coast may create a false sense of security for people who live in the area, and could cause them to think that the seawall will prevent ALL storm damage from hurricanes.

While large structures could theoretically prevent some of the storm surge from hitting the coast, there are several other factors that contribute to hurricane damage - the two most prominent being wind and localized flooding due to rainfall. Many places that are far inland have been severely flooded as a result of downpours that occur with hurricanes. Wind can also cause significant damage. For example, much damage is caused by high winds or tornados spawned by hurricanes. If the storm surge exceeds large structures capabilities areas could end up under water. Inland floodwaters, unless released, will be trapped by large structures and exacerbate flooding behind them. In addition, the storm surge behind large structures in Galveston Bay cannot be eliminated.

This false sense of security would also contribute to a greater increase in development on the coast because of the 'protection' provided by larges structures. Should we encourage greater development of coastal areas? We must not forget that barrier islands are Nature's 'seawall' for the mainland. These islands take the worst of a storm's force, and allow less damage to occur on the mainland. When people moved to Galveston Island they built on top of the natural seawall. It makes more sense that we encourage people to move away from threatened areas in order to protect fragile ecosystems, human lives, and property from storms.

40) The Corps should, via the SPGBTS, make geo-hazard maps for the UTGC and their implementation for human safety and environmental protection an issue in the EIS.

41) The Corps should, via the SPGBTS, should prepare a set of questions in the EIS that will be answered about any alternatives that utilize large structures. Some of these questions include:

1. **Political Questions**

a. Are regulations/rules going to be implemented to keep development out of flood-prone areas?

b. What is the goal of larges structures; can that goal be accomplished; and what social, economic, financial, and environmental studies are required to determine if the goal can be accomplished?

c. What will be the process for studying the feasibility and environmental, social, and financial impacts of larges structures?

d. How will the decision be made to build or not build and who will make the decision to build/not build large structures?

e. Which entities will be involved and where will the public input occur during the study and approval/disapproval process to build/not build larges structures?

f. Will the construction of large structures lead to the dredging of the Houston Ship Channel to 60-75 feet?

g. Will there be a vote to determine whether larges structures or some other systems are implemented?

2. **Financial and Economic Questions**

a. Who is willing to finance, construct, maintain, repair, and operate a large structure system?

b. What is the full cost of large structures and any associated facilities or activities including its financing, construction, maintenance, repair, and operation?

c. Who benefits and who takes the losses financially if a large structure system is constructed?

3. **Design Questions**

a. What are alternatives to large structures?

b. How long would large structures be effective given sea level rise?

c. How long will it take to construct large structures?

d. Where will the sand come from for re-nourishment of beaches as part of a large structure proposal?

e. Where exactly will large structures be constructed and what will be the total size (footprint)?

f. If large structures are built near State Highway (SH) 3005 how will they impact the houses that are located seaward of the large structures on Galveston Island and Bolivar Peninsula?

g. Will large structures be built and used on existing roads and infrastructure or in new areas?

g. What level of protection, in hurricane category, height of storm surge, and flood or storm protection will large structures provide?

4. **Environmental Questions**

a. When will the environmental impact statement (EIS) be available?

b. What will be the environmental effect of new development caused/assisted by large structures?

c. Will more wetlands/other habitats be destroyed and more people/property put at risk due to new development?

d. Which beach organisms will be affected and how will they be affected; how will nesting sea turtles, migrating sea turtles, and the continued growth of the sea turtle population be affected; how will shorebirds be affected; and what type and how much wetlands and other wildlife habitat will be required for mitigation for large structures?

e. What monitoring of environmental affects will be conducted; who will conduct the environmental monitoring; how long will the environmental monitoring last; how much will environmental monitoring cost; and who will pay for the environmental monitoring for large structures?

f. What environmental effects will large structures have on areas that are outside of large structures but adjacent or nearby?

g. How will the natural migration of Galveston Island, as a barrier island, be affected by larges structures and will large structures prevent Galveston Island from migrating?

h. Will large structures increase subsidence of wetlands behind it by reducing sand migration and deposition?

i. Will large structures cause or enhance the storm surge ricochet that occurs within Galveston Bay during a hurricane?

j. What mitigation will be required for perpetual environmental losses from large structures?

5. **Social Questions**

a. Will large structures make it safe for people to remain on the UTGC during hurricanes?

b. What coastal mitigation alternatives are needed, other than larges structures, to protect citizens' health and welfare from hurricanes and storms?

c. Will large structures obscure/mar the natural ocean view of our wild UTGC?

d. Will taxpayer dollars be used to benefit and subsidize private interests?

e. Will large structures result in a false sense of security and encourage increased development due to the perceived protection?

f. Can people be protected from inside-the-bay storm surges?

g. What is the sustainability of the City of Galveston and Bolivar Peninsula due to their vulnerability to hurricanes and sea level rise?

42) The Corps should, via the SPGBTS, make invasive species an issue for the EIS.

43) The Corps should, via the SPGBTS, make non-point water pollution an issue in the EIS. We must ensure that large structures, roads, and associated areas (parking lots) are required to control and reduce their effluent. Roads cause much of the sediment, herbicide, and toxic pollutants that are in non-point source pollution run-off from urban areas which enter bays and estuaries.

44) The Corps should, via the SPGBTS, make the impacts of any alternatives on the Galveston Bay Estuary Program and Coastal Barrier Resources Act an issue in the EIS.

45) The Corps should, via the SPGBTS, make "public-private partnerships" an issue in the EIS. The Sierra Club is concerned that often "public-private partnerships" result in the commercialization and privatization of public resources. We must keep public resources public and managed by professionals that work for the "people" and not other interests that have other goals, like the "maximization of profit" by using public resources.

46) The Corps should, via the SPGBTS, make "political will" an issue in the EIS. The real crux of the matter is "political will." If we are not going to be serious about regulating what can and cannot happen in the coastal zone and how and how much cannot occur then all else means nothing. We will have a slow, or not so slow, decline into degradation and destruction via cumulative impacts of all actions.

We need sometimes to "just say no" to what happens in the coastal zone. Otherwise we may not have a coastal zone at all someday. We need to take responsibility now or our children will not understand why we did not. We are less in need of "innovative ideas" than "political will".

47) The Corps should, via the SPGBTS, make economic impacts that this proposal has in relation to environmental impacts an issue in the EIS. This includes the qualitative and quantitative impacts due to nature tourism and existing recreational pursuits in the area. NEPA requires such analysis as follows:

1. **Section 101(a)** of the NEPA states, "The Congress, recognizing the profound impact of man's activity on the interrelations of all components of the natural environment, particularly the profound influences of population growth, high-density urbanization, industrial expansion, resource exploitation, and new and expanding technological advances ... to use all practicable means and measures, including financial and technical assistance, in a manner calculated to foster and promote the general welfare, to create and maintain conditions under which man and nature can exist in productive harmony, and fulfill the social, economic, and other requirements of present and future generations of Americans."

2. **Section 101(b)(5)** of the NEPA states, "achieve a balance between population and resource use which will permit high standards of living and a wide sharing of life's amenities".

3. **Section 102(1)(B)** of the NEPA states, "... which will insure that presently un-quantified environmental amenities and values may be given appropriate consideration in decision-making along with economic and technical considerations".

4. **Section 102(1)(C)** of the NEPA states, "... major Federal actions significantly affecting the quality of the human environment". (what is economics but a part of the human environment)

5. **Section 201(2)** of the NEPA states, "current and foreseeable trends in the quality, management and utilization of such environments and the effects of those trends on the social, economic, and other requirements of the Nation".

6. **Section 201(3)** of the NEPA states, "the adequacy of available natural resources for fulfilling human and economic requirements of the National in the light of expected population pressures".

7. **Section 202** of the NEPA states, "to be conscious of and responsive to the scientific, economic, social, esthetic, and cultural needs and interests of the Nation".

8. **Section 204(4)** of the NEPA states, "to develop and recommend to the president national policies to foster and promote the improvement of environmental quality to meet the conservation, social, economic, health, and other requirements and goals of the Nation".

9. **Section 1501.2(b)** of CEQ NEPA regulations states, "Identify environmental effects and values in adequate detail so they can be compared to economic and technical analyses."

10. **Section 1508.8(b)** of CEQ NEPA regulations states, "... Effects includes ecological ... aesthetic, historic, cultural, economic, social or health, whether direct, indirect, or cumulative".

11. **Section 1508.14** of CEQ NEPA regulations states, "... This means that economic or social effects are not intended by themselves to require preparation of an environmental impact statement. When an environmental impact statement is prepared and economic or social and natural or physical environmental effects are interrelated, then the environmental impact statement will discuss all of these effects on the human environment".

Without a full accounting of the economic and environmental costs the Corps will not be integrating all costs of storm damage reduction, ecosystem restoration, and flood risk management and providing that information to the public for its review and comment about all costs and benefits of the proposal.

48) The Corps should, via the SPGBTS, use public interest review factors including flood hazards, land use, fish and wildlife values, wetlands, aesthetics, economics, conservation, shore erosion and accretion, safety, water quality, and general environmental concerns in preparing the EIS.

49) The Corps should, via the SPGBTS, make long-term protection of mitigation areas and whether created habitat will be appropriately done an issue for the EIS. Some of the questions that must be answered include:

1. What agency will be responsible for monitoring and enforcement of mitigation areas?

2. What resources does this agency have to conduct unannounced inspections? What is that agency's track record?

3. How often will that agency monitor the mitigation for this proposal?

4. What criteria will be used to determine if the mitigation is functioning as required by the permit?

5. How will this be determined and or measured?

50) The Corps should, via the SPGBTS, examine all cumulative impacts and make this an issue in the EIS. The cumulative impacts of all past, present, and future foreseeable actions must be identified and their impacts must be assessed, analyzed, and evaluated. The cumulative impacts analysis in the EIS must comply with the Council on Environmental Quality (CEQ) NEPA implementing regulations, 40 CFR 1502.16, 1508.7, 1508.8, 1508.25, and 1508.27.

The CEQ has extensively described the minimum requirements for analysis and mitigation of cumulative impacts on environmental quality. At minimum, an adequate cumulative effects analysis must:

1. Identify the past, present, and reasonably foreseeable actions of the Corps and other parties affecting each particular aspect of the affected environment

2. Must provide quantitative information regarding past changes in habitat quality and quantity, water quality, resource values, and other aspects of the affected environment that are likely to be altered by Corps actions

3. Must estimate incremental changes in these conditions that will result from Corps actions in combination with actions of other parties, including synergistic effects

4. Must identify any critical thresholds of environmental concern that may be exceeded by Corps actions in combination with actions of other parties

5. Must identify specific mitigation measures that will be implemented to reduce or eliminate such effects

The Corps must use the CEQ's January 1997 document, "Considering Cumulative Effects Under the National Environmental Policy Act" for determining cumulative impacts and carrying out its analysis, assessment, and evaluation. It is clear that the Corps has an affirmative duty, a statutory duty, and a regulatory duty to carry out cumulative impacts assessment.

Some of the especially important quotes from the CEQ document include:

a. On page v, "Only by reevaluating and modifying alternatives in light of the projected cumulative effects can adverse consequences be effectively avoided or minimized. Considering cumulative effects in also essential to developing appropriate mitigation and monitoring its effectiveness."

b. On page v, "By evaluating resource impact zones and the life cycle of effects rather than projects, the analyst can properly bound the cumulative effects analysis. Scoping can also facilitate the interagency cooperation needed to identify agency plans and other actions whose effects might overlap those of the proposed action."

c. On page vi, "When the analyst describes the affected environment, he or she is setting the environmental baseline and thresholds of environmental change that are important for analyzing cumulative effects. Recently developed indicators of ecological integrity. (e.g., index of biotic integrity for fish) and landscape conditions (e.g., fragmentation of habitat patches) can be used as benchmarks of accumulated change over time ... GIS technologies provide improved means to analyze historical change in indicators of the condition of resources, ecosystems, and human communities, as well as the relevant stress factors.

d. On page vi, "Most often, the historical context surrounding the resource is critical to developing these baselines and thresholds and to supporting both imminent and future decision-making."

e. On page ... the consequences of human activities will vary from those that were predicted and mitigated ... therefore, monitoring the accuracy of predictions and the success of mitigation measures is critical.

f. On page vi, "Special methods are also available to address the unique aspects of cumulative effects, including carrying capacity analysis, ecosystem analysis, economic impacts analysis, and social impact analysis.

g. On page vii, Table E-1, "CEA Principles ... Cumulative effects analysis ...Address additive, countervailing, and synergistic effects ... Look beyond the life of the action.

h. On page 1, "The range of actions that must be considered includes not only the projects proposal but all connected and similar actions that could contribute to cumulative effects.

i. On page 3, "The purpose of cumulative effects analysis, therefore is to ensure that federal decisions consider the full range of consequences of actions ... If cumulative effects become apparent as agency programs are being planned or as larger strategies and policies are developed then potential cumulative effects should be analyzed at that times.

j. On page 3, Cumulative effects analysis necessarily involves assumptions and uncertainties, but useful information can be put on the decision-making table now ... Important research and monitoring programs can be identified that will improve analyses in the future, but their absence should not be used as a reason for not analyzing cumulative effects to the extent possible now ... adaptive management provisions for flexible project implementation can be incorporated into the selected alternative."

k. On page 4, "The Federal Highway Administration and state transportation agencies frequently make decisions on highway projects that may not have significant direct environmental effects, but that may induce indirect and cumulative effects by permitting other development activities that have significant effects on air and water resources at a regional or national scale, The highway and other development activities can reasonably be foreseen as "connected actions.

l. On page 7, "Increasingly, decision makers are recognizing the importance of looking at their projects in the context of other development in the community or region (i.e., of analyzing the cumulative effects) ... Without a definitive threshold, the NEPA practitioner should compare the cumulative effects of multiple actions with appropriate national, regional, state, or community goals to determine whether the total effect is significant ... Cumulative effects results from spatial (geographic) and temporal (time) crowding of environmental perturbations. The effects of human activities will accumulate when a second perturbation occurs at a site before the ecosystem can fully rebound from the effect of the first perturbation."

m. On page 8, Table 1-2, lists 8 principles of cumulative effects analysis. See copy enclosed.

n. On page 19, "The first step in identifying future actions is to investigate the plans of the proponent agency and other agencies in the area. Commonly, analysts only include those plans for actions which are funded or for which other NEPA analysis is being prepared. This approach does not meet the letter or intent of CEQ's regulations ... The analyst should develop guidelines as to what constitutes "reasonably foreseeable future actions" based on planning process within each agency ... In many cases, local government planning agencies can provide useful information on the likely future development of the region, such as master plans. Local zoning requirements, water supply plans, economic development plans, and various permitting records will help in identifying reasonably foreseeable private actions ... These plans can be considered in the analysis, but it is important to indicate in the NEPA analysis whether these plans were presented by the private party responsible for originating the action. Whenever speculative projections of future development are used, the analyst should provide an explicit description of the assumptions involved ... NEPA litigation ... has made it clear that "reasonable forecasting" is implicit in NEPA and that it is the responsibility of federal agencies to predict the environmental effects of proposed actions before they are fully known.

o. On page 23, "Characterizing the affected environment in a NEPA analysis that addresses cumulative effects requires special attention to defining baseline conditions. These baseline conditions provide the context for evaluating environmental consequences and should include historical cumulative effects to the extent feasible.

p. On page 29, "Lastly, trends analysis of change in the extent and magnitude of stresses in critical for projecting the future cumulative effects.

q. On page 29, "Government regulations and administrative standards ... often influence developmental activity and the resultant cumulative stress on resources, ecosystems, and human communities.

r. On page 31, "Cumulative effects occur through the accumulation of effects over varying periods of time. For this reason, an understanding of the historical context of effects is critical to assessing the direct, indirect, and cumulative effects of proposed actions. Trends data can be used ... to establish the baseline for the affected environment more accurately (i.e., by incorporating variation over time) ... to evaluate the significance of effects relative to historical degradation (i.e., by helping to estimate how close the resource is to a threshold of degradation) ... to predict the effects of the actions (i.e., by using the model of cause and effects established by past actions)."

s. On pages 38-40, "Using information gathered to describe the affected environment, the factors that affect resources (i.e., the causes in the cause-and-effect relationships) can be identified and a conceptual model of cause and effect developed ... The cause-and-effect model can aid in the identification of past, present, and future actions that should be considered in the analysis ... The cause-and effect relationships for each resource are used to determine the magnitude of the cumulative effect resulting from all actions included in the analysis ... one of the most useful approaches for determining the likely response of the resource ... to environmental change is to evaluate the historical effects of activities similar to those under consideration.

t. On page 41, "The analyst's primary goal is to determine the magnitude and significance of the environmental consequences of the proposed action in the context of the cumulative effects of other past, present, and future actions ... The critical element in this conceptual model is defining an appropriate baseline or threshold condition of the resource.

u. On page 43, "Situations can arise where an incremental effect that exceeds the threshold of concern for cumulative effects results, not from the proposed action, but the reasonably foreseeable but still uncertain future actions.

v. On page 45, "The significance of effects should be determined based on context and intensity ... Intensity refers to the severity of effect ... As discussed above, the magnitude of an effect reflects relative size or amount of an effect. Geographic extent considers how widespread the effect might be. Duration and frequency refers to whether the effect is a one-time event, intermittent, or chronic.

w. On page 45, "Determinations of significance ... are the focus of analysis because they lead to additional (more costly) analysis or to inclusion of additional mitigation (or a detailed justification for not implementing mitigation) ... the project proponent should avoid, minimize, or mitigate adverse effects by modifying alternatives ... in most cases, however, avoidance or minimization are more effective than remediating unwanted effects."

y. On page 51, "different resource effects that cumulatively affect interconnected systems must be addressed in combination."

51) The Corps should, via the SPGBTS, make the inclusion of important information an issue in the EIS. If this is not done then important information will be hidden from the public and decision-makers about the magnitude and significance of storm damage reduction, ecosystem restoration, and flood risk management alternatives. The need for this information in an EIS is documented by the following:

1. **CEQ NEPA Regulation, 1500.1(b),** "NEPA procedures must insure that environmental information is available to public officials and citizens before decisions are made and before actions are taken. The information must be of high quality. Accurate scientific analysis, expert agency comments, and public scrutiny are essential to implementing NEPA."

2. **CEQ NEPA Regulation, 1500.1(c),** "The NEPA process is intended to help public officials make decisions that are based on understanding of environmental consequences."

3. **CEQ NEPA Regulation, 1500.2(b),** "Implement procedures to make the NEPA process more useful to decision-makers and the public."

4. **CEQ NEPA Regulation, 1500.2(d),** "Encourage and facilitate public involvement in decisions which affect the quality of the human environment."

5. **CEQ NEPA Regulation, 1500.4(b),** "Preparing analytic rather than encyclopedic environmental impact statements."

6. **CEQ NEPA Regulation, 1500.4(f),** "Emphasizing the portions of the EIS that are useful to decision-makers and the public."

7. **CEQ NEPA Regulation, 1501.2(b),** "Identify environmental effects and values in adequate detail so they can be compared to economic and technical analyses."

8. **CEQ NEPA Regulation, 1502.2,** "EISs shall be analytic rather than encyclopedic."

9. **CEQ NEPA Regulation, 1502.4(a),** "Agencies shall make sure the proposal which is the subject of an EIS is properly defined."

10. **CEQ NEPA Regulation 1502.16,** "This section forms the scientific and analytic basis for the comparisons ... environmental impacts of the alternatives including the proposed action, any adverse environmental effects which cannot be avoided should the proposal be implemented, the relationship between short-term uses of man's environment and the maintenance and enhancement of long-term productivity, and irreversible or irretrievable commitments of resources."

11. **CEQ NEPA Regulation, 1502.21,** "No material may be incorporated by reference unless it is reasonably available for inspection by potentially interested persons within the time allowed for comment."

12. **CEQ NEPA Regulation, 1502.24,** "Agencies shall insure the professional integrity, including scientific integrity, of the discussions and analyses in EISs. They shall identify any methodologies used and shall make explicit reference by footnote to the scientific and other sources relied upon for conclusions in the statement."

13. **CEQ NEPA Regulation, 1506.6(a),** "Agencies shall make diligent efforts to involve the public in preparing and implementing their NEPA procedures."

14. **CEQ NEPA Regulation, 1508.3,** "Affecting means will or may have an effect on."

15. **CEQ NEPA Regulation, 1508.14,** "Human Environment shall be interpreted comprehensively to include the natural and physical environment and the relationship of people with that environment ... When an EIS is prepared and economic or social and natural or physical environmental effects are interrelated then the EIS will discuss all of these effects on the human environment."

16. **CEQ NEPA Regulation, 1508.18,** "Major Federal action includes actions with effects that may be major and which are potentially subject to Federal control and responsibility. Major reinforces but does not have a meaning independent of significantly ... Actions include new and continuing activities, including projects ... approval of specific projects, such as construction or management activities located in a defined geographic area."

17. **CEQ NEPA Regulation, 1508.27,** "Significantly as used in NEPA requires considerations of both context and intensity ... Context means that the significance of an action must be analyzed in several contexts ... For instance, in the case of a site-specific action, significance would usually depend upon the effects in the locale rather than in the world as whole ... Intensity refers to the severity of impact ... impacts may be both beneficial and adverse. A significant effect may exist even if the Federal agency believe that on balance the effect will be beneficial ... Unique characteristics of the geographic area ... The degree to which the effects on the quality of the human environment are likely to be highly controversial ... The degree to which the possible effects ... are highly uncertain or involve unique or unknown risks ... Whether the action is related to other actions with individually insignificant but cumulatively significant impacts ... Whether the action threatens a violation of Federal, State, or local law or requirements imposed for the protection of the environment."

52) The Corps should, via the SPGBTS, ensure that dictionary usage of words or phrases do not suffice to provide the public with a clear picture of what the intensity, significance, and context of environmental impacts are in the EIS. An all qualitative assessment, analysis, and evaluation of environmental impacts is not sufficient to deal

with the clearly articulated CEQ requirements in **Section 1502.14,** that the EIS "should present the environmental impacts of the proposal and the alternatives in comparative form, thus **sharply defining the issues and providing a clear basis for choice among options by the decision-maker and the public".**

1. Quantitative assessment, analysis, and evaluation are necessary to ensure that alternatives and environmental impacts are clearly defined and shown in the EIS. As stated in the CEQ NEPA implementing regulations, **Section 1500.1(b),** Purpose, "NEPA procedures must insure that environmental information is available to public officials and citizens ... The information must be of high quality. Accurate scientific analysis ... are essential to implementing NEPA".

2. As stated in **Section 1501.2(b),** "Identify environmental effects and values in adequate detail so they can be compared to economic and technical analyses."

3. As stated in **Section 1502.8,** "which will be based upon the analysis and supporting data from the natural and social sciences and the environmental design arts."

4. As stated in **Section 1502.18(b),** about the Appendix, "Normally consist of material which substantiates any analysis fundamental to the impact statement".

5. As stated in **Section 1502.24,** "Agencies shall insure the professional integrity, of the discussions and analyses ... They shall identify any methodologies used and shall make explicit reference by footnote to the scientific and other sources relied upon for conclusions in the statement."

The analysis that the Corps must conduct for this EIS is much more than **"best professional judgment". "Best professional judgment"** is where a group of people, using their experience, decide what is important. This level of assessment, analyses, and evaluation for environmental impacts and alternatives is an insufficient foundation upon which to base an EIS.

The Corps should, via the SPGBTS, define what phrases and words mean so that the public can review, comment on, and understand what the Corps refers to in the EIS. Decision-makers must know this information.

The qualitative description of phrases used to describe environmental impacts or the protectiveness of an alternative does not provide the public with the degree of comparison required by the CEQ's mandatory NEPA implementing regulations. These regulations state, in **Section 1502.14, Alternatives including the proposed action,** that, "This section is the heart of the EIS ... it should present the environmental impacts of the proposal and the alternatives in comparative form, thus sharply defining the issues and providing a clear basis for choice among options by the decision-maker and the public ... Devote substantial treatment to each alternative in detail ... so that reviewers may evaluate their comparative merits."

The CEQ also states, in **Section 1502.16 and (d), Environmental consequences,** that, "This section forms the scientific and analytic basis for the comparisons ... The environmental effects of alternatives including the proposed action the comparisons under **Section 1502.14** will be based on this discussion."

It is key that the Corps clearly compare and make apparent the distinctiveness of each alternative and its impacts or protectiveness. This is not accomplished when phrases are used qualitatively instead of quantitatively with more detailed and clear descriptions of qualitative information. **The Sierra Club requests that the Corps clarify and detail clearly the comparative differences between each alternative and define clearly what the words or phrases used mean.**

The Sierra Club appreciates this opportunity to comment. Thank you.

Sincerely,

Brandt Mannchen
Conservation Committee
Houston Regional Group of the Sierra Club
5431 Carew
Houston, Texas 77096
713-664-5962
brandtshnfbt@juno.com

From: Ray Taft [mailto:raybacliff@verizon.net]
Sent: Thursday, March 01, 2012 5:02 PM
To: SabinePassToGalvestonBay
Subject: Comment concerning USACE Galveston NEPA and flood control meetings.

Hello,

I think the starting point for storm damage reduction, flood risk management and ecosystem restoration should be with maintaining the current storm drain systems.

As you all probably know, the storm drain inlets, pipes and ditches all need periodic cleaning. Without cleaning, debris and trash can choke up a drain system resulting in reduced efficiency.

According to the EPA, pollution prevention depends upon good housekeeping. Pollutants, in the form of undesirable debris and trash, in a drain system can be washed into the waterways if not removed.

This all adds up to the need to clean storm drain systems on a regular basis. The municipal organizations responsible for maintaining our current systems should be performing storm drain system cleaning on a periodic schedule.

Drain systems may also need periodical engineering reviews. Sediment build-up or erosion in ditches can cause a system to fail to operate as originally designed. Increased drain inputs from added development can overload a drain system if the system was not designed for expansion.

Let’s ensure the local municipalities can demonstrate they are maintaining the current systems properly before spending taxpayer money on new systems and new projects.

I urge the group to first institute a program that will educate local municipalities on the need to maintain current storm drain systems and if needed to provide training on how to maintain storm drain systems according to accepted practices.

Regards,
Ray Taft
Bacliff, TX

From: Winston Denton [mailto:Winston.Denton@tpwd.state.tx.us]
Sent: Wednesday, March 14, 2012 5:01 PM
To: SabinePassToGalvestonBay
Cc: Michael Rezsutek; Cherie OBrien
Subject: Sabine Pass to Galveston Bay Risk Reduction

Comments provided by Texas Parks and Wildlife Department Upper Coast Region for the Wildlife Division J. D. Murphree Wildlife Management Area (WMA) and the Coastal Fisheries Division Ecosystem Resources Program. Contact information regarding specific projects are provided below.

Please let me know if you have any questions

Sincerely,

Winston Denton
Ecosystem Resources Program
Coastal Fisheries Division
Texas Parks and Wildlife Department
1502 FM 517 E
Dickinson, TX 77539
281-534-0138
winston.denton@tpwd.state.tx.us

1. Inverted Siphons Under the Gulf Intracoastal Waterway and the Keith Lake Fish Pass Cross Section Reduction

Construct two sets of inverted siphons under the GIWW to move excess freshwater from the marshes north of the GIWW to salt-stressed marshes south of the GIWW. This portion of the project will: 1) Reduce the salinity within the marshes around the discharge points lessening the level of sulfide stress in the plants. 2) Create a head of freshwater against the salt water entering through the Keith Lake Fish Pass. 3) Re-establish salinities gradients from Willow and Barnett Lakes on McFaddin National Wildlife Refuge (NWR) to the Keith Lake Fish Pass.

Reduce the cross section of Keith Lake Fish Pass from its current size to the original cross section. This project has been studied by USACOE under a CAP 1135.

Project Contacts:

Richard LeBlanc, Jr., General Manager of Drainage District 6 at 409-842-1818. (Siphon Project)

Mike Rezsutek at 409-736-2551, michael.rezsutek@tpwd.state.tx.us <mailto:michael.rezsutek@tpwd.state.tx.us> (Siphon and Keith Lake Fish Pass Projects)

The feasibility of the siphons is supported by a Texas Water Development Board study completed in 2009. The complete citation is: Dharhas Pothina and Carla G. Guthrie, Ph.D. 2009. Evaluating inverted siphons as a means of mitigating

salinity intrusion in the Keith Lake/Salt Bayou System, Jefferson County, Texas. A report submitted to US Environmental Protection Agency Gulf of Mexico Program. Grant Number MX-96401704."

2. Beneficial Use of Dredged Material to Restore Marshes in the Keith Lake Watershed

Expand the beneficial use of dredged maintenance material from Golden Pass LNG and other dredging projects to restore elevations and marsh communities on the J. D. Murphree WMA Salt Bayou Unit, the McFaddin NWR and private property within the Keith Lake watershed. Coordination with multiple landowners and the USACOE would result in a larger and cost effective project. The restoration of a healthy marsh community will reduce the impacts of storm surges.

Project Contact:

Mike Rezsutek at 409-736-2551, michael.rezsutek@tpwd.state.tx.us <mailto:michael.rezsutek@tpwd.state.tx.us>

3. Stabilization and Erosion Protection of the Banks and Adjacent Habitats Along the GIWW

Continue the placement of rock breakwaters in front of the banks along the GIWW. This technique reduces erosion of the bank, provides protection to the adjacent freshwater and intermediate marshes, and traps sediment behind the breakwaters creating a narrow fringe of salt marsh habitat. This is a well established method of preventing erosion that is practiced in Louisiana and Texas.

4. Infrastructure Development for the Continued Use of Dredge Material in the Nelda Stark Unit, Lower Neches WMA

Complete the necessary magnetometer and bathymetric surveys and design and construct a system of containment levees/terraces for future placement of dredge material. The completion of this phase would allow for Restoration of Nelda Stark Unit as material becomes available from local industries along the Sabine Neches Waterway. The area would be suitable for the beneficial use of maintenance and new work dredged material.

Project Contact:

Mike Rezsutek at 409-736-2551, michael.rezsutek@tpwd.state.tx.us <mailto:michael.rezsutek@tpwd.state.tx.us>

5. Restoration of the Beach Ridge from McFaddin NWR to High Island

Restore the beach ridge from McFaddin NWR to High Island. The primary intent of the project is to prevent frequent infusions of salt water from the Gulf of Mexico into the freshwater and intermediate marshes between the existing beach ridge remnants and the GIWW.

Project Contacts:

Patrick Walther and Tim Cooper at the Texas Chenier Plain Refuge Complex

6. Re-evaluation of the Current Use of Maintenance Dredged Material Under existing EA's and EIS's

Regionally (Sabine Pass to San Luis Pass) evaluate and amend/improve existing EA's and EIS's associated with dredging projects, mainly projects whose maintenance is under the authority of the Corps' Operations [and Maintenance] Division. The emphasis of the evaluation should be to revise the projects' Placement Areas (PA's) incorporating newer ideas, science, and techniques such as beneficial use of dredge material to mitigate, and protect against shoreline erosion (beach and bay), loss of wetlands and other natural resources (undeveloped costal prairie, bird rookery islands), and destruction to private and commercial property and to restore shorelines (beach and bay), wetlands, and other natural resources (bird rookery island).

Project Contact:

Cherie O'Brien at 281-534-0132, cherie.obrien@tpwd.state.tx.us <mailto:cherie.obrien@tpwd.state.tx.us>

7. Projects Promoting Sand Migration at Shipping Channels

Design and evaluate alternative techniques that would allow/promote the migration of sand to by-pass ship channels. The project should include the construction of a pilot project.

Project Contact:

Cherie O'Brien at 281-534-0132, cherie.obrien@tpwd.state.tx.us <mailto:cherie.obrien@tpwd.state.tx.us>

PART II

COMMENTS
ON
DRAFT INTEGRATED FEASIBILITY REPORT/
ENVIRONMENTAL IMPACT STATEMENT

Placeholder for Comments Received on DIFR-EIS

Sabine Pass to Galveston Bay, Texas
Coastal Storm Risk Reduction and Ecosystem Restoration
Draft Integrated Feasibility Report and Environmental Impact Study

DRAFT APPENDIX G

AGENCY AND TRIBAL COORDINATION

September 2015

Tribal Cooperating Agency Request Letters

DEPARTMENT OF THE ARMY
FORT WORTH DISTRICT, CORPS OF ENGINEERS
P.O. BOX 17300
FORT WORTH, TEXAS 76102-0300
November 19, 2014

REPLY TO
ATTENTION OF

NEPA/Cultural Resources Section

Bryant Celestine
Historic Preservation Officer
Alabama-Coushatta Tribe of Texas
571 State Park Road 56
Livingston, TX 77351

Dear Mr. Celestine:

The Galveston District, Corps of Engineers, and the non-federal sponsor, the Texas General Land Office, would like to invite your tribe to participate as a cooperating agency in the development of an Environmental Impact Statement (EIS) for the Sabine Pass to Galveston Bay, Texas, Coastal Storm Risk Management and Ecosystem Restoration Study. The integrated feasibility report and EIS (IFR-EIS) will evaluate structural and non-structural alternatives which address coastal storm risk management (CSRM) and ecosystem restoration (ER) opportunities in Orange, Jefferson, Chambers, Harris, Galveston and Brazoria counties on the upper Texas Gulf coast. The Draft IFR-EIS is currently scheduled to be released for public review and comment in August 2015.

Structural alternatives that will be evaluated are: (1) new surge protection levees and small, navigable surge gates on Cow and Adams Bayous in Orange and Jefferson Counties; (2) a large navigable surge gate in the Neches River near the Rainbow Bridge (eliminated); and (3) reevaluation of the existing Port Arthur and Freeport Hurricane Flood Protection (HFP) systems in Jefferson and Brazoria Counties, respectively. Maps showing the location of the existing HPFs and the structural alternatives are enclosed. Non-structural measures such as targeted buy-outs, conservation of natural landscapes, and flood-proofing will also be evaluated. Structural and non-structural alternatives to address storm surge impacts in the Galveston Bay system (Galveston, Harris and Chambers Counties), as well as ER measures throughout the six-county study area will be evaluated programmatically, with recommendations being made for detailed analyses of feasible alternatives in future studies.

If your tribe has any concerns regarding potential project impacts to Native American archeological sites or areas of religious or cultural interest from the potential project described above, we request that you contact us so that further consultation can be initiated. We would also like to coordinate with you our schedule for study completion so that all reviews and approvals will, to the maximum extent practicable, be conducted concurrently. The following review periods for the IFR-EIS have been established in accordance with the current project schedule:

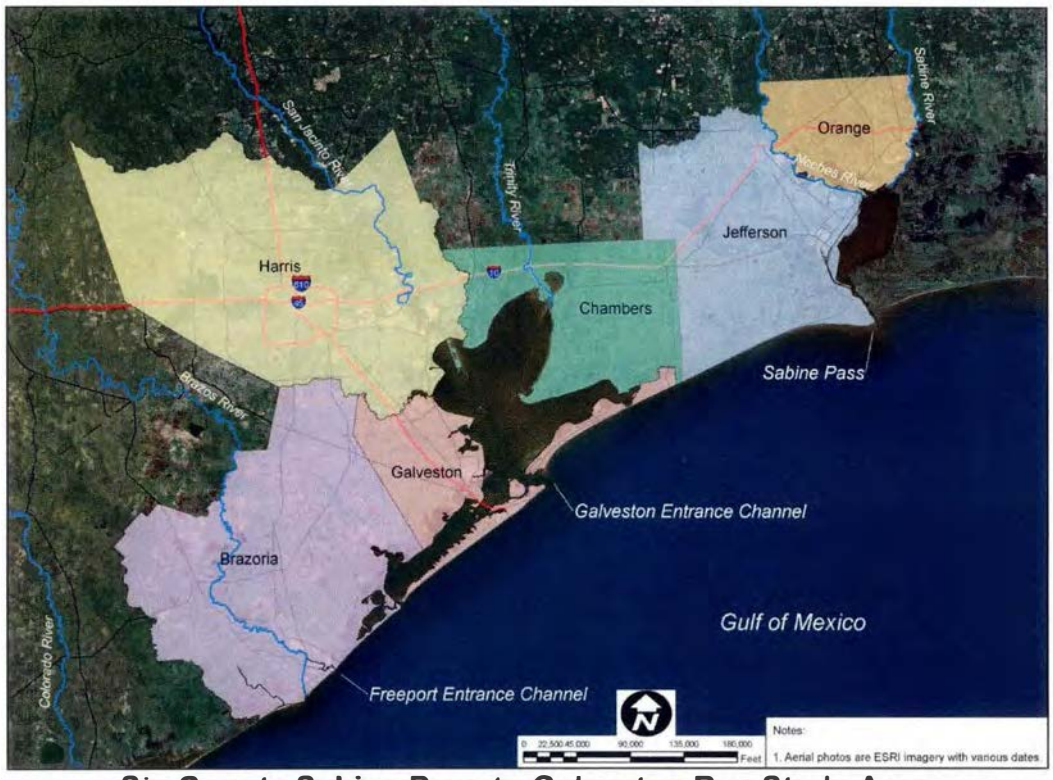
- Review of Draft IFR-EIS --45-day review period (August 29 through October 12, 2015)
- State and Agency Review of Final IFR-EIS – 30-day review (July 15 through August 14, 2016)

We appreciate this opportunity to consult regarding any concerns your tribe may have with potential project impacts or review periods. If you should have any questions regarding this request, please contact Janelle Stokes of my staff at (409) 766-3039.

Sincerely,

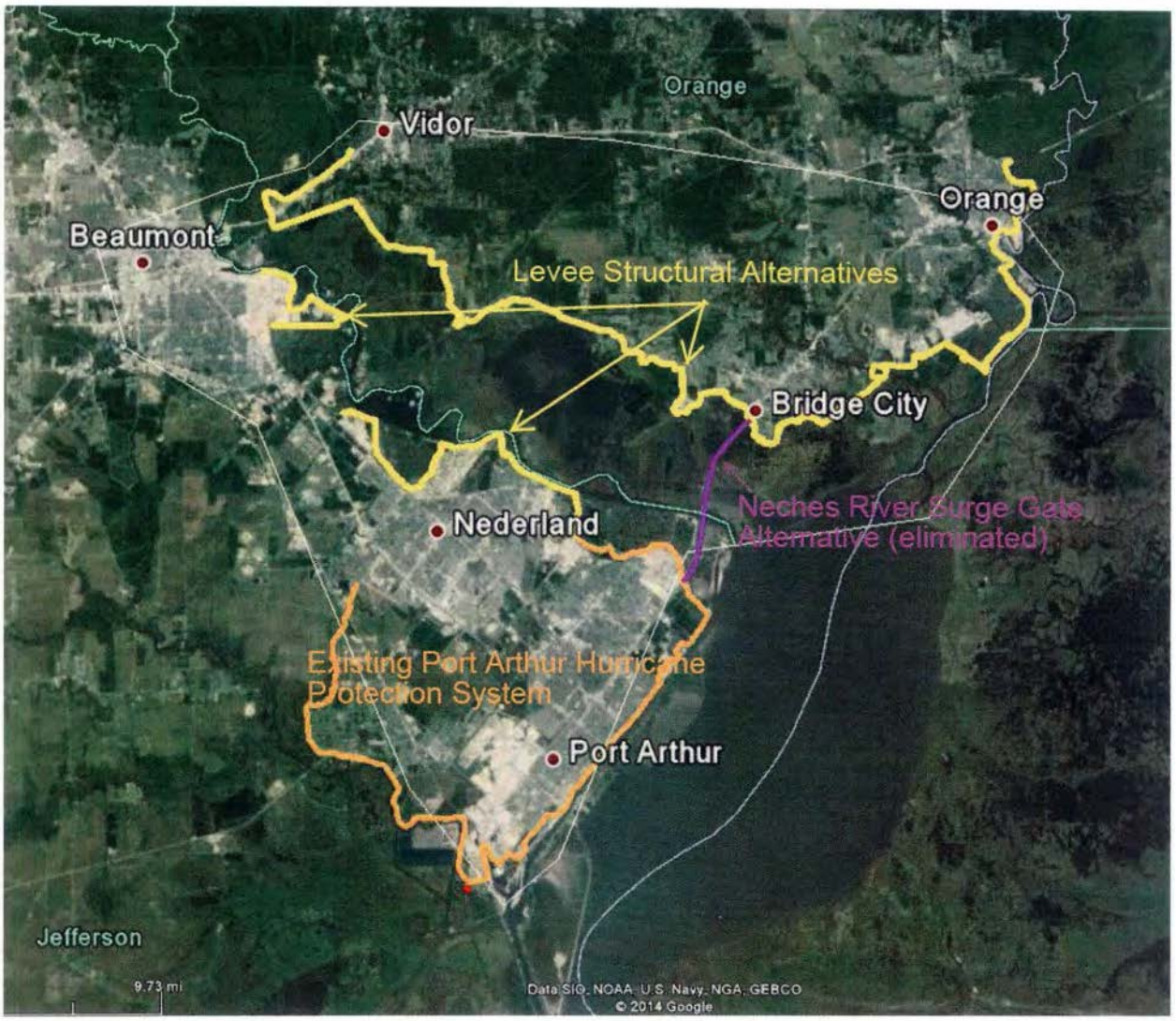
Carolyn Murphy
Chief, Unit A, NEPA/Cultural
Resources Section

Enclosures



Six County Sabine Pass to Galveston Bay Study Area

Existing Freeport Hurricane Flood Protection System



Existing Port Arthur Hurricane Flood Protection System, Levee Structural Alternatives and Neches River Surge Gate Alternative

DEPARTMENT OF THE ARMY
FORT WORTH DISTRICT, CORPS OF ENGINEERS
P.O. BOX 17300
FORT WORTH, TEXAS 76102-0300
November 19, 2014

REPLY TO
ATTENTION OF

NEPA/Cultural Resources Section

Mr. Jimmy Arterberry
Tribal Historic Preservation Officer
Comanche Nation of Oklahoma
P.O. Box 908
Lawton, OK 73502

Dear Mr. Arterberry:

The Galveston District, Corps of Engineers, and the non-federal sponsor, the Texas General Land Office, would like to invite your tribe to participate as a cooperating agency in the development of an Environmental Impact Statement (EIS) for the Sabine Pass to Galveston Bay, Texas, Coastal Storm Risk Management and Ecosystem Restoration Study. The integrated feasibility report and EIS (IFR-EIS) will evaluate structural and non-structural alternatives which address coastal storm risk management (CSRM) and ecosystem restoration (ER) opportunities in Orange, Jefferson, Chambers, Harris, Galveston and Brazoria counties on the upper Texas Gulf coast. The Draft IFR-EIS is currently scheduled to be released for public review and comment in August 2015.

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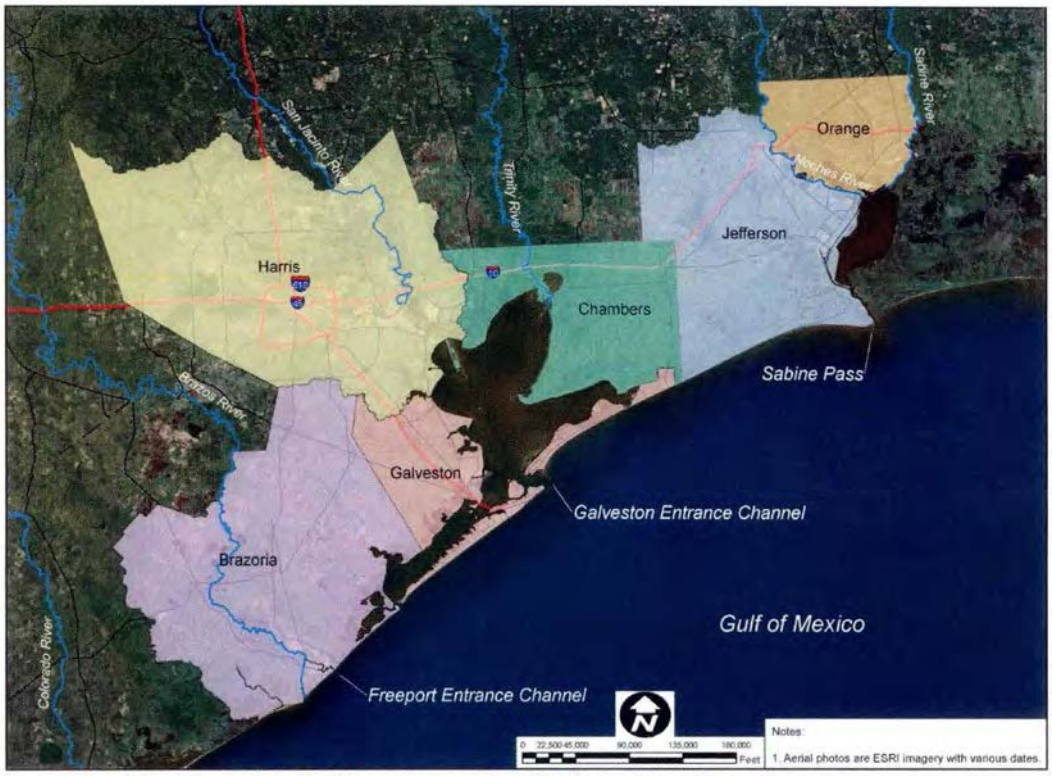
We appreciate this opportunity to consult regarding any concerns your tribe may have with potential project impacts or review periods. If you should have any questions regarding this request, please contact Janelle Stokes of my staff at (409) 766-3039.

Sincerely,

Carolyn Murphy

Carolyn Murphy
Chief, Unit A, NEPA/Cultural
Resources Section

Enclosures



Six County Sabine Pass to Galveston Bay Study Area

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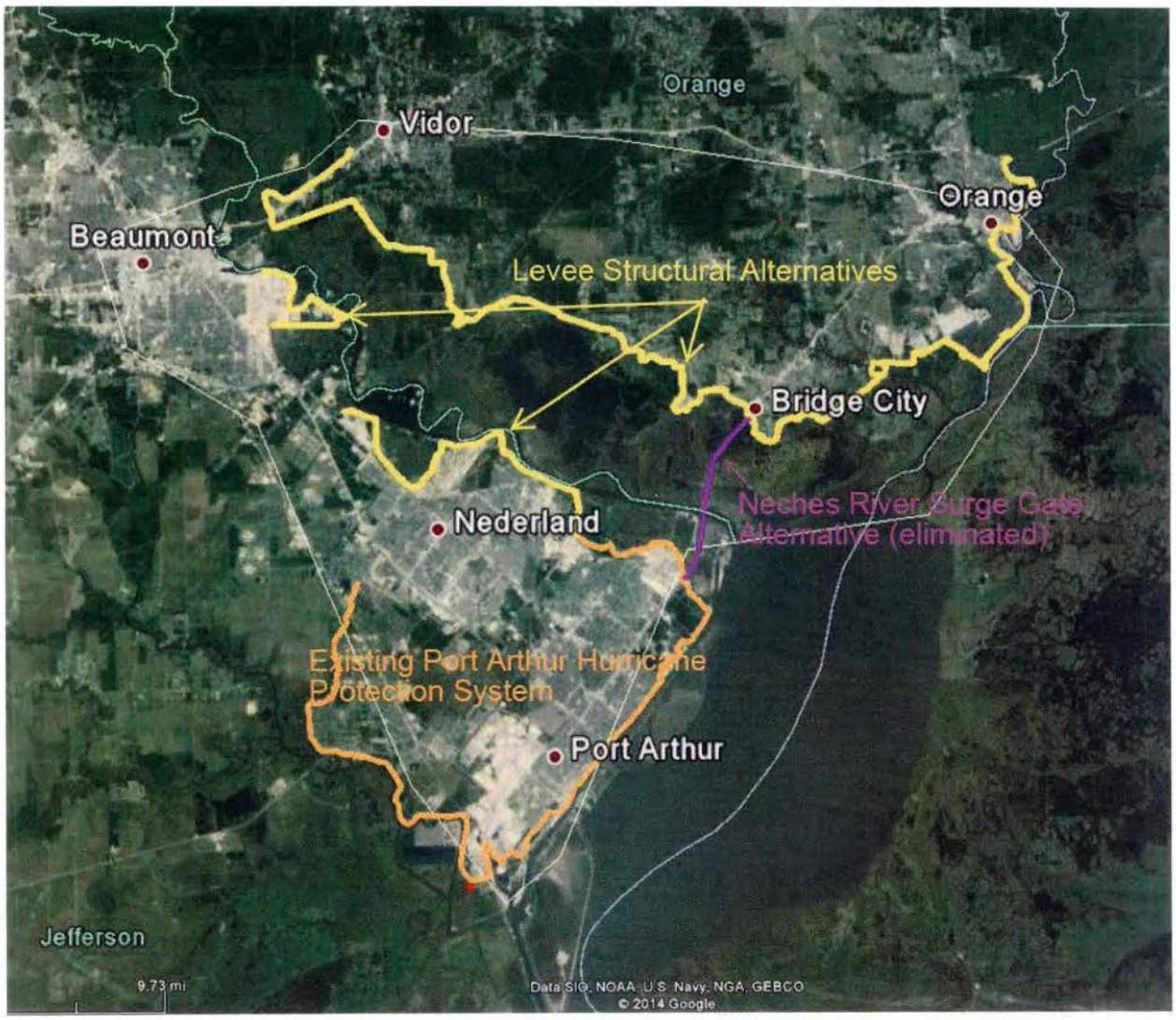

Existing Port Arthur Hurricane Flood Protection System, Levee Structural Alternatives and Neches River Surge Gate Alternative

DEPARTMENT OF THE ARMY
FORT WORTH DISTRICT, CORPS OF ENGINEERS
P.O. BOX 17300
FORT WORTH, TEXAS 76102-0300
November 19, 2014

REPLY TO
ATTENTION OF

NEPA/Cultural Resources Section

Dr. Linda Langley
Tribal Historic Preservation Officer
Coushatta Tribe of Louisiana
Administrative Building
1940 C.C. Bel Road
Elton, Louisiana 70532

Dear Dr. Langley:

The Galveston District, Corps of Engineers, and the non-federal sponsor, the Texas General Land Office, would like to invite your tribe to participate as a cooperating agency in the development of an Environmental Impact Statement (EIS) for the Sabine Pass to Galveston Bay, Texas, Coastal Storm Risk Management and Ecosystem Restoration Study. The integrated feasibility report and EIS (IFR-EIS) will evaluate structural and non-structural alternatives which address coastal storm risk management (CSRM) and ecosystem restoration (ER) opportunities in Orange, Jefferson, Chambers, Harris, Galveston and Brazoria counties on the upper Texas Gulf coast. The Draft IFR-EIS is currently scheduled to be released for public review and comment in August 2015.

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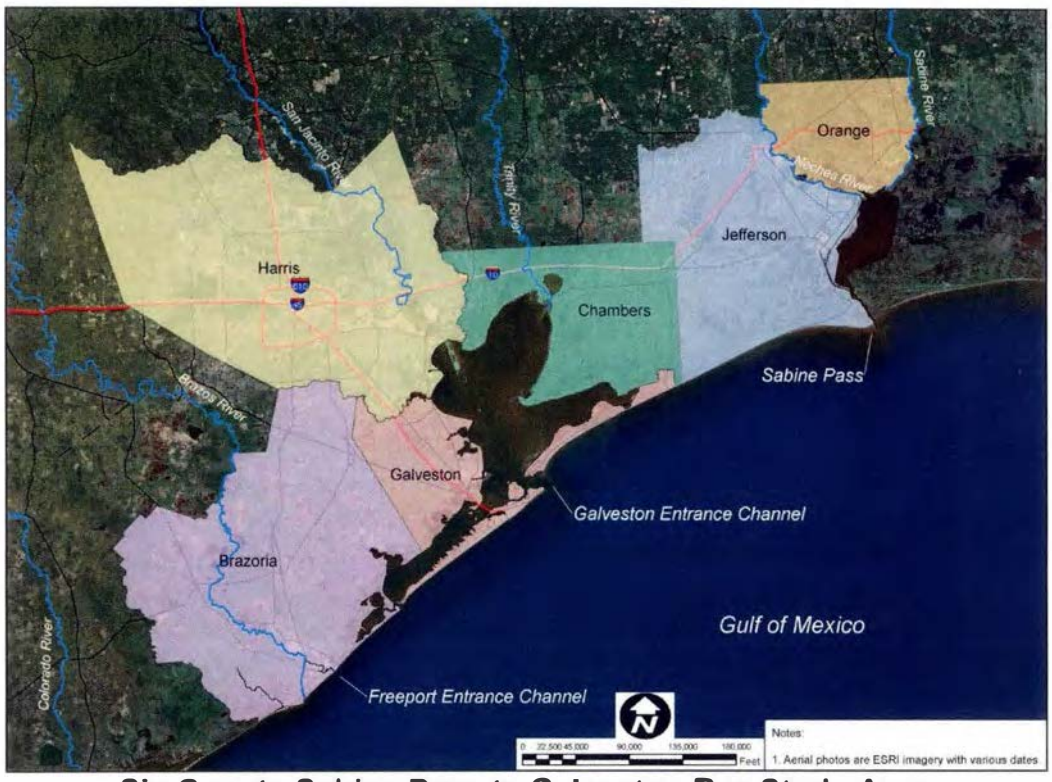
Sincerely,

Carolyn Murphy
Chief, Unit A, NEPA/Cultural
Resources Section

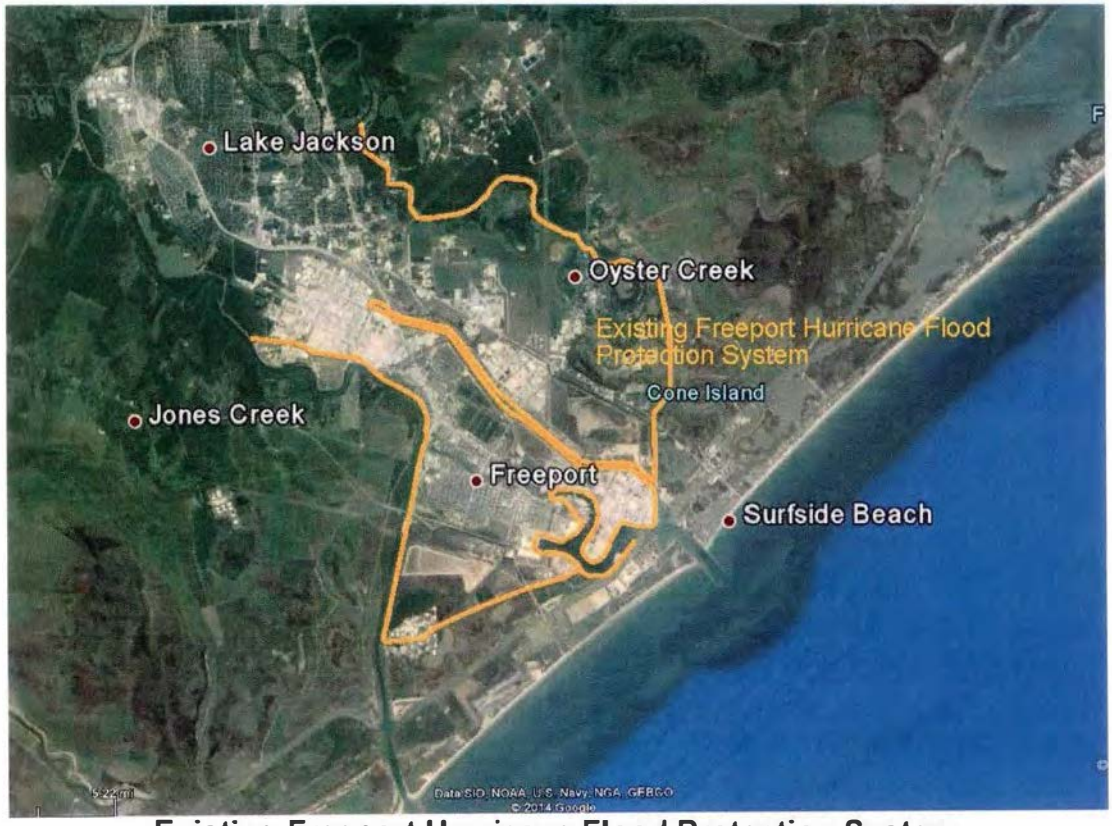
Enclosures

CF:

Mr. Michael Tarpley
Historic Preservation Office
Coushatta Tribe of Louisiana
Administrative Building
1940 C.C. Bel Road
Elton, Louisiana 70532



Six County Sabine Pass to Galveston Bay Study Area



Existing Freeport Hurricane Flood Protection System

Existing Port Arthur Hurricane Flood Protection System, Levee Structural Alternatives and Neches River Surge Gate Alternative

DEPARTMENT OF THE ARMY
FORT WORTH DISTRICT, CORPS OF ENGINEERS
P.O. BOX 17300
FORT WORTH, TEXAS 76102-0300

REPLY TO
ATTENTION OF

November 19, 2014

NEPA/Cultural Resources Section

Ms. Amie Tah-Bone
Historic Preservation Office
Kiowa Indian Tribe of Oklahoma
P.O. Box 369
Carnegie, OK 73015

Dear Ms. Tah-Bone:

The Galveston District, Corps of Engineers, and the non-federal sponsor, the Texas General Land Office, would like to invite your tribe, to participate as a cooperating agency in the development of an Environmental Impact Statement (EIS) for the Sabine Pass to Galveston Bay, Texas, Coastal Storm Risk Management and Ecosystem Restoration Study. The integrated feasibility report and EIS (IFR-EIS) will evaluate structural and non-structural alternatives which address coastal storm risk management (CSRM) and ecosystem restoration (ER) opportunities in Orange, Jefferson, Chambers, Harris, Galveston and Brazoria counties on the upper Texas Gulf coast. The Draft IFR-EIS is currently scheduled to be released for public review and comment in August 2015.

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Sincerely,

Carolyn Murphy
Chief, Unit A, NEPA/Cultural
Resources Section

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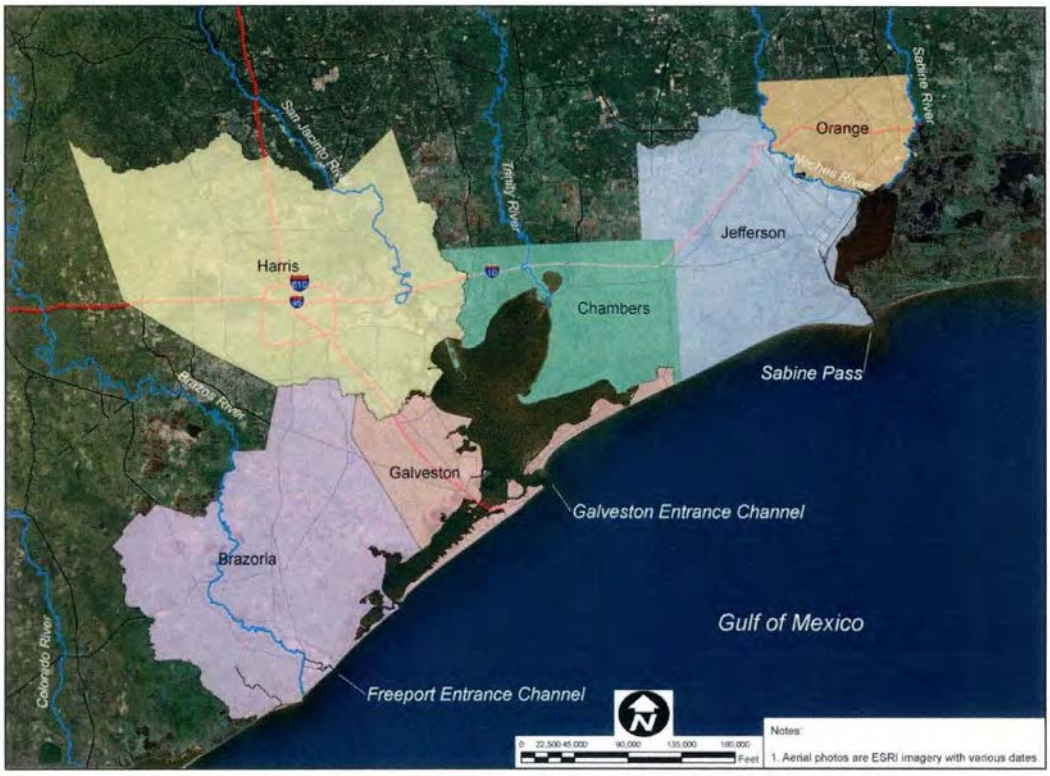
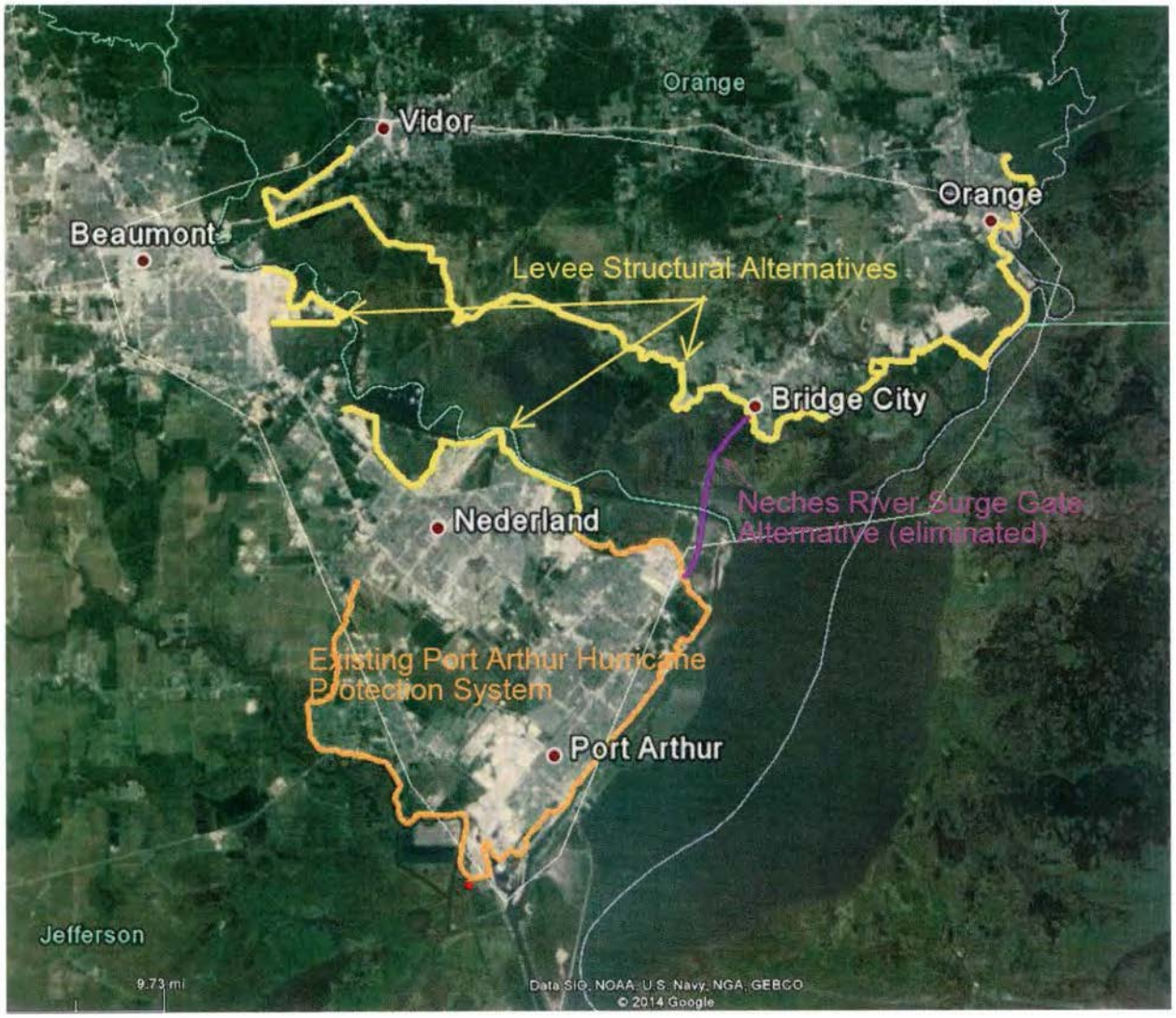


Six County Sabine Pass to Galveston Bay Study Area

Existing Freeport Hurricane Flood Protection System



Existing Port Arthur Hurricane Flood Protection System, Levee Structural Alternatives and Neches River Surge Gate Alternative

DEPARTMENT OF THE ARMY
FORT WORTH DISTRICT, CORPS OF ENGINEERS
P.O. BOX 17300
FORT WORTH, TEXAS 76102-0300

November 19, 2014

REPLY TO
ATTENTION OF

NEPA/Cultural Resources Section

Holly Houghton
Tribal Historic Preservation Officer
Mescalero Apache Tribe
P.O. Box 227
Mescalero, NM 88340

Dear Ms. Houghton:

The Galveston District, Corps of Engineers, and the non-federal sponsor, the Texas General Land Office, would like to invite your tribe to participate as a cooperating agency in the development of an Environmental Impact Statement (EIS) for the Sabine Pass to Galveston Bay, Texas, Coastal Storm Risk Management and Ecosystem Restoration Study. The integrated feasibility report and EIS (IFR-EIS) will evaluate structural and non-structural alternatives which address coastal storm risk management (CSRM) and ecosystem restoration (ER) opportunities in Orange, Jefferson, Chambers, Harris, Galveston and Brazoria counties on the upper Texas Gulf coast. The Draft IFR-EIS is currently scheduled to be released for public review and comment in August 2015.

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Sincerely,

Carolyn Murphy
Chief, Unit A, NEPA/Cultural
Resources Section

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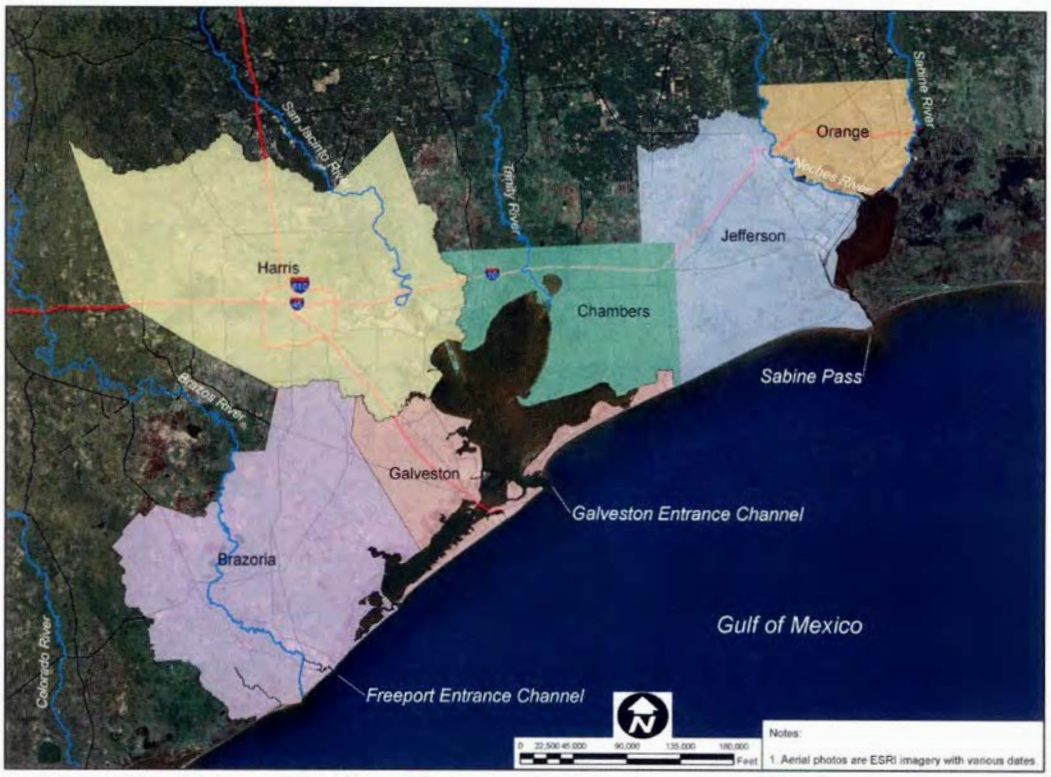
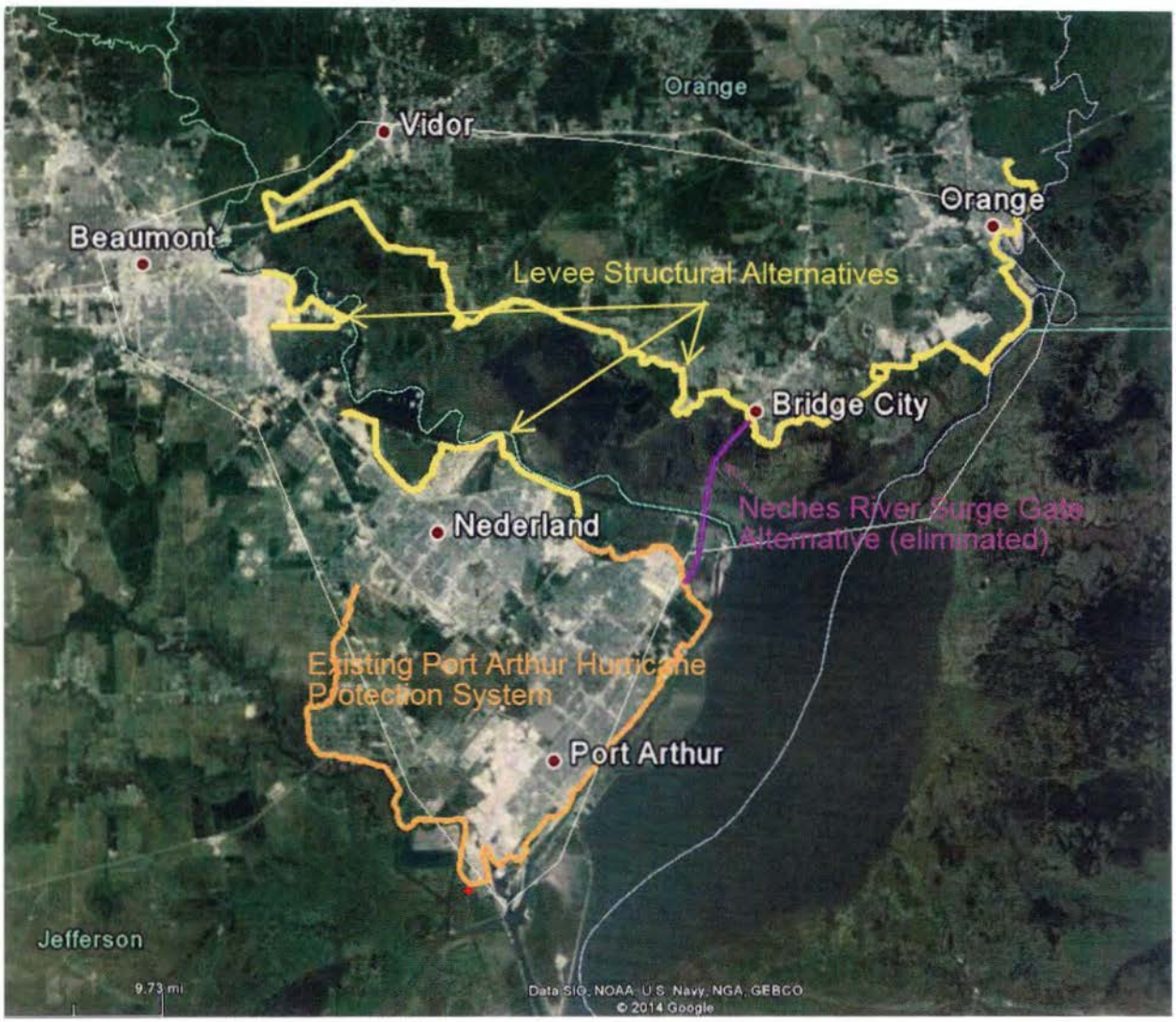


Six County Sabine Pass to Galveston Bay Study Area

Existing Freeport Hurricane Flood Protection System



Existing Port Arthur Hurricane Flood Protection System, Levee Structural Alternatives and Neches River Surge Gate Alternative

DEPARTMENT OF THE ARMY
FORT WORTH DISTRICT, CORPS OF ENGINEERS
P.O. BOX 17300
FORT WORTH, TEXAS 76102-0300
November 19, 2014

REPLY TO
ATTENTION OF

NEPA/Cultural Resources Section

President Don L. Patterson
Tonkawa Tribe of Oklahoma
1 Rush Buffalo Road
Tonkawa, OK 74653

Dear President Patterson:

The Galveston District, Corps of Engineers, and the non-federal sponsor, the Texas General Land Office, would like to invite your tribe to participate as a cooperating agency in the development of an Environmental Impact Statement (EIS) for the Sabine Pass to Galveston Bay, Texas, Coastal Storm Risk Management and Ecosystem Restoration Study. The integrated feasibility report and EIS (IFR-EIS) will evaluate structural and non-structural alternatives which address coastal storm risk management (CSRM) and ecosystem restoration (ER) opportunities in Orange, Jefferson, Chambers, Harris, Galveston and Brazoria counties on the upper Texas Gulf coast. The Draft IFR-EIS is currently scheduled to be released for public review and comment in August 2015.

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Carolyn Murphy
Chief, Unit A, NEPA/Cultural
Resources Section

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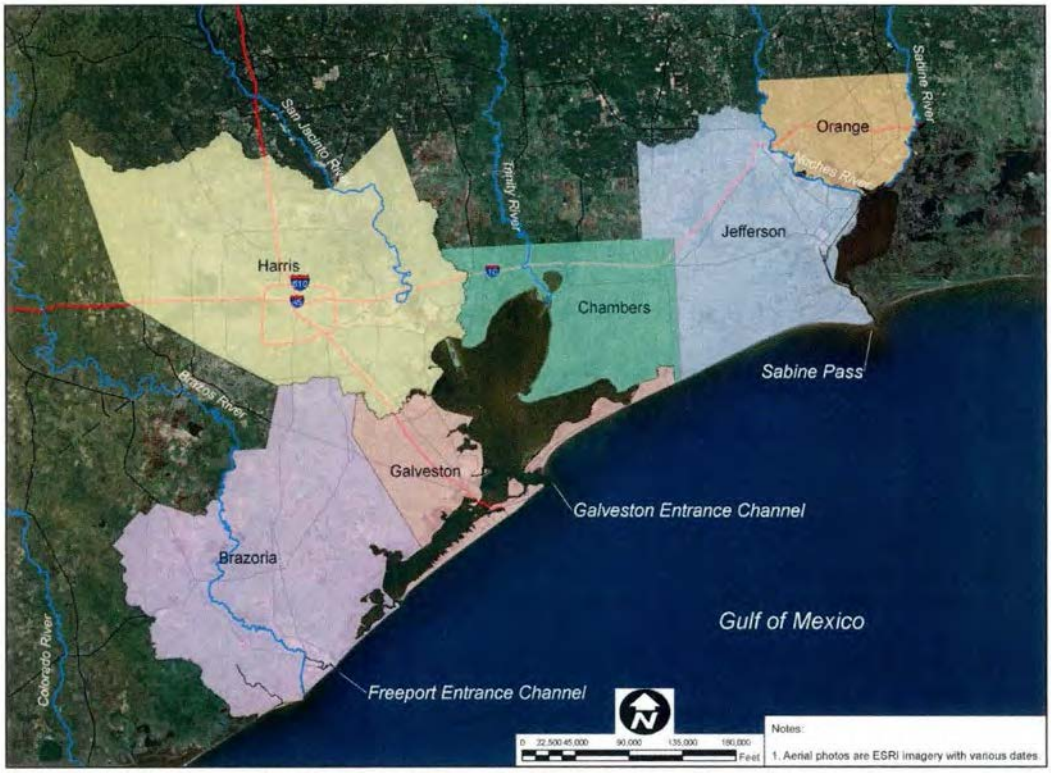
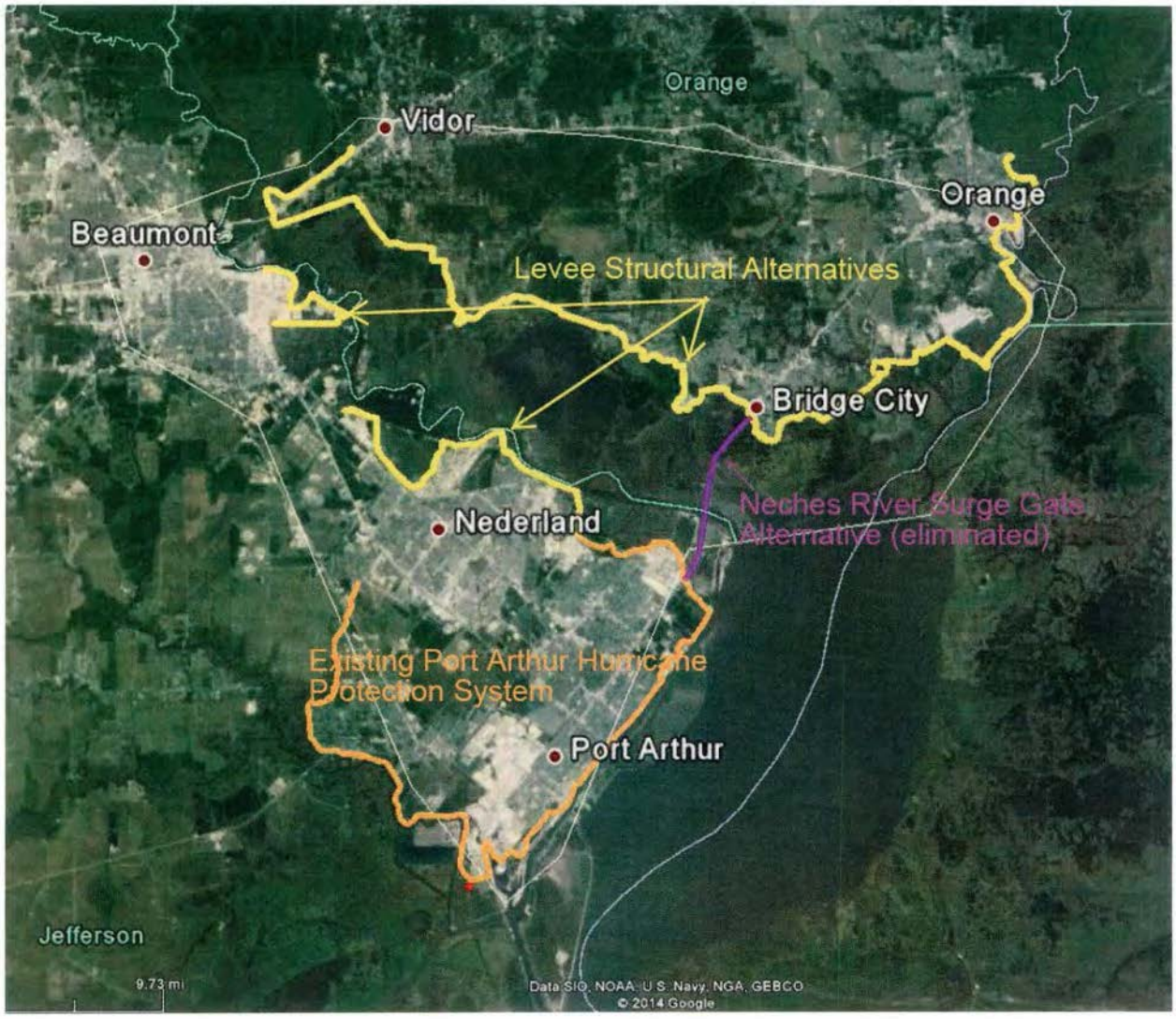


Six County Sabine Pass to Galveston Bay Study Area

Existing Freeport Hurricane Flood Protection System



Existing Port Arthur Hurricane Flood Protection System, Levee Structural Alternatives and Neches River Surge Gate Alternative

Cooperating Agency Request Letters

DEPARTMENT OF THE ARMY
FORT WORTH DISTRICT, CORPS OF ENGINEERS
P.O. BOX 17300
FORT WORTH, TEXAS 76102-0300
November 19, 2014

REPLY TO
ATTENTION OF

NEPA/Cultural Resources Section

Edith Erfling
Field Supervisor
Clear Lake Ecological Services Field Office
17629 El Camino Real, Suite 211
Houston, Texas 77058

Dear Ms. Erfling:

The Galveston District, Corps of Engineers, and the non-federal sponsor, the Texas General Land Office, would like to invite your agency to participate as a cooperating agency in the development of an Environmental Impact Statement (EIS) for the Sabine Pass to Galveston Bay, Texas, Coastal Storm Risk Management and Ecosystem Restoration Feasibility Study. The Integrated Feasibility Report and Environmental Impact Statement (IFR-EIS) will evaluate structural and non-structural alternatives which address coastal storm risk management (CSRM) impacts and ecosystem restoration (ER) opportunities in Orange, Jefferson, Chambers, Harris, Galveston and Brazoria Counties. The Draft IFR-EIS is currently scheduled to be released for public review and comment in August 2015.

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We are inviting your participation as a cooperating agency pursuant to Council on Environmental Quality (CEQ) Regulations for Implementing the National Environmental Policy Act (NEPA) (40 CFR Part 1501.6). Furthermore, we would like to coordinate with you our schedule for study completion so that all reviews and approvals will, to the maximum extent practicable, be conducted concurrently. This concurrent coordination is required by Section 2045 of the Water Resources Development Act of 2007. The following review periods for the Biological Opinion (if needed) and the IFR-EIS have been established in accordance with the current project schedule:

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Sincerely,

Carolyn Murphy
Chief, Unit A, NEPA/Cultural
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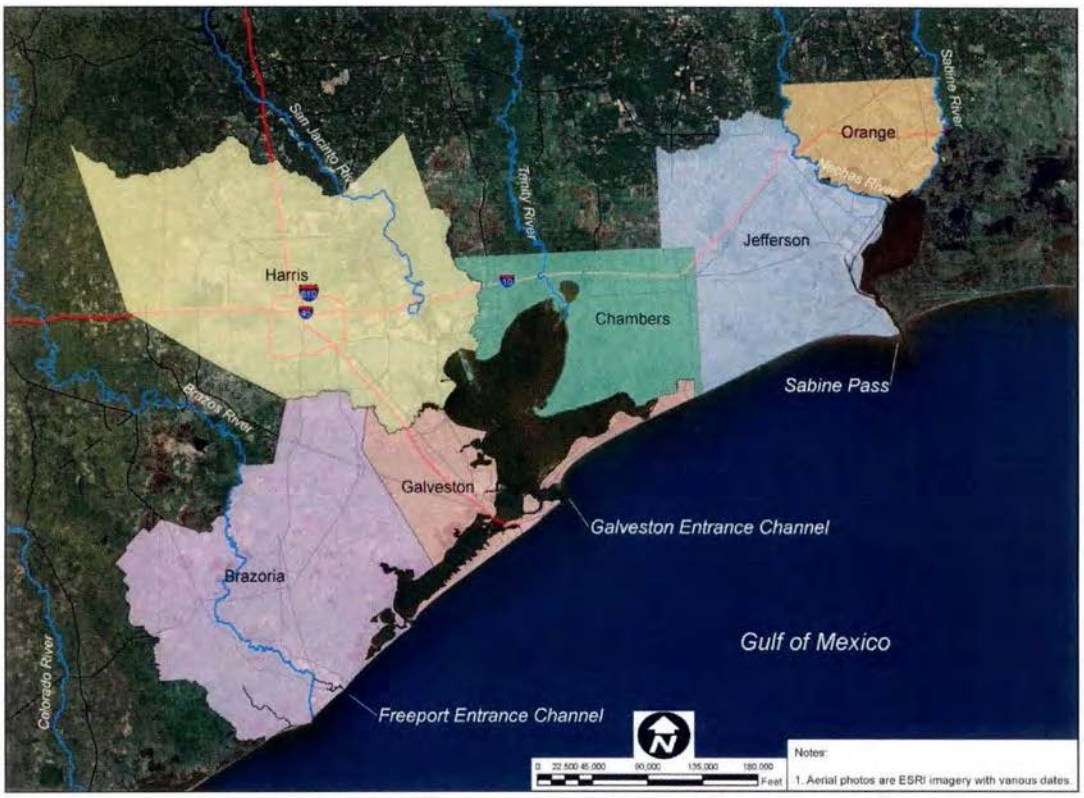

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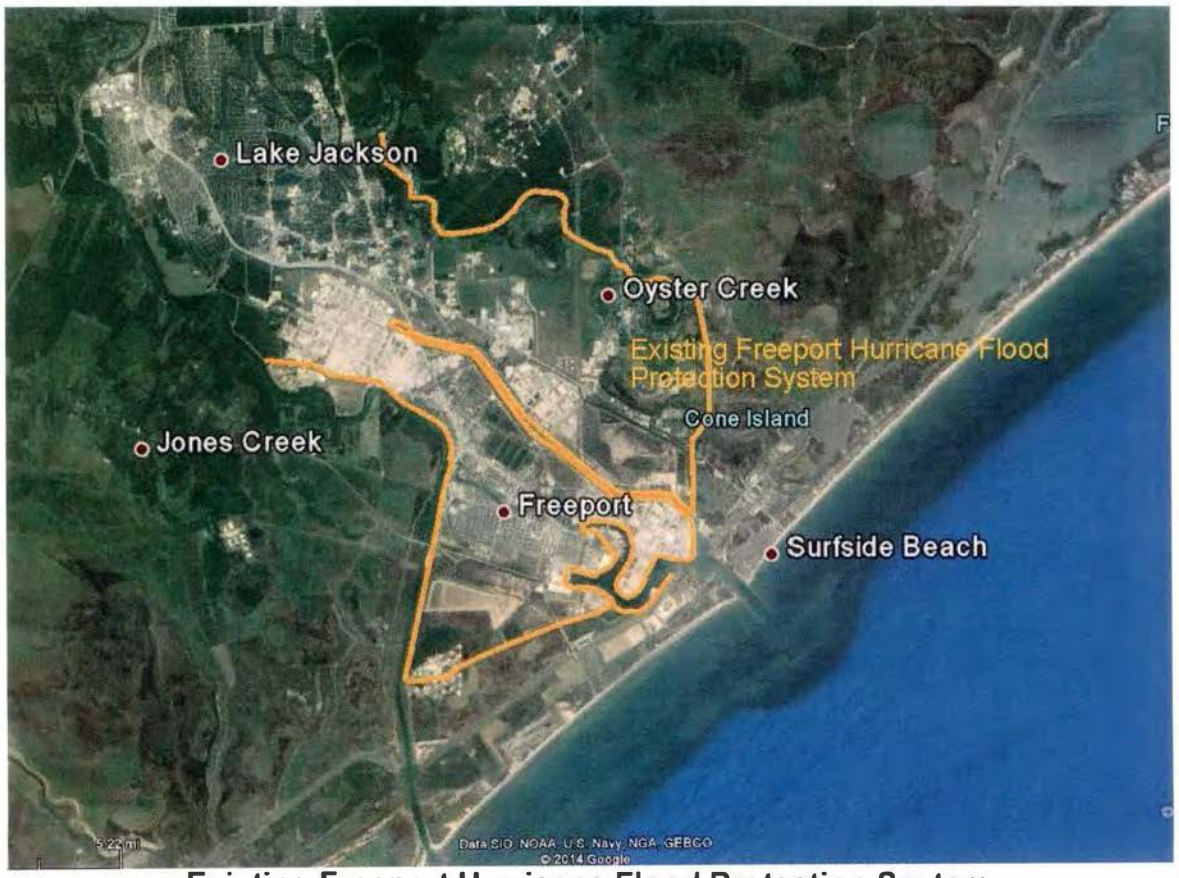

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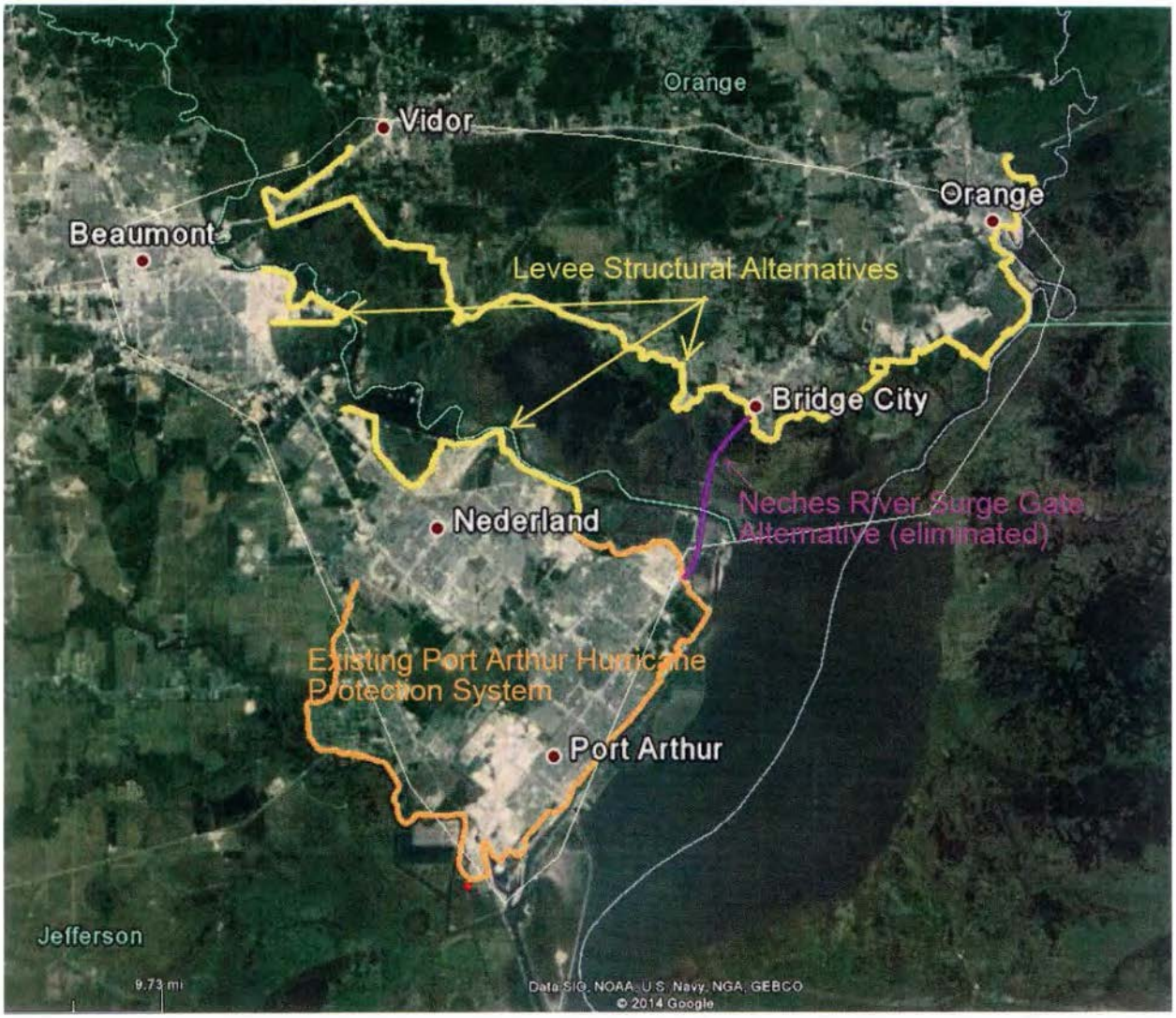

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DEPARTMENT OF THE ARMY
FORT WORTH DISTRICT, CORPS OF ENGINEERS
P.O. BOX 17300
FORT WORTH, TEXAS 76102-0300
November 19, 2014

REPLY TO
ATTENTION OF

NEPA/Cultural Resources Section

Roy E. Crabtree, Ph.D.
Regional Administrator
National Marine Fisheries Service
Southeast Regional Office
263 13th Avenue South
St. Petersburg, FL 33701

Dear Mr. Crabtree:

The Galveston District, Corps of Engineers, and the non-federal sponsor, the Texas General Land Office, would like to invite your agency to participate as a cooperating agency in the development of an Environmental Impact Statement (EIS) for the Sabine Pass to Galveston Bay, Texas, Coastal Storm Risk Management and Ecosystem Restoration Feasibility Study. The Integrated Feasibility Report and Environmental Impact Statement (IFR-EIS) will evaluate structural and non-structural alternatives which address coastal storm risk management (CSRM) impacts and ecosystem restoration (ER) opportunities in Orange, Jefferson, Chambers, Harris, Galveston and Brazoria Counties. The Draft IFR-EIS is currently scheduled to be released for public review and comment in August 2015.

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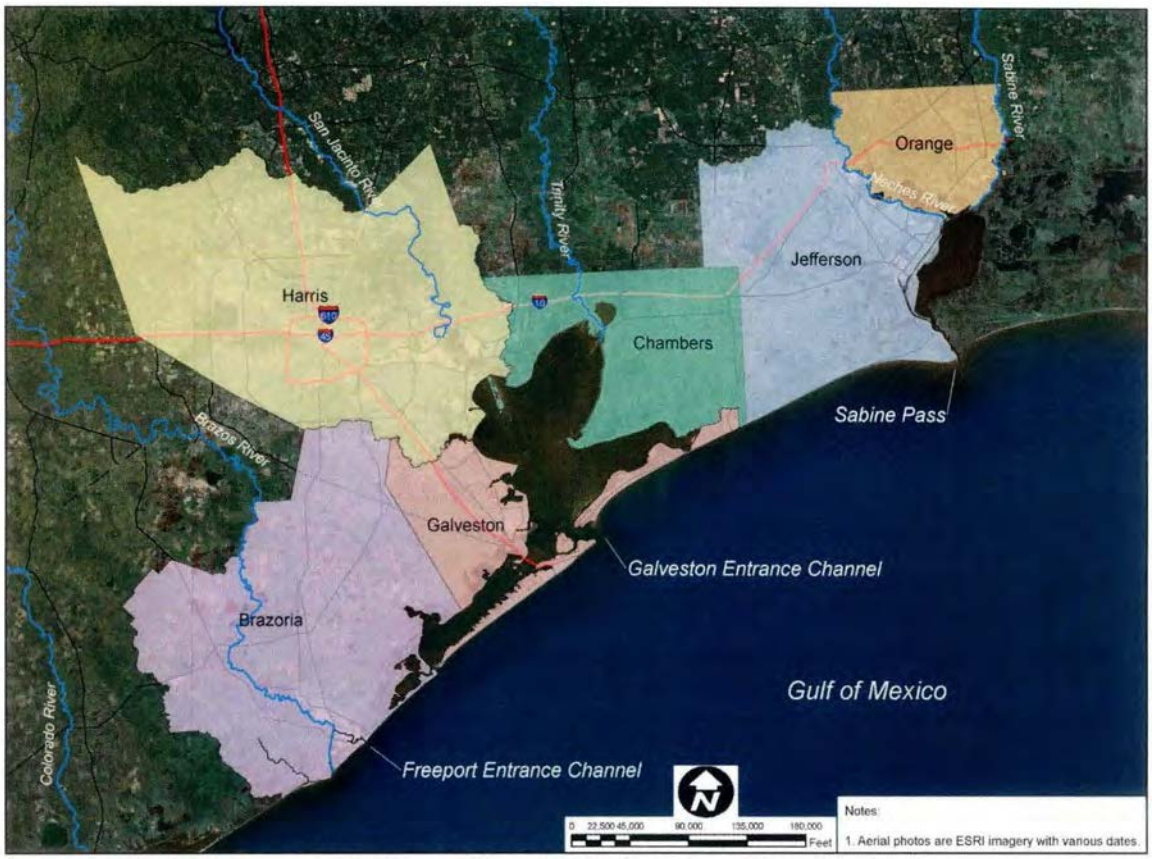
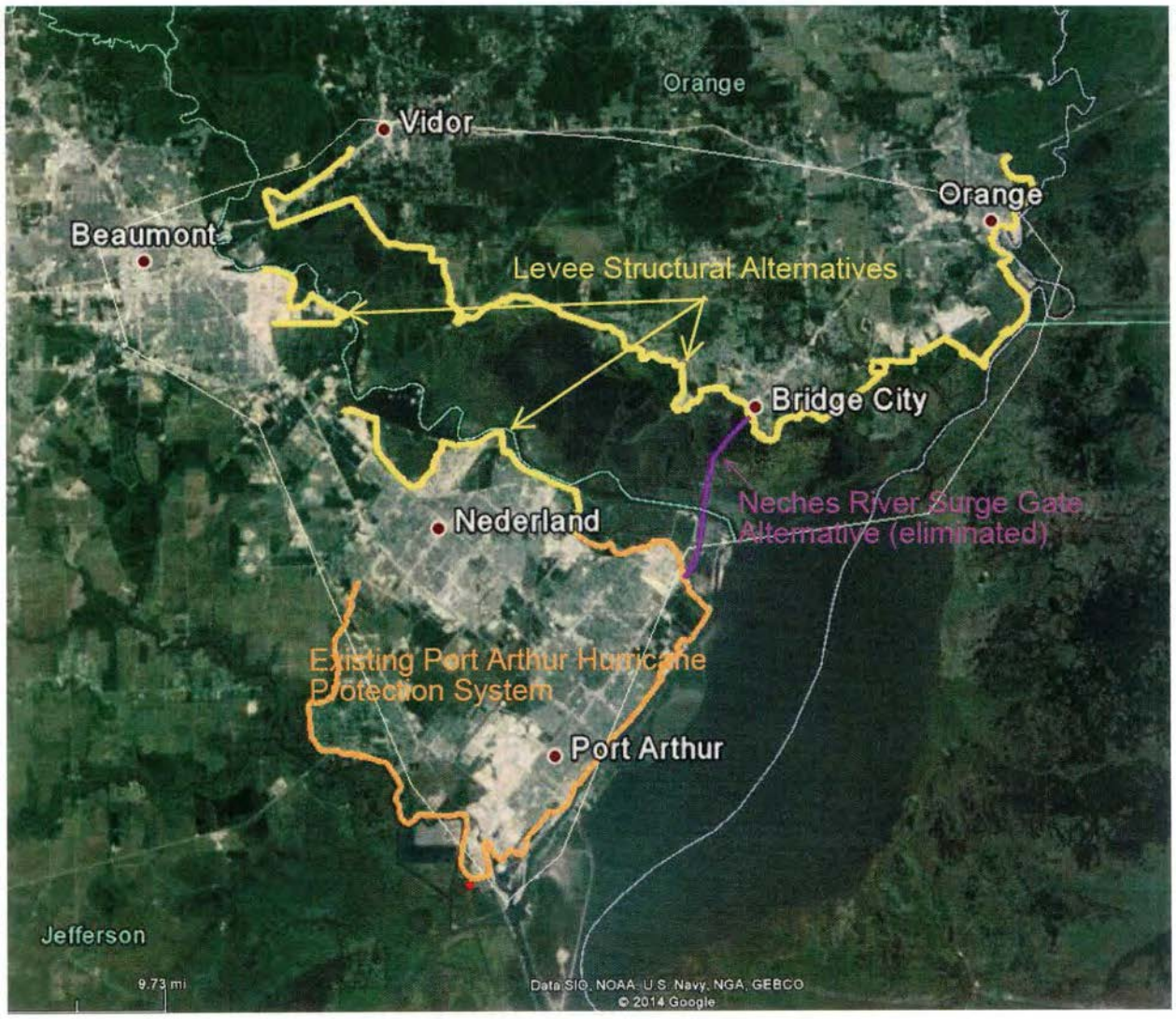


Six County Sabine Pass to Galveston Bay Study Area

Existing Freeport Hurricane Flood Protection System



Existing Port Arthur Hurricane Flood Protection System, Levee Structural Alternatives and Neches River Surge Gate Alternative

DEPARTMENT OF THE ARMY
FORT WORTH DISTRICT, CORPS OF ENGINEERS
P.O. BOX 17300
FORT WORTH, TEXAS 76102-0300
November 19, 2014

REPLY TO
ATTENTION OF

NEPA/Cultural Resources Section

Rusty Swafford
National Marine Fisheries Service
4700 Avenue U
Galveston, Texas 77551

Dear Mr. Swafford:

The Galveston District, Corps of Engineers, and the non-federal sponsor, the Texas General Land Office, would like to invite your agency to participate as a cooperating agency in the development of an Environmental Impact Statement (EIS) for the Sabine Pass to Galveston Bay, Texas, Coastal Storm Risk Management and Ecosystem Restoration Feasibility Study. The Integrated Feasibility Report and Environmental Impact Statement (IFR-EIS) will evaluate structural and non-structural alternatives which address coastal storm risk management (CSRM) impacts and ecosystem restoration (ER) opportunities in Orange, Jefferson, Chambers, Harris, Galveston and Brazoria Counties. The Draft IFR-EIS is currently scheduled to be released for public review and comment in August 2015.

Structural alternatives that are being evaluated are: (1) new surge protection levees and small, navigable surge gates on Cow and Adams Bayous in Orange and Jefferson Counties; (2) a large navigable surge gate in the Neches River near the Rainbow Bridge (eliminated); and (3) reevaluation of the existing Port Arthur and Freeport Hurricane Flood Protection (HFP) systems in Jefferson and Brazoria Counties, respectively. Maps showing the location of the existing HPFs and the structural alternatives are enclosed. Non-structural measures such as targeted buy-outs will also be evaluated. Structural and non-structural alternatives to address storm surge impacts in the Galveston Bay system, as well as ER measures throughout the six-county study area will be evaluated programmatically, with recommendations being made for detailed analyses of feasible alternatives in future studies.

We are inviting your participation as a cooperating agency pursuant to Council on Environmental Quality (CEQ) Regulations for Implementing the National Environmental Policy Act (NEPA) (40 CFR Part 1501.6). Furthermore, we would like to coordinate with you our schedule for study completion so that all reviews and approvals will, to the maximum extent practicable, be conducted concurrently. This concurrent coordination is required by Section 2045 of the Water Resources Development Act of 2007. The following review periods for Essential Fish Habitat consultation (if needed) and the IFR-EIS have been established in accordance with the current project schedule:

Essential Fish Habitat Consultation (if needed) – January 5 through April 17, 2015

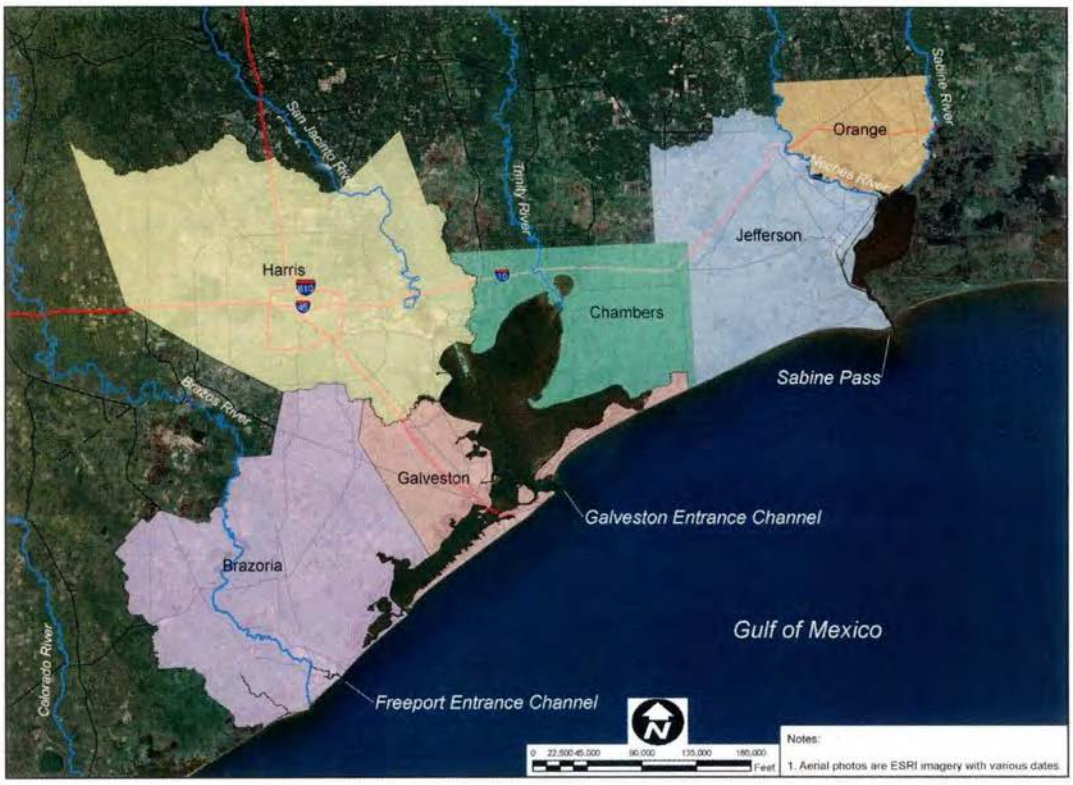
Review of Draft IFR-EIS --45-day review period (August 29 through October 12, 2015)
State and Agency Review of Final IFR-EIS – 30-day review (July 15 through August 14, 2016)

We appreciate this opportunity to invite your agency's participation as a cooperating agency and request that you advise us as to whether the review periods are acceptable to your agency. If you should have any questions regarding this request, please contact Janelle Stokes of my staff at (409) 766-3039.

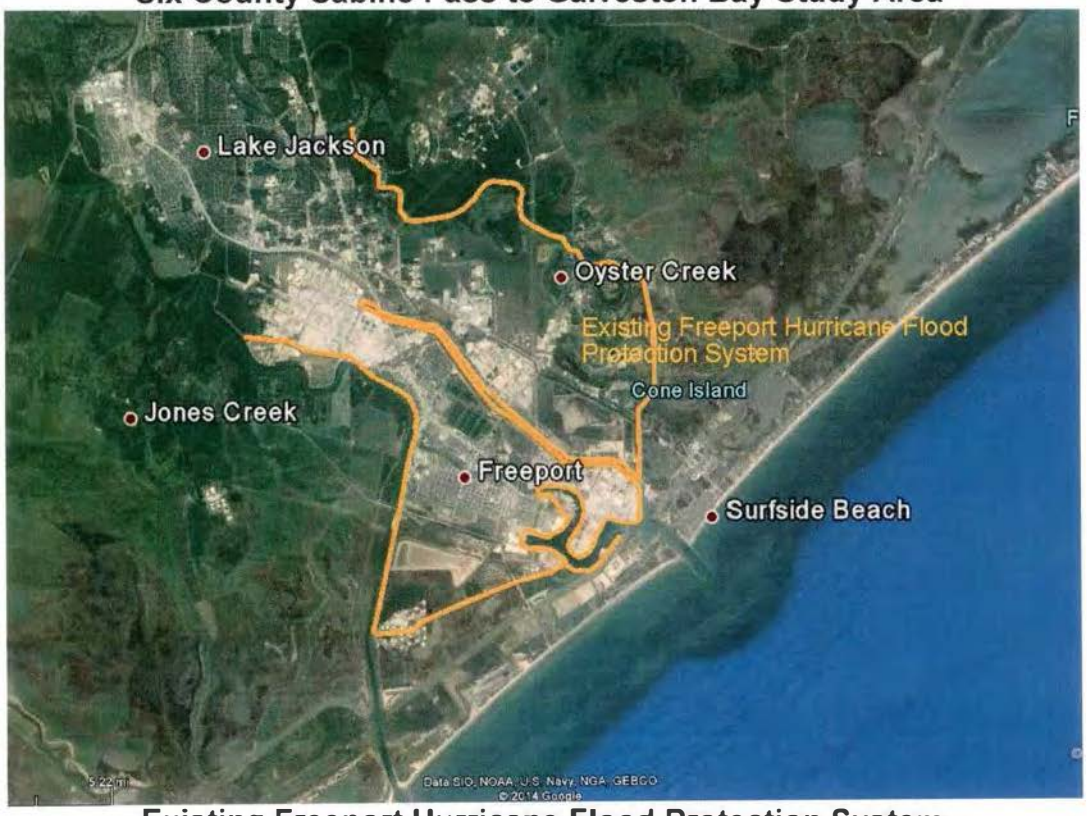
Sincerely,

Carolyn Murphy
Chief, Unit A, NEPA/Cultural
Resources Section

Enclosures



Six County Sabine Pass to Galveston Bay Study Area



Existing Freeport Hurricane Flood Protection System

Existing Port Arthur Hurricane Flood Protection System, Levee Structural Alternatives and Neches River Surge Gate Alternative

DEPARTMENT OF THE ARMY
FORT WORTH DISTRICT, CORPS OF ENGINEERS
P.O. BOX 17300
FORT WORTH, TEXAS 76102-0300
November 19, 2014

REPLY TO
ATTENTION OF

NEPA/Cultural Resources Section

Rebecca Hensley
Ecosystem Resources Program Regional Director
Texas Parks and Wildlife Department
1502 FM 517 East
Dickinson, Texas 77539

Dear Ms. Hensley:

The Galveston District, Corps of Engineers, and the non-federal sponsor, the Texas General Land Office, would like to invite your agency to participate as a cooperating agency in the development of an Environmental Impact Statement (EIS) for the Sabine Pass to Galveston Bay, Texas, Coastal Storm Risk Management and Ecosystem Restoration Feasibility Study. The Integrated Feasibility Report and Environmental Impact Statement (IFR-EIS) will evaluate structural and non-structural alternatives which address coastal storm risk management (CSRM) impacts and ecosystem restoration (ER) opportunities in Orange, Jefferson, Chambers, Harris, Galveston and Brazoria Counties. The Draft IFR-EIS is currently scheduled to be released for public review and comment in August 2015.

Structural alternatives that will be evaluated are: (1) new surge protection levees and small, navigable surge gates on Cow and Adams Bayous in Orange and Jefferson Counties; (2) a large navigable surge gate in the Neches River near the Rainbow Bridge (eliminated); and (3) reevaluation of the existing Port Arthur and Freeport Hurricane Flood Protection (HFP) systems in Jefferson and Brazoria Counties, respectively. Maps showing the location of the existing HPFs and the structural alternatives are enclosed. Non-structural measures such as targeted buy-outs will also be evaluated. Structural and non-structural alternatives to address storm surge impacts in the Galveston Bay system, as well as ER measures throughout the six-county study area will be evaluated programmatically, with recommendations being made for detailed analyses of feasible alternatives in future studies.

We are inviting your participation as a cooperating agency pursuant to Council on Environmental Quality (CEQ) Regulations for Implementing the National Environmental Policy Act (NEPA) (40 CFR Part 1501.6). Furthermore, we would like to coordinate with you our schedule for study completion so that all reviews and approvals will, to the maximum extent practicable, be conducted concurrently. This concurrent coordination is required by Section 2045 of the Water Resources Development Act of 2007. The following review periods for the IFR-EIS have been established in accordance with the current project schedule:

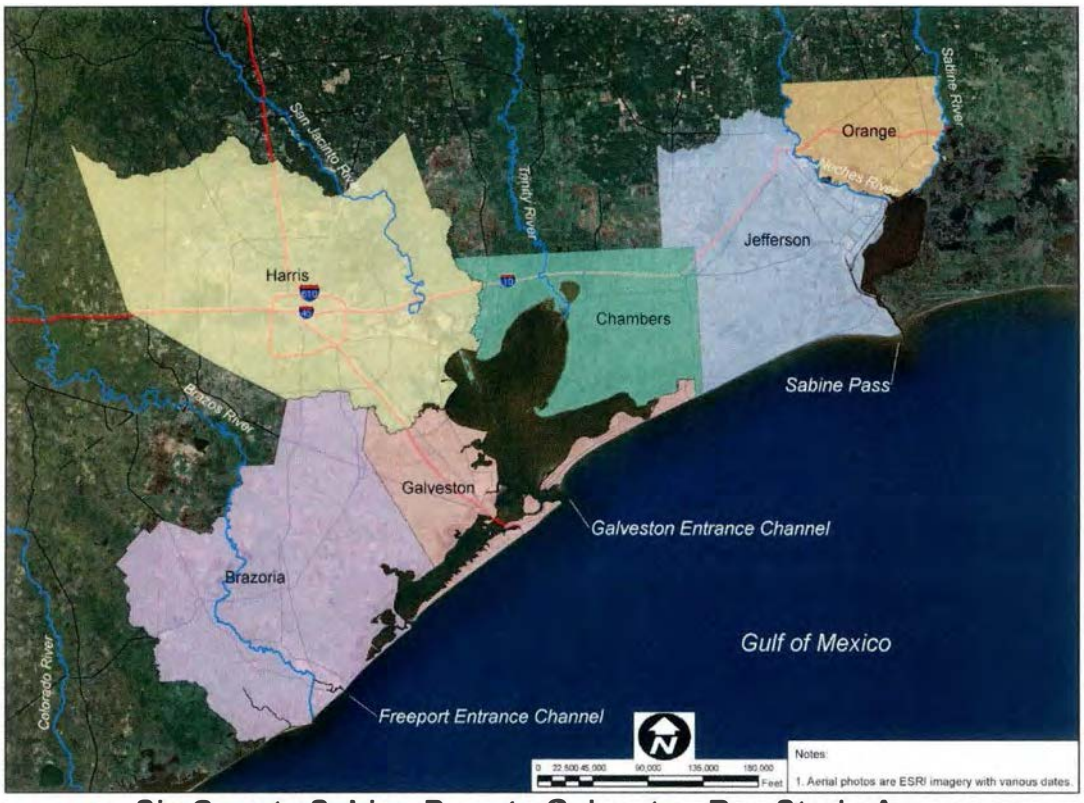
Review of Draft IFR-EIS --45-day review period (August 29 through October 12, 2015)
State and Agency Review of Final IFR-EIS – 30-day review (July 15 through August 14, 2016)

We appreciate this opportunity to invite your agency's participation as a cooperating agency and request that you advise us as to whether the review periods are acceptable to your agency. If you should have any questions regarding this request, please contact Janelle Stokes of my staff at (409) 766-3039.

Sincerely,

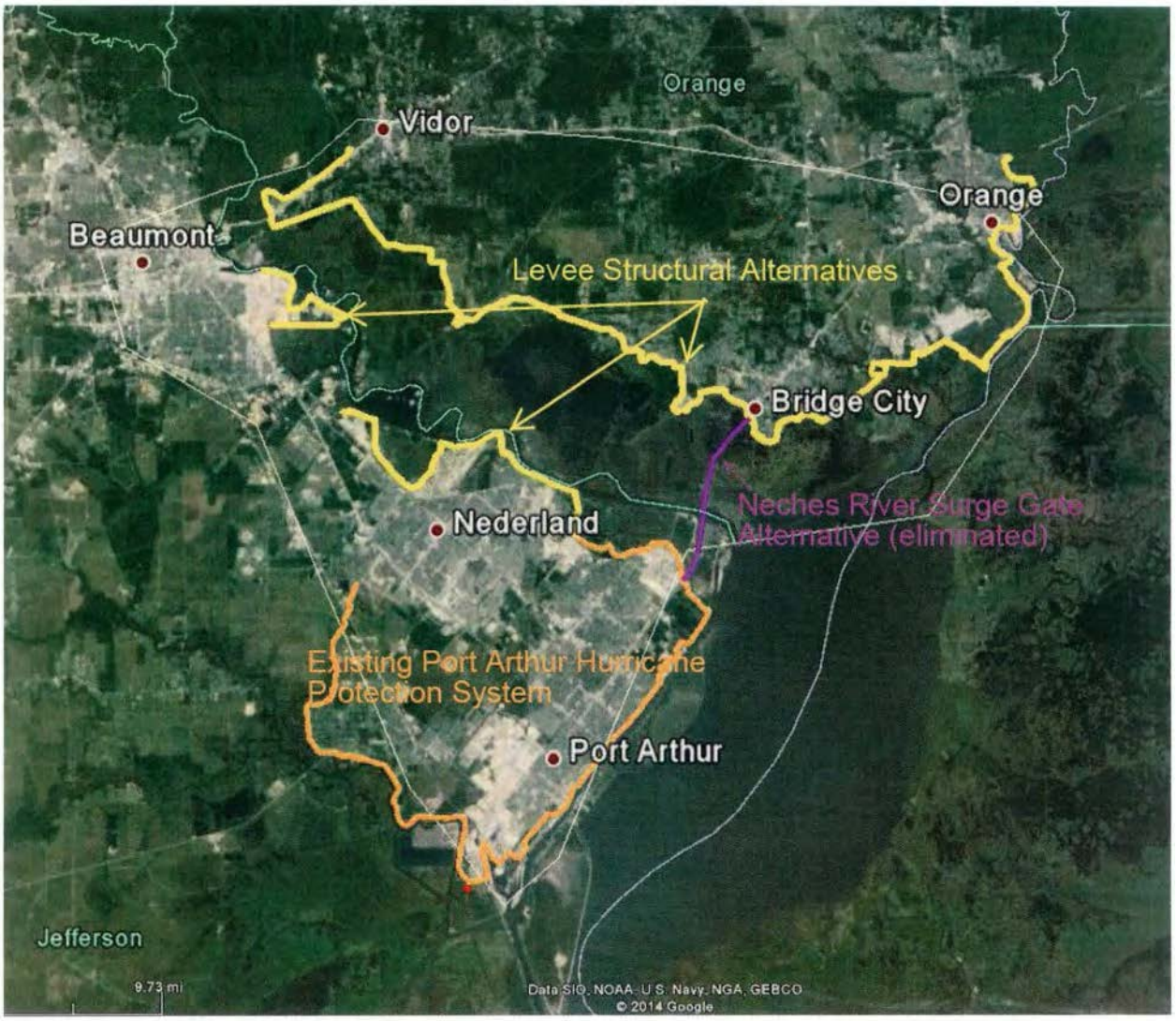
Carolyn Murphy
Chief, Unit A, NEPA/Cultural
Resources Section

Enclosures



Six County Sabine Pass to Galveston Bay Study Area

Existing Freeport Hurricane Flood Protection System



Existing Port Arthur Hurricane Flood Protection System, Levee Structural Alternatives and Neches River Surge Gate Alternative

DEPARTMENT OF THE ARMY
FORT WORTH DISTRICT, CORPS OF ENGINEERS
P.O. BOX 17300
FORT WORTH, TEXAS 76102-0300
November 19, 2014

REPLY TO
ATTENTION OF

NEPA/Cultural Resources Section

Greg Easley
Texas Commission on Environmental Quality
P.O. Box 13087, MC-150
Austin, Texas 78711-3087

Dear Mr. Easely:

The Galveston District, Corps of Engineers, and the non-federal sponsor, the Texas General Land Office, would like to invite your agency to participate as a cooperating agency in the development of an Environmental Impact Statement (EIS) for the Sabine Pass to Galveston Bay, Texas, Coastal Storm Risk Management and Ecosystem Restoration Feasibility Study. The Integrated Feasibility Report and Environmental Impact Statement (IFR-EIS) will evaluate structural and non-structural alternatives which address coastal storm risk management (CSRM) impacts and ecosystem restoration (ER) opportunities in Orange, Jefferson, Chambers, Harris, Galveston and Brazoria Counties. The Draft IFR-EIS is currently scheduled to be released for public review and comment in August 2015.

Structural alternatives that will be evaluated are: (1) new surge protection levees and small, navigable surge gates on Cow and Adams Bayous in Orange and Jefferson Counties; (2) a large navigable surge gate in the Neches River near the Rainbow Bridge (eliminated); and (3) reevaluation of the existing Port Arthur and Freeport Hurricane Flood Protection (HFP) systems in Jefferson and Brazoria Counties, respectively. Maps showing the location of the existing HPFs and the structural alternatives are enclosed. Non-structural measures such as targeted buy-outs will also be evaluated. Structural and non-structural alternatives to address storm surge impacts in the Galveston Bay system, as well as ER measures throughout the six-county study area will be evaluated programmatically, with recommendations being made for detailed analyses of feasible alternatives in future studies.

We are inviting your participation as a cooperating agency pursuant to Council on Environmental Quality (CEQ) Regulations for Implementing the National Environmental Policy Act (NEPA) (40 CFR Part 1501.6). Furthermore, we would like to coordinate with you our schedule for study completion so that all reviews and approvals will, to the maximum extent practicable, be conducted concurrently. This concurrent coordination is required by Section 2045 of the Water Resources Development Act of 2007. The following review period for the Clean Water Act Section 404(b)(1) Evaluation, in conjunction with the IFR-EIS, has been established in accordance with the current project schedule:

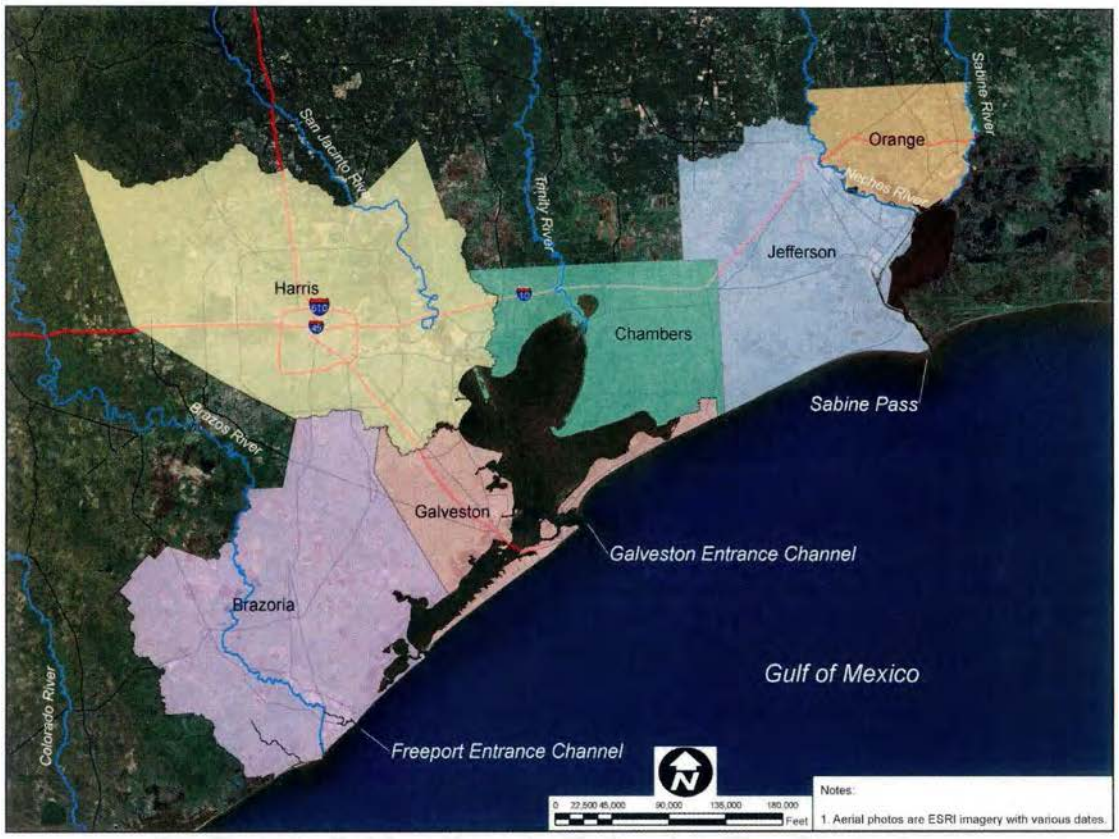
Review of Draft IFR-EIS --45-day review period (August 29 through October 12, 2015)
State and Agency Review of Final IFR-EIS – 30-day review (July 15 through August 14, 2016)

We appreciate this opportunity to invite your agency's participation as a cooperating agency and request that you advise us as to whether the review period is acceptable to your agency. If you should have any questions regarding this request, please contact Janelle Stokes of my staff at (409) 766-3039.

Sincerely,

Carolyn Murphy
Chief, Unit A, NEPA/Cultural
Resources Section

Enclosures



Six County Sabine Pass to Galveston Bay Study Area

Existing Freeport Hurricane Flood Protection System

Existing Port Arthur Hurricane Flood Protection System, Levee Structural Alternatives and Neches River Surge Gate Alternative

DEPARTMENT OF THE ARMY
FORT WORTH DISTRICT, CORPS OF ENGINEERS
P.O. BOX 17300
FORT WORTH, TEXAS 76102-0300
November 19, 2014

REPLY TO
ATTENTION OF

NEPA/Cultural Resources Section

Matthew Mahoney
Waterways Program Coordinator
Texas Department of Transportation
Maritime Division
118 E. Riverside Drive
Austin, Texas 78704

Dear Mr. Mahoney:

The Galveston District, Corps of Engineers, and the non-federal sponsor, the Texas General Land Office, would like to invite your agency to participate as a cooperating agency in the development of an Environmental Impact Statement (EIS) for the Sabine Pass to Galveston Bay, Texas, Coastal Storm Risk Management and Ecosystem Restoration Feasibility Study. The Integrated Feasibility Report and Environmental Impact Statement (IFR-EIS) will evaluate structural and non-structural alternatives which address coastal storm risk management (CSRM) impacts and ecosystem restoration (ER) opportunities in Orange, Jefferson, Chambers, Harris, Galveston and Brazoria Counties. The Draft IFR-EIS is currently scheduled to be released for public review and comment in August 2015.

Structural alternatives that will be evaluated are: (1) new surge protection levees and small, navigable surge gates on Cow and Adams Bayous in Orange and Jefferson Counties; (2) a large navigable surge gate in the Neches River near the Rainbow Bridge (eliminated); and (3) reevaluation of the existing Port Arthur and Freeport Hurricane Flood Protection (HFP) systems in Jefferson and Brazoria Counties, respectively. Maps showing the location of the existing HPFs and the structural alternatives are enclosed. Non-structural measures such as targeted buy-outs will also be evaluated. Structural and non-structural alternatives to address storm surge impacts in the Galveston Bay system, as well as ER measures throughout the six-county study area will be evaluated programmatically, with recommendations being made for detailed analyses of feasible alternatives in future studies.

We are inviting your participation as a cooperating agency pursuant to Council on Environmental Quality (CEQ) Regulations for Implementing the National Environmental Policy Act (NEPA) (40 CFR Part 1501.6). Furthermore, we would like to coordinate with you our schedule for study completion so that all reviews and approvals will, to the maximum extent practicable, be conducted concurrently. This concurrent coordination is required by Section 2045 of the Water Resources Development Act of 2007. The following review periods for the IFR-EIS have been established in accordance with the current project schedule:

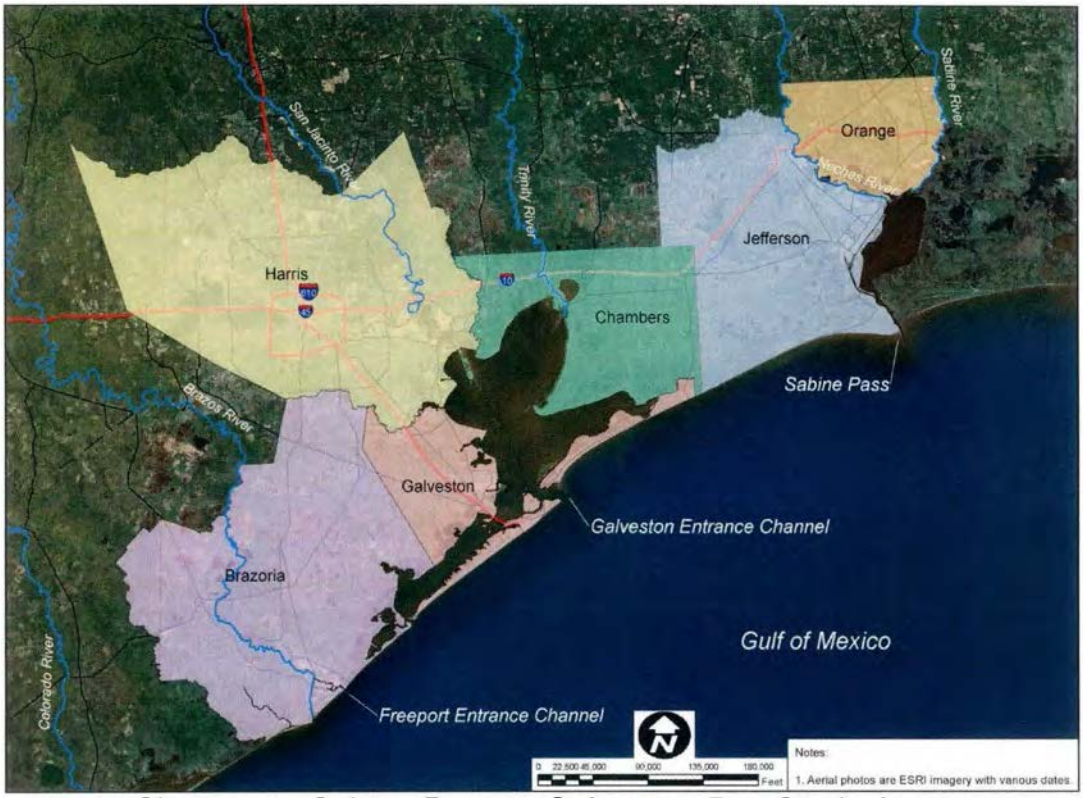
Review of Draft IFR-EIS --45-day review period (August 29 through October 12, 2015)
State and Agency Review of Final IFR-EIS – 30-day review (July 15 through August 14, 2016)

We appreciate this opportunity to invite your agency's participation as a cooperating agency and request that you advise us as to whether the review periods are acceptable to your agency. If you should have any questions regarding this request, please contact Janelle Stokes of my staff at (409) 766-3039.

Sincerely,

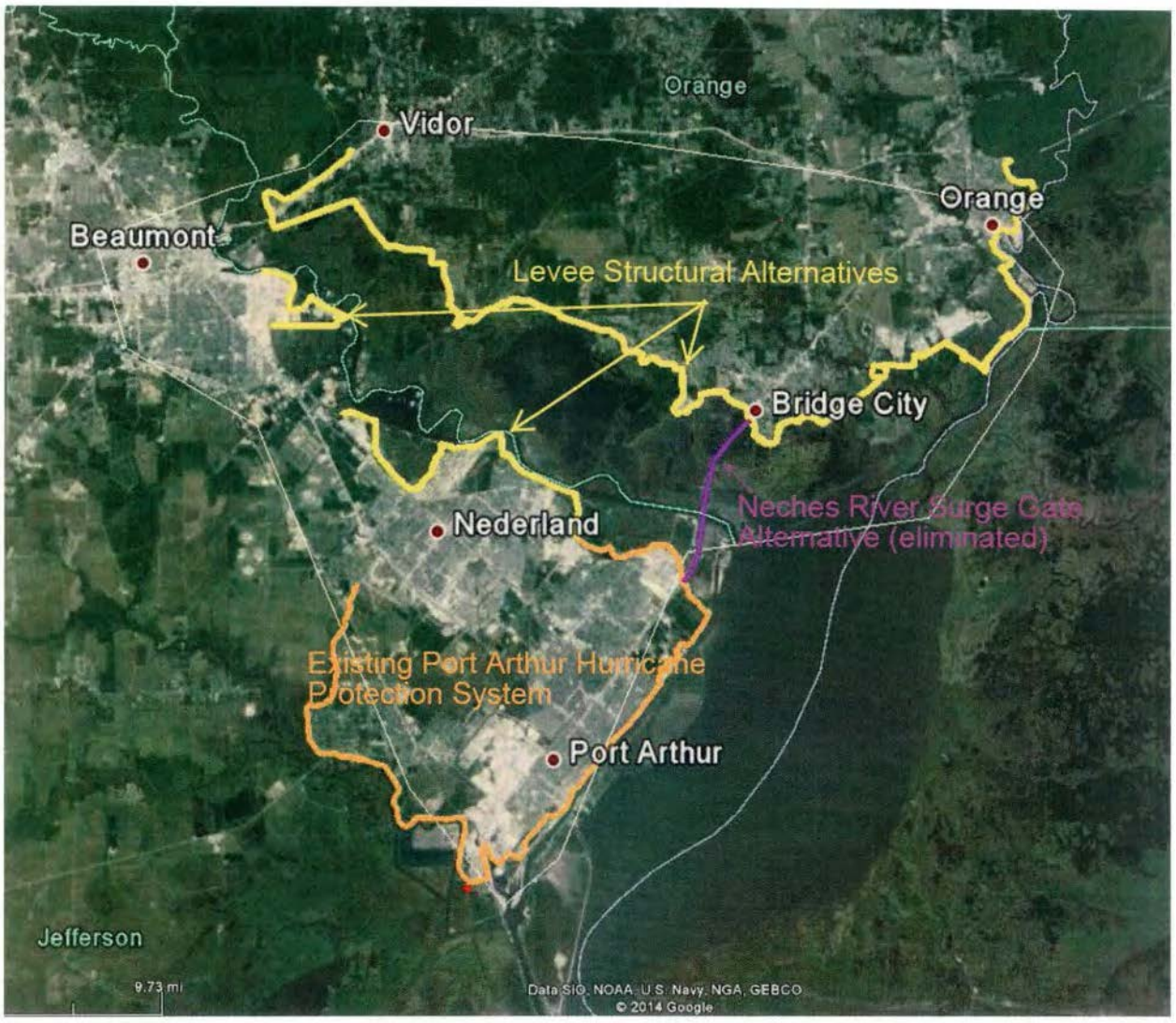
Carolyn Murphy
Chief, Unit A, NEPA/Cultural
Resources Section

Enclosures



Six County Sabine Pass to Galveston Bay Study Area

Existing Freeport Hurricane Flood Protection System



Existing Port Arthur Hurricane Flood Protection System, Levee Structural Alternatives and Neches River Surge Gate Alternative

DEPARTMENT OF THE ARMY
FORT WORTH DISTRICT, CORPS OF ENGINEERS
P.O. BOX 17300
FORT WORTH, TEXAS 76102-0300

November 19, 2014

REPLY TO
ATTENTION OF

NEPA/Cultural Resources Section

Ray Newby
Coastal Resources Division
Texas General Land Office
P.O. Box 12873
Austin, Texas 78711-2873

Dear Mr. Newby:

The Galveston District, Corps of Engineers is currently preparing an Environmental Impact Statement (EIS) for the Sabine Pass to Galveston Bay, Texas, Coastal Storm Risk Management and Ecosystem Restoration Feasibility Study. The Integrated Feasibility Report and Environmental Impact Statement (IFR-EIS) will evaluate structural and non-structural alternatives which address coastal storm risk management (CSRM) impacts and ecosystem restoration (ER) opportunities in Orange, Jefferson, Chambers, Harris, Galveston and Brazoria Counties. The Draft IFR-EIS is currently scheduled to be released for public review and comment in August 2015.

Structural alternatives that will be evaluated are: (1) new surge protection levees and small, navigable surge gates on Cow and Adams Bayous in Orange and Jefferson Counties; (2) a large navigable surge gate in the Neches River near the Rainbow Bridge (eliminated); and (3) reevaluation of the existing Port Arthur and Freeport Hurricane Flood Protection (HFP) systems in Jefferson and Brazoria Counties, respectively. Maps showing the location of the existing HPFs and the structural alternatives are enclosed. Non-structural measures such as targeted buy-outs will also be evaluated. Structural and non-structural alternatives to address storm surge impacts in the Galveston Bay system, as well as ER measures throughout the six-county study area will be evaluated programmatically, with recommendations being made for detailed analyses of feasible alternatives in future studies.

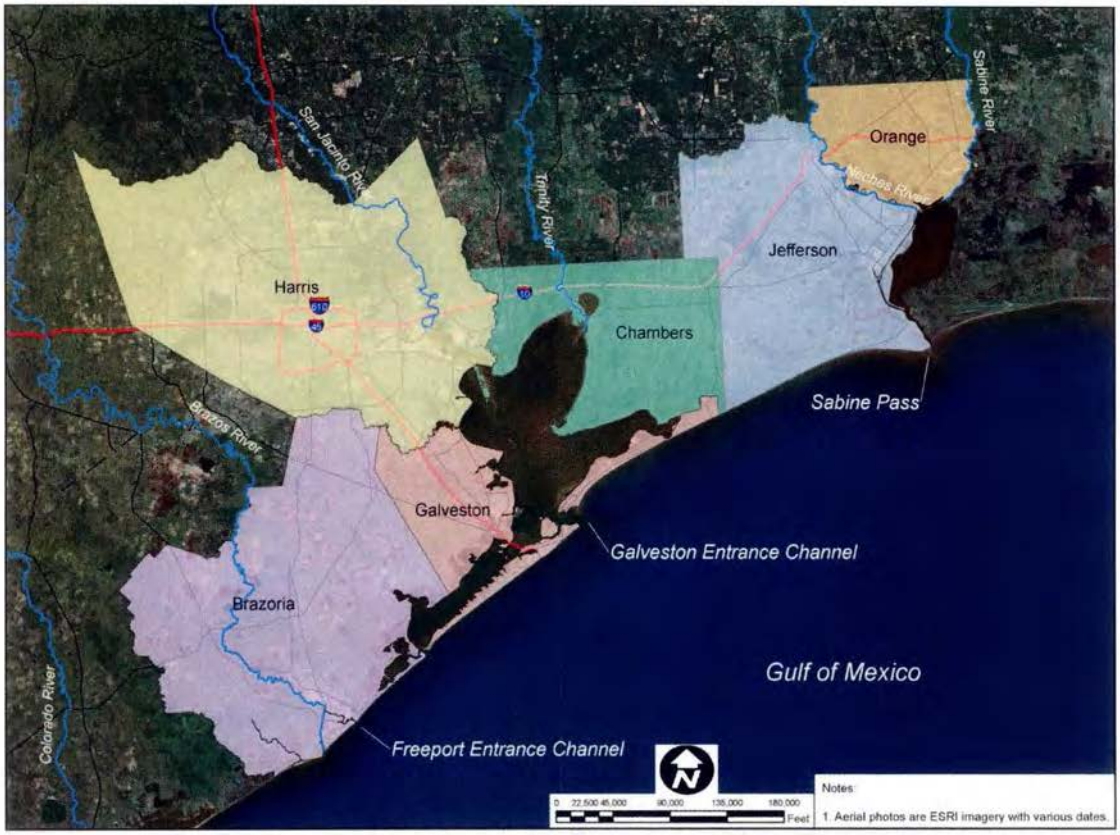
We would like to coordinate with you our schedule for study completion so that all reviews and approvals will, to the maximum extent practicable, be conducted concurrently. This concurrent coordination is required by Section 2045 of the Water Resources Development Act of 2007. Your agency's Federal Consistency Review, required under the Texas Coastal Management Plan, is currently scheduled to occur from August 29 through October 12, 2015 in conjunction with public review of the Draft IFR-EIS.

We request that you advise us as to whether the review period is acceptable to your agency. If you should have any questions regarding this request, please contact Janelle Stokes of my staff at (409) 766-3039.

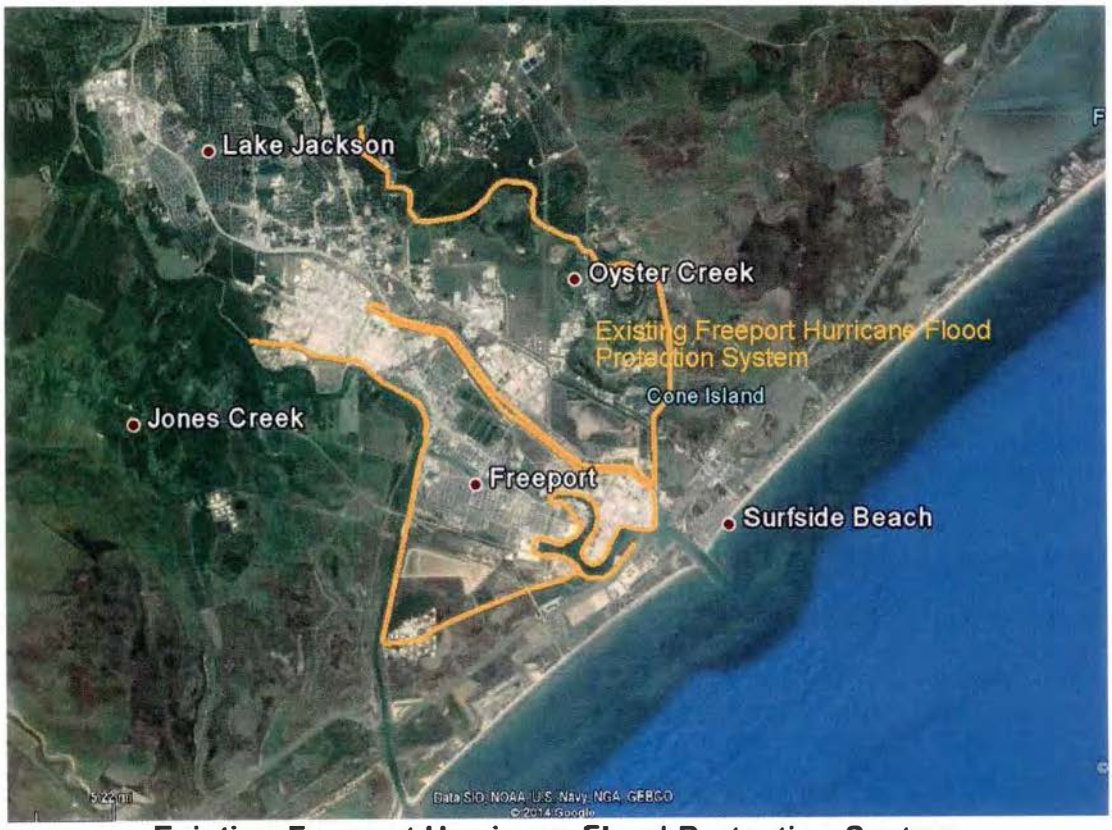
Sincerely,

Carolyn Murphy
Chief, Unit A, NEPA/Cultural
Resources Section

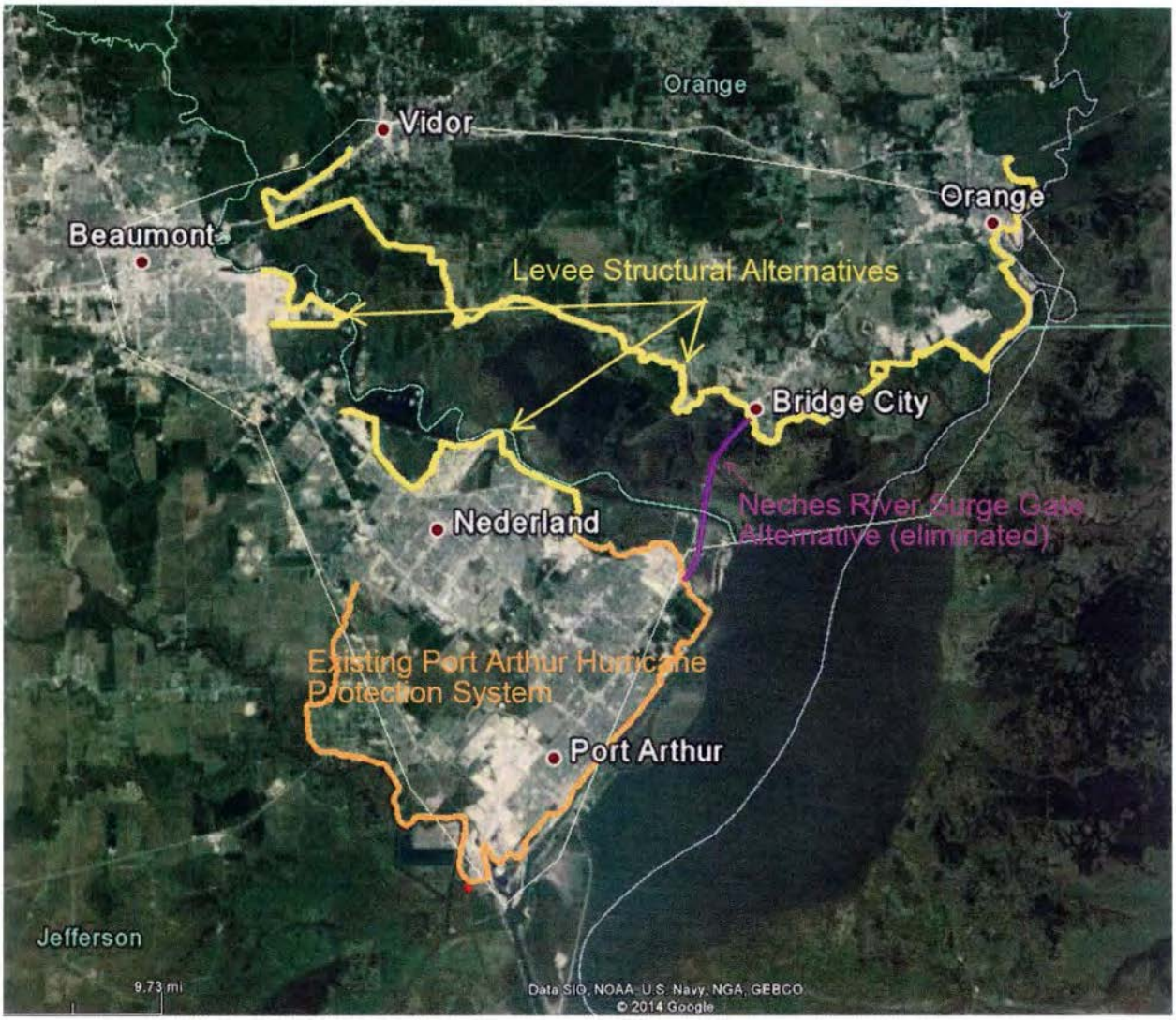
Enclosures



Six County Sabine Pass to Galveston Bay Study Area



Existing Freeport Hurricane Flood Protection System



Existing Port Arthur Hurricane Flood Protection System, Levee Structural Alternatives and Neches River Surge Gate Alternative

DEPARTMENT OF THE ARMY
FORT WORTH DISTRICT, CORPS OF ENGINEERS
P.O. BOX 17300
FORT WORTH, TEXAS 76102-0300
November 19, 2014

REPLY TO
ATTENTION OF

NEPA/Cultural Resources Section

Phil Kelley
Manager
Jefferson County Drainage District No. 7
P.O. Box 3244
Port Arthur, Texas 77643

Dear Mr. Kelley:

The Galveston District, Corps of Engineers, and the non-federal sponsor, the Texas General Land Office, would like to invite your agency to participate as a cooperating agency in the development of an Environmental Impact Statement (EIS) for the Sabine Pass to Galveston Bay, Texas. Coastal Storm Risk Management and Ecosystem Restoration Feasibility Study. The Integrated Feasibility Report and Environmental Impact Statement (IFR-EIS) will evaluate structural and non-structural alternatives which address coastal storm risk management (CSRM) impacts and ecosystem restoration (ER) opportunities in Orange, Jefferson, Chambers, Harris, Galveston and Brazoria Counties. The Draft IFR-EIS is currently scheduled to be released for public review and comment in August 2015.

Structural alternatives that will be evaluated are: (1) new surge protection levees and small, navigable surge gates on Cow and Adams Bayous in Orange and Jefferson Counties; (2) a large navigable surge gate in the Neches River near the Rainbow Bridge (eliminated); and (3) reevaluation of the existing Port Arthur and Freeport Hurricane Flood Protection (HFP) systems in Jefferson and Brazoria Counties, respectively. Maps showing the location of the existing HPFs and the structural alternatives are enclosed. Non-structural measures such as targeted buy-outs will also be evaluated. Structural and non-structural alternatives to address storm surge impacts in the Galveston Bay system, as well as ER measures throughout the six-county study area will be evaluated programmatically, with recommendations being made for detailed analyses of feasible alternatives in future studies.

We are inviting your participation as a cooperating agency pursuant to Council on Environmental Quality (CEQ) Regulations for Implementing the National Environmental Policy Act (NEPA) (40 CFR Part 1501.6). Furthermore, we would like to coordinate with you our schedule for study completion so that all reviews and approvals will, to the maximum extent practicable, be conducted concurrently. This concurrent coordination is required by Section 2045 of the Water Resources Development Act of 2007. The following review periods for the IFR-EIS have been established in accordance with the current project schedule:

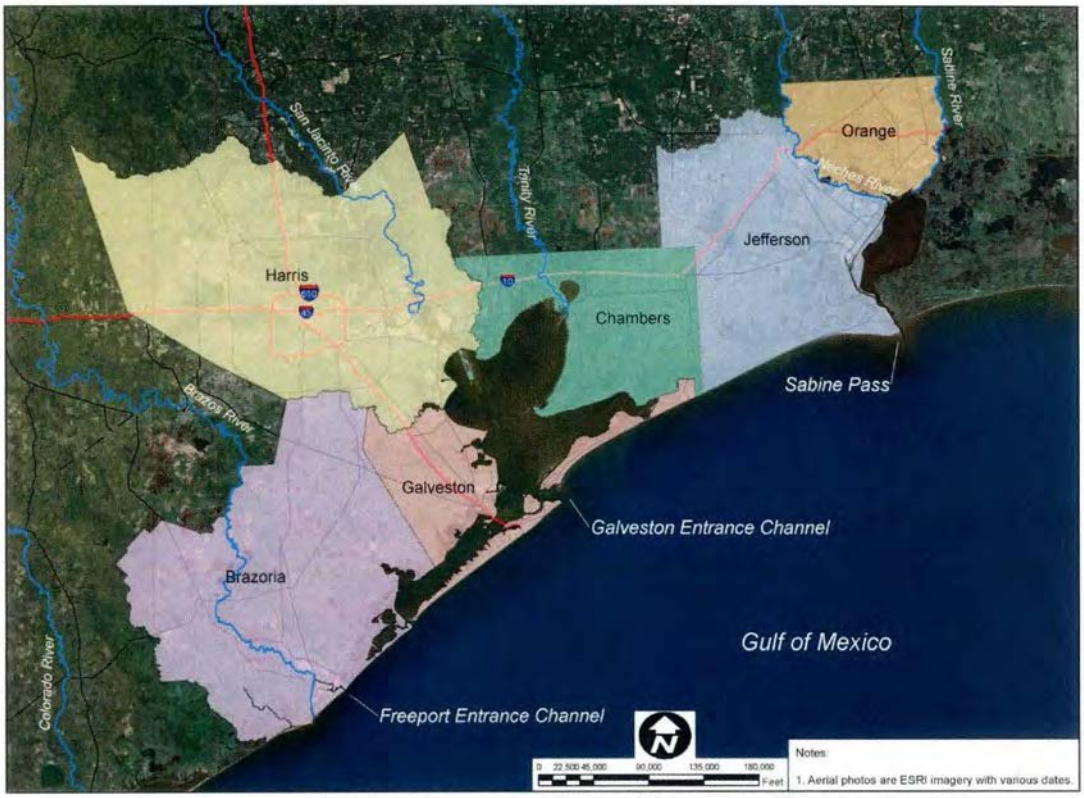
Review of Draft IFR-EIS --45-day review period (August 29 through October 12, 2015)
State and Agency Review of Final IFR-EIS – 30-day review (July 15 through August 14, 2016)

We appreciate this opportunity to invite your agency's participation as a cooperating agency and request that you advise us as to whether the review periods are acceptable to your agency. If you should have any questions regarding this request, please contact Janelle Stokes of my staff at (409) 766-3039.

Sincerely,

Carolyn Murphy
Chief, Unit A, NEPA/Cultural
Resources Section

Enclosures



Six County Sabine Pass to Galveston Bay Study Area

Existing Freeport Hurricane Flood Protection System

Existing Port Arthur Hurricane Flood Protection System, Levee Structural Alternatives and Neches River Surge Gate Alternative

DEPARTMENT OF THE ARMY
FORT WORTH DISTRICT, CORPS OF ENGINEERS
P.O. BOX 17300
FORT WORTH, TEXAS 76102-0300
November 19, 2014

REPLY TO
ATTENTION OF

NEPA/Cultural Resources Section

Brent Peveto
Director-At-Large
Orange County Drainage District
8081 Old Highway 90
Orange, Texas 77630

Dear Mr. Peveto:

The Galveston District, Corps of Engineers, and the non-federal sponsor, the Texas General Land Office, would like to invite your agency to participate as a cooperating agency in the development of an Environmental Impact Statement (EIS) for the Sabine Pass to Galveston Bay, Texas, Coastal Storm Risk Management and Ecosystem Restoration Feasibility Study. The Integrated Feasibility Report and Environmental Impact Statement (IFR-EIS) will evaluate structural and non-structural alternatives which address coastal storm risk management (CSRM) impacts and ecosystem restoration (ER) opportunities in Orange, Jefferson, Chambers, Harris, Galveston and Brazoria Counties. The Draft IFR-EIS is currently scheduled to be released for public review and comment in August 2015.

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We are inviting your participation as a cooperating agency pursuant to Council on Environmental Quality (CEQ) Regulations for Implementing the National Environmental Policy Act (NEPA) (40 CFR Part 1501.6). Furthermore, we would like to coordinate with you our schedule for study completion so that all reviews and approvals will, to the maximum extent practicable, be conducted concurrently. This concurrent coordination is required by Section 2045 of the Water Resources Development Act of 2007. The following review periods for the IFR-EIS have been established in accordance with the current project schedule:

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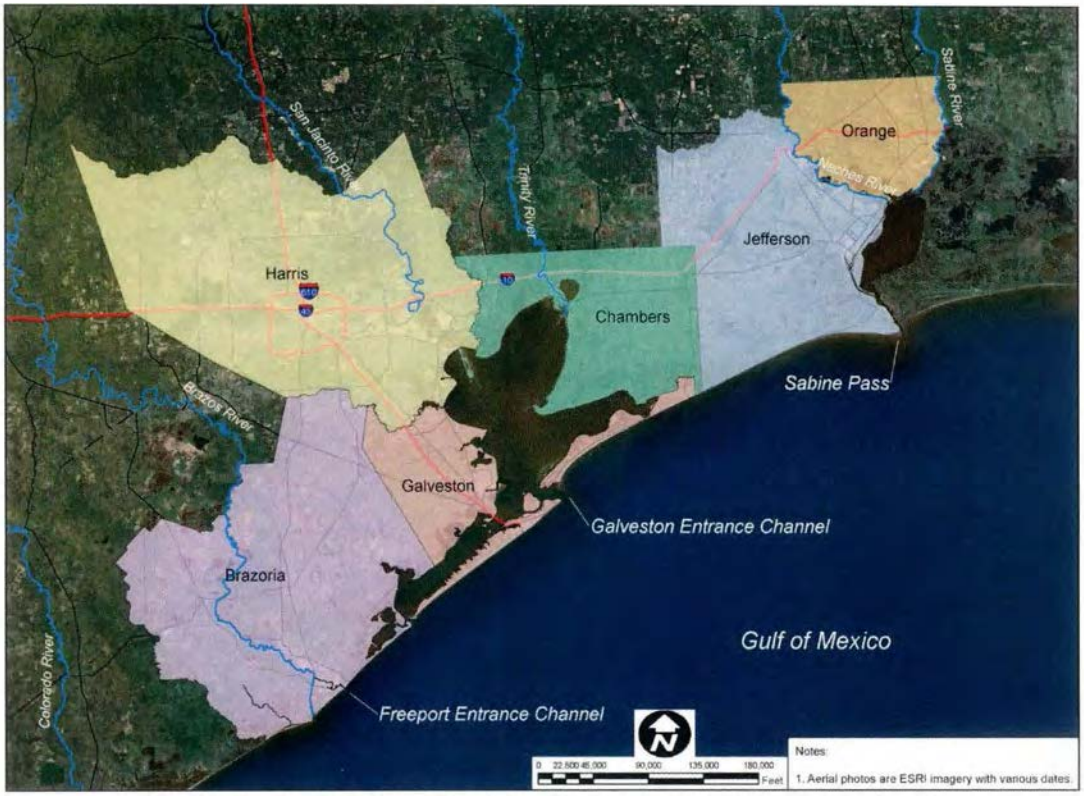
We appreciate this opportunity to invite your agency's participation as a cooperating agency and request that you advise us as to whether the review periods are acceptable to your agency. If you should have any questions regarding this request, please contact Janelle Stokes of my staff at (409) 766-3039.

Sincerely,

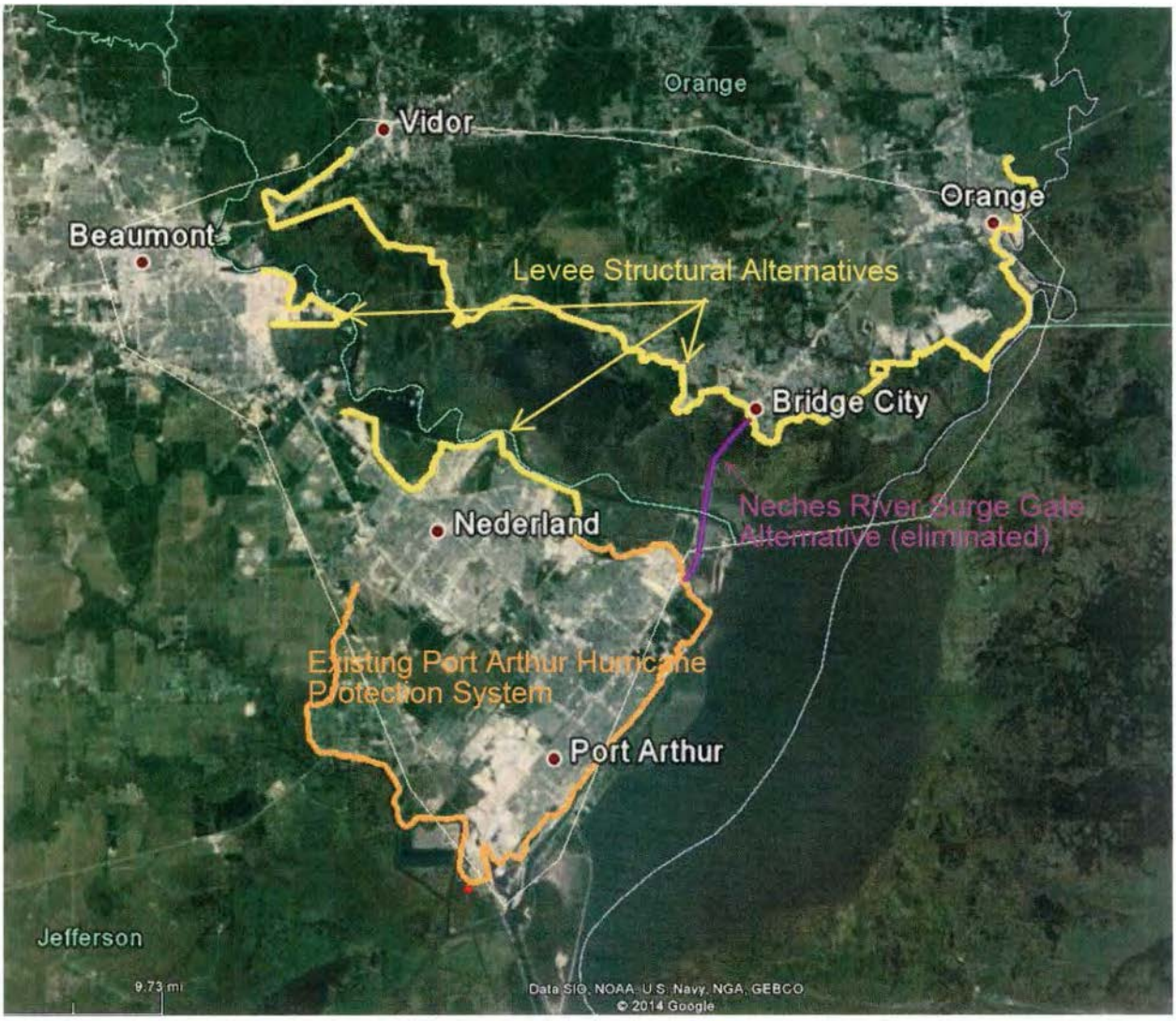
Carolyn Murphy
Chief, Unit A, NEPA/Cultural
Resources Section

Enclosures



Six County Sabine Pass to Galveston Bay Study Area

Existing Freeport Hurricane Flood Protection System



Existing Port Arthur Hurricane Flood Protection System, Levee Structural Alternatives and Neches River Surge Gate Alternative

DEPARTMENT OF THE ARMY
FORT WORTH DISTRICT, CORPS OF ENGINEERS
P.O. BOX 17300
FORT WORTH, TEXAS 76102-0300
November 19, 2014

REPLY TO
ATTENTION OF

NEPA/Cultural Resources Section

George Kidwell
Chairman
Velasco Drainage District
915 Stratton Ridge Road
Clute, Texas 77531

Dear Mr. Kidwell:

The Galveston District, Corps of Engineers, and the non-federal sponsor, the Texas General Land Office, would like to invite your agency to participate as a cooperating agency in the development of an Environmental Impact Statement (EIS) for the Sabine Pass to Galveston Bay, Texas, Coastal Storm Risk Management and Ecosystem Restoration Feasibility Study. The Integrated Feasibility Report and Environmental Impact Statement (IFR-EIS) will evaluate structural and non-structural alternatives which address coastal storm risk management (CSRM) impacts and ecosystem restoration (ER) opportunities in Orange, Jefferson, Chambers, Harris, Galveston and Brazoria Counties. The Draft IFR-EIS is currently scheduled to be released for public review and comment in August 2015.

Structural alternatives that will be evaluated are: (1) new surge protection levees and small, navigable surge gates on Cow and Adams Bayous in Orange and Jefferson Counties; (2) a large navigable surge gate in the Neches River near the Rainbow Bridge (eliminated); and (3) reevaluation of the existing Port Arthur and Freeport Hurricane Flood Protection (HFP) systems in Jefferson and Brazoria Counties, respectively. Maps showing the location of the existing HPFs and the structural alternatives are enclosed. Non-structural measures such as targeted buy-outs will also be evaluated. Structural and non-structural alternatives to address storm surge impacts in the Galveston Bay system, as well as ER measures throughout the six-county study area will be evaluated programmatically, with recommendations being made for detailed analyses of feasible alternatives in future studies.

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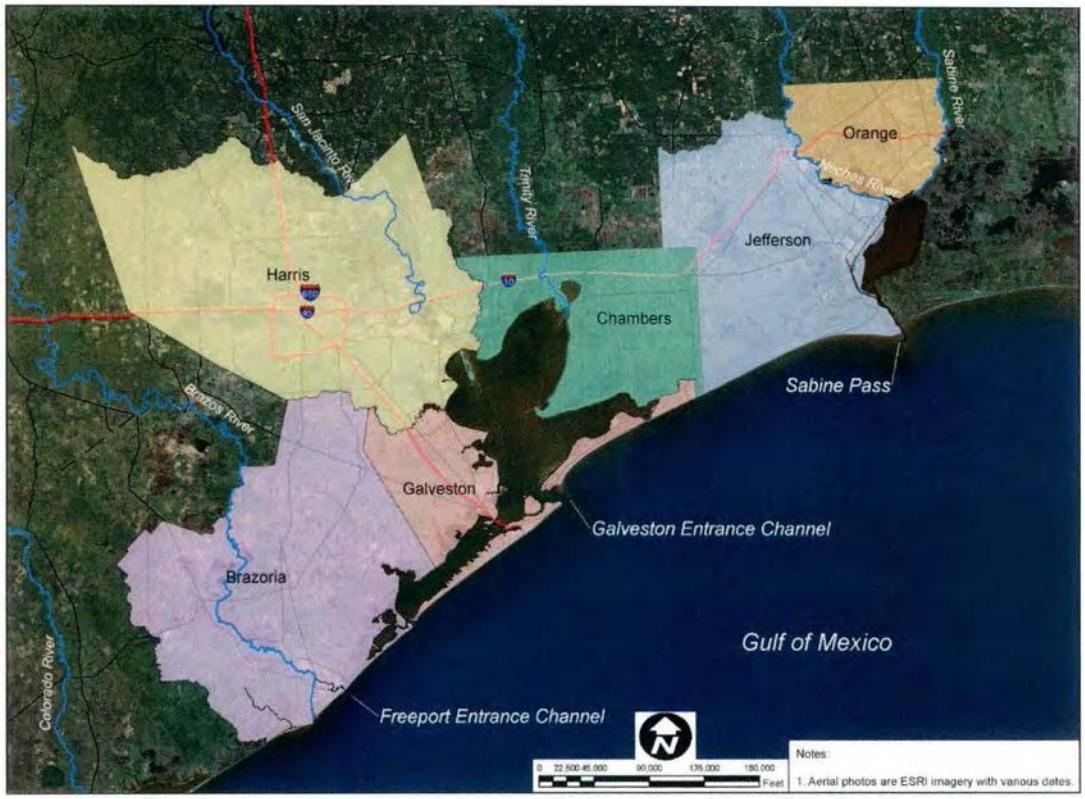
State and Agency Review of Final IFR-EIS – 30-day review (July 15 through August 14, 2016)

We appreciate this opportunity to invite your agency's participation as a cooperating agency and request that you advise us as to whether the review periods are acceptable to your agency. If you should have any questions regarding this request, please contact Janelle Stokes of my staff at (409) 766-3039.

Sincerely,

Carolyn Murphy
Chief, Unit A, NEPA/Cultural
Resources Section

Enclosures



Six County Sabine Pass to Galveston Bay Study Area

Existing Freeport Hurricane Flood Protection System

Existing Port Arthur Hurricane Flood Protection System, Levee Structural Alternatives and Neches River Surge Gate Alternative

Comments Letters on Draft Report

(to be added in Final Integrated Feasibility Report-
Environmental Impact Statement)