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

Appendix B

Plan Formulation

May 2017

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1 PLAN FORMULATION RATIONALE

Plan formulation is the process of building alternative plans that meet planning objectives and develop alternatives within the planning constraints. Alternative plans are a set of one or more management measures functioning together to address one or more planning objectives. A management measure is a feature or activity that can be implemented at a specific geographic site to address one or more planning objectives. A feature is a structural element that requires construction, whereas an activity is a nonstructural action.

The planning process for this feasibility study is driven by the overall objective of developing a comprehensive plan that will help manage risks associated with coastal storms within the study counties while avoiding and minimizing impacts on the area's environmental resources.

Preliminary plans were formulated by combining management measures. Each plan was formulated in consideration of the following four criteria described in the Principles and Guidelines (P&G):

- Completeness: Extent to which the plan provides and accounts for all necessary investments or actions to ensure realization of the planning objectives
- Effectiveness: Extent to which the plan contributes to achieving the planning objectives
- Efficiency: Extent to which the plan is the most cost-effective means of addressing the specified problems and realizing the specified opportunities, consistent with protecting the nation's environment
- Acceptability: Workability and viability of the alternative plan with respect to acceptance by Federal and non-federal entities and the public, and compatibility with existing laws, regulations, and public policies

Initial study efforts involved a determination of the magnitude and extent of the problems within the study area in order to develop and evaluate an array of alternative solutions that meet the existing and long-range future needs of the non-Federal sponsor and the public. At the initiation of the feasibility phase of the project, lines of communication were opened with Federal, state, and local agencies, private groups, and the affected public. Four regional public scoping meeting were held across the study area during February to March 2012.

2 MANAGEMENT MEASURES

The initial array of measures was developed with public, local government, and agency input gathered during the four scoping meetings. During the scoping process, the measures were grouped geographically into the three major regions (Sabine, Galveston, and Brazoria).

Potential structural and nonstructural measures considered in this study were:

- Structural (raising roadways, levees, flood walls, flood gates, breakwaters, marsh/dune/shoreline restoration, hardening of infrastructure, etc.)
- Nonstructural (buyouts, raising structures, flood warning systems, floodplain management, regional sediment management, etc.)

Potential projects for the Sabine area include Gulf shoreline protection and restoration measures such as beach nourishment, dune restoration, Chenier ridge restoration, sediment management, shoreline armoring, and submerged near-shore breakwaters. Potential projects for the Galveston area include various Gulf shoreline protection and restoration measures such as beach nourishment, dune restoration, beach ridge restoration, sediment management, shoreline armoring, and submerged near-shore segmented breakwaters. Specific targets include but are not limited to the shoreline west of Rollover Pass and near Fort Travis. Projects may include development of a comprehensive regional sediment management plan for the Galveston Bay system and Gulf shoreline. Viability of Gulf shoreline projects is dependent on the General Land Office's (GLO) ability to acquire easements. Potential projects for the Brazoria area include various Gulf shoreline protection and restoration measures such as beach nourishment, dune restoration, sediment management, shoreline armoring and submerged near-shore breakwaters. Specific targets include Quintana/Bryan Beach, Surfside beach, and Follets Island.

At the SMART Planning Charrette, the full Vertical Team (USACE District, Division, Headquarters, and Office of Water Project Review) worked through an abbreviated version of the six-step planning process, considering a full array of measures and alternatives, and then formulated comprehensive (regional) plans to include in the Initial Alternative Plans Array. Information gathered during the public scoping process combined with work conducted at the Charrette resulted in identification of approximately 39 individual implementable measures; and five comprehensive regional alternative plans addressing the entire six-county area. Each plan included structural and nonstructural measures that would address CSRM and ER objectives.

During the Charrette, the team identified three criteria that would be utilized to evaluate the initial array of alternatives. The three criteria are: 1) Implementation Costs; 2) Damages Reduced; and 3) Environmental Benefits.

It was envisioned at the Charrette that these criteria would be used to evaluate the five alternatives that were developed from the measures during the Charrette. After the FCSA was signed and efforts began on data collection, the study team determined that many of the components of the different alternatives were redundant and that information on the measures was incomplete. The

Project Delivery Team (PDT) decided to deconstruct the alternatives, collect available targeted information, and refine/reformulate the measures for completeness and to eliminate redundancies.

This resulted in a list of about 75 reformulated initial measures that served as the building blocks of alternative plans. These nonstructural and structural measures are discussed in more detail in the sections below.

Nonstructural and structural measures were considered as part of the study analysis and were developed to address study objectives. These measures can be combined with other measures, nonstructural or structural, to form alternatives to be evaluated in this study process. Should additional measures be identified during the Plan Formulation Phase, measures will be appropriately reviewed and considered in the alternative analysis. These alternatives are screened in the Plan Formulation Phase, as discussed in the next chapter.

2.1 NONSTRUCTURAL MEASURES

The nonstructural measures considered included:

- Buyouts and Relocations; and
- Recreational / Conservation Areas

2.2 STRUCTURAL MEASURES

The structural measures included new coastal and inland structural barriers, reconstruction of existing and construction of new regional hurricane protection systems, local surge protection systems, and raising roads as surge or overwash protection barriers, Gulf shoreline protection (beach and dune restoration, nearshore breakwaters, chenier ridge restoration), Gulf Intracoastal Waterway (GIWW) erosion protection, marsh restoration, and salinity/water control structures.

Details on specific proposals were requested from proponents of several regional measures, in particular Measures 1, 2, and 3-3 through 3-9. Only the proponents of the existing Freeport and Vicinity Hurricane Flood Protection project (3-3) and Countywide Protection System for Orange (Measures 3-4 through 3-9) provided feasibility-level details. The information collected on other measures, including the Galveston Bay Coastal Barrier (Measure 1) and the Surge Gate and Barrier at the Hartman Bridge (Measure 2), were based on conference presentations or other publicly available information.

Using the criteria developed during the Charrette, the reformulated measures were screened and ranked. Table 2-1 presents the reformulated initial array of measures with initial implementation costs, economic benefits, and environmental benefits.

Table 2-1. Sabine Pass to Galveston Bay, Texas Structural Measures

Measure Number	Measure Name	Total Cost ($)	Economic Benefits ($)	Environmental Benefits* ($)
1	Galveston Bay Coastal Barrier, Chambers, Galveston and Harris Co.	6,232,500,000	14,042,424,000	121,000
2	Surge Gate and Barrier at Hartman Bridge, Harris Co.	801,842,000	3,054,181,000	3,200
3-1	Port Arthur and Vicinity, Texas Hurricane Flood Protection	64,148,000	4,446,704,000	0
3-2	Texas City, Texas Hurricane Flood Protection	36,985,000	2,139,339,000	0
3-3	Freeport and Vicinity, Texas Hurricane Flood Protection	123,784,000	2,195,837,000	0
3-4	Co.-Wide Protection System on Sabine River and East Bank of Neches River, Orange Co.	1,487,800,000	1,492,324,000	7,000
3-5	Co.-Wide Protection System on the East and West Bank of the Neches River, Orange Co. and Part of Jefferson Co.	1,743,500,000	1,535,553,000	7,400
3-6	Co.-Wide Protection System with Neches River Closure and Port Arthur Levee Tie-In, Orange Co. and Part of Jefferson Co.	1,549,463,000	1,849,554,000	31,500
3-7	Sabine River Crossing, Orange Co. and Calcasieu Parish	1,842,580,000	1,869,790,000	37,000
3-8	Orange Co. Industrial Complex Protection System, Orange Co.	212,970,000	115,004,000	650
3-9	Galveston Ring Levee, Galveston Co.	556,116,000	3,296,295,000	300
3-10.1	Local Surge Protection, Houston Ship Channel North, Harris Co.	1,161,307,000	624,822,000	2,000
3-10.2	Local Surge Protection, Houston Ship Channel South, Harris Co.	1,267,906,000	1,089,324,000	400
3-10.3	Local Surge Protection, Baytown, Harris Co.	327,545,000	2,368,000	6
3-10.4	Local Surge Protection, NASA, Harris Co.	154,571,000	15,276,000	20
3-10.5	Local Surge Protection, UTMB, Galveston Co.	85,661,000	34,832,000	0
3-10.6	Local Surge Protection, Chocolate Bayou, Brazoria Co.	472,997,000	5,109,000	125
4-1	Raise State Highway 146, Galveston and Harris Co.	563,090,000	3,073,296,000	2,900
4-2.1	Raise State Highway 87 from Sabine Pass to High Island, Jefferson and Chambers Co.	427,054,000	83,752,000	65,500
4-2.2	Raise State Highway 87 from High Island to Port Bolivar, Galveston Co.	366,947,000	15,432,000	10,400
4-2.3	Raise Co. Road 257, Brazoria Co.	177,974,000	35,709,000	4,100
5-1	Chenier Ridge Restoration, Jefferson Co.	328,136,000	-	1,200
5-2	BU of Dredged Material for Shoreline Nourishment at Texas Point, Jefferson Co.	256,210,000	-	250
5-3	Dune Restoration and Beach Nourishment, Sabine Pass to High Island, Jefferson and Chambers Co.	3,351,642,000	-	65,500
5-4	Restore Beach Ridge, Sabine Pass to High Island, Jefferson and Chambers Co.	33,027,000	83,752,000	65,500

Measure Number	Measure Name	Total Cost ($)	Economic Benefits ($)	Environmental Benefits* ($)
5-5	Segmented Nearshore Breakwaters, Sabine Pass to High Island, Jefferson and Chambers Co.	226,676,000	-	65,500
5-6	Dune Restoration and Beach Nourishment, High Island to Galveston East Jetty, Galveston Co.	1,660,837,000	-	530
5-7	Beach Nourishment, East Galveston Island Seawall, Galveston Island	453,368,000	-	235
5-8	Dune Restoration and Beach Nourishment, West Galveston Island, Galveston Co.	1,201,816,000	-	420
5-9	Segmented Nearshore Breakwaters, West Galveston Island to San Luis Pass	165,435,000	-	420
5-10	Closing of Rollover Pass, Galveston Co.	6,873,000	-	42
5-11	Dune Restoration and Beach Nourishment, San Luis Pass to Surfside, Brazoria Co.	667,903,000	-	500
5-12	Dune Restoration and Beach Nourishment, Surfside to Brazos River, Brazoria Co.	247,862,000	-	45
5-13	Dune Restoration and Beach Nourishment, Brazos River to Brazos River Diversion channel, Brazoria Co.	409,410,000	-	540
5-15	Segmented Nearshore Breakwaters, San Luis Pass to Brazos River Diversion Channel, Brazoria Co.	137,217,000	-	1,415
5-16	Groin at State Highway 332, Brazoria Co.	4,010,000	-	50
6-1.1	GIWW Breakwater at Old River Cove, Orange Co.	20,480,000	-	50
6-1.2	GIWW Barrier Island Restoration, Old River and Hickory Coves, Orange Co.	10,215,000	-	131
6-2	GIWW Breakwaters, Neches River to High Island, Jefferson Co.	181,509,000	-	761
6-3	GIWW Barrier Island Restoration, North Pleasure Island, Jefferson Co.	3,542,000	-	64
6-4.1	GIWW Breakwaters, Bolivar Peninsula, Galveston Co.	141,782,000	-	867
6-4.2	GIWW Barrier Island Restoration, Bolivar Peninsula, Galveston Co.	10,017,000	-	246
6-5.1	GIWW Breakwaters, West Bay, Galveston Co.	43,406,000	-	222
6-5.2	GIWW Barrier Island Restoration, West Bay 1, Galveston Co.	9,764,000	-	112
6-5.3	GIWW Barrier Island Restoration, West Bay 2, Galveston Co.	4,037,000	-	35
6-6.1	GIWW Breakwaters, Brazoria Co.	219,877,000	-	1,110
6-6.2	GIWW Barrier Island Restoration, West Bay, Brazoria Co.	18,202,000	-	215
7-1	Shoreline Protection, East Bay, Chambers Co.	137,121,000	-	600
7-2	Shoreline Protection, Bastrop Bay , Brazoria Co.	20,420,000	-	40
7-3	Island Restoration, Vingt-et-un, Chambers Co.	5,386,000	-	27

Measure Number	Measure Name	Total Cost ($)	Economic Benefits ($)	Environmental Benefits* ($)
8-1	Marsh Restoration, Bessie Heights East , Orange Co.	177,687,000	-	2,076
8-2	Marsh Restoration, Old River Cove , Orange Co.	23,805,000	-	1,210
8-3	Marsh Restoration, Rose City East , Orange Co.	25,833,000	-	568
8-4.1	Marsh Restoration, Pepper Grove Cove, Galveston Co.	17,047,000	-	294
8-4.2	Marsh Restoration, Long Point Marsh, Galveston Co.	45,561,000	-	1,661
8-5.1	Marsh Restoration, South of Keith Lake, Jefferson Co.	65,631,000	-	4,132
8-5.2	Marsh Restoration, Texas Point NWR, Jefferson Co.	80,098,000	-	5,172
8-6.1	Marsh Restoration, Pierce Marsh, Galveston Co.	52,173,000	-	2,076
8-6.2	Marsh Restoration, IH-10 Causeway, Galveston Co.	21,478,000	-	633
8-6.3	Marsh Restoration, Greens Lake, Galveston Co.	70,718,000	-	3,293
8-7. 1	Marsh Restoration, Gangs to Oxen Bayou, Galveston Co.	7,662,000	-	176
8-7.2	Marsh Restoration, Oxen to Mantel Bayou, Galveston Co.	15,679,000	-	390
8-7.3	Marsh Restoration, Dana Cove, Galveston Co.	12,301,000	-	213
8-7.4	Marsh Restoration, Jumbile Cove, Galveston Co.	14,652,000	-	316
8-7.5	Marsh Restoration, Bird Island to Maggies Cove, Galveston Co.	22,174,000	-	467
8-7.6	Marsh Restoration, Snake Island Cove, Galveston Co.	19,711,000	-	457
8-7.7	Marsh and Bayou Restoration, Sweetwater Preserve, Galveston Co.	7,257,000	-	447
9-1 & 9-2	9-1 Salt Water Control Structure, Keith Lake Fish Pass, Jefferson Co. 9-2 Inverted Siphons Under GIWW, Jefferson Co.	19,051,000	-	20,200
9-3	Sabine River Levee and Surge Gate including Louisiana levee extension	293,117,000	20,236,000	5,500
10-1.1	Sabine area buyouts			
10-1.2	Galveston area buyouts			
10-1.3	Brazoria County area buyouts			
10-2.1	Sabine area conservation area			
10-2.2	Galveston area conservation area			
10-2.3	Brazoria County area conservation area			

*Environmental Benefits calculated as number of wetland acres protected by measure

Measure Information Sheets with descriptions and maps of each measure are presented in Appendix A. Underlying assumptions and details for the benefit and cost estimates are provided in the Measure Information Sheets.

The economic benefits are the difference between without-project damages that would occur under the existing condition, and residual damages that would occur with a given measure in place. The extent of potential storm surge impacts were mapped using existing ADCIRC modeling (100-year storm event) recently completed by FEMA under the Flood Plain Map Modernization effort. Future-with (FWP) and without-project (FWOP) damages to structures, contents, and vehicles were calculated using the HEC-FIA (Flood Impact Analysis) software package which analyzes consequences for a given flood event, in this case, a 1% annual exceedance probability (100-year). Figure 2-1 shows the area for which economic damages were calculated. It is the economics map for the six-county region with cross-hatching that corresponds to the footprint of the 100-year event.

Environmental benefits for structural measures providing protection from a 100-year storm event were calculated using the acreages of wetlands impacted as identified by the ADCIRC modeling. Acreages for wetland benefits were calculated using GIS shape files based on the FWP flood depth grids. The shape files were used to clip wetland acreage from the 2012 National Wetlands Inventory (NWI) dataset. Some measures are intended to improve the resiliency of barrier islands and floodplains by preserving and/or restoring marsh or preventing marsh erosion. The effectiveness of these areas in attenuating storm surge could not be modeled with the 100-year storm event. Therefore, the acres of marsh restoration were based on the acres of marsh or barrier islands that would be restored. Other measures would raise roadways on barrier islands and headlands by about 6 feet. These barriers would have minimal protective effect against a 100-year storm, but they would have a significant effect as a first line of defense for storms of lower magnitude such as 10-, 20-, 30-year events. The higher roadbeds would prevent scouring and salinity insults to fresher wetland environments over a large area inland from the roadway. No H&H modeling was conducted to determine areas that would be protected by measures for the smaller but more frequent storm events. The wetland acre benefits for these measures assume that the raised highways would protect the marshes inland up to the vicinity of the Gulf Intracoastal Waterway.

Estimated costs for each measure are also provided in each table. These are Class 5 estimates, suitable for screening of concepts only. Some are based on total estimated costs provided by others and others were developed by analogy to other costs.

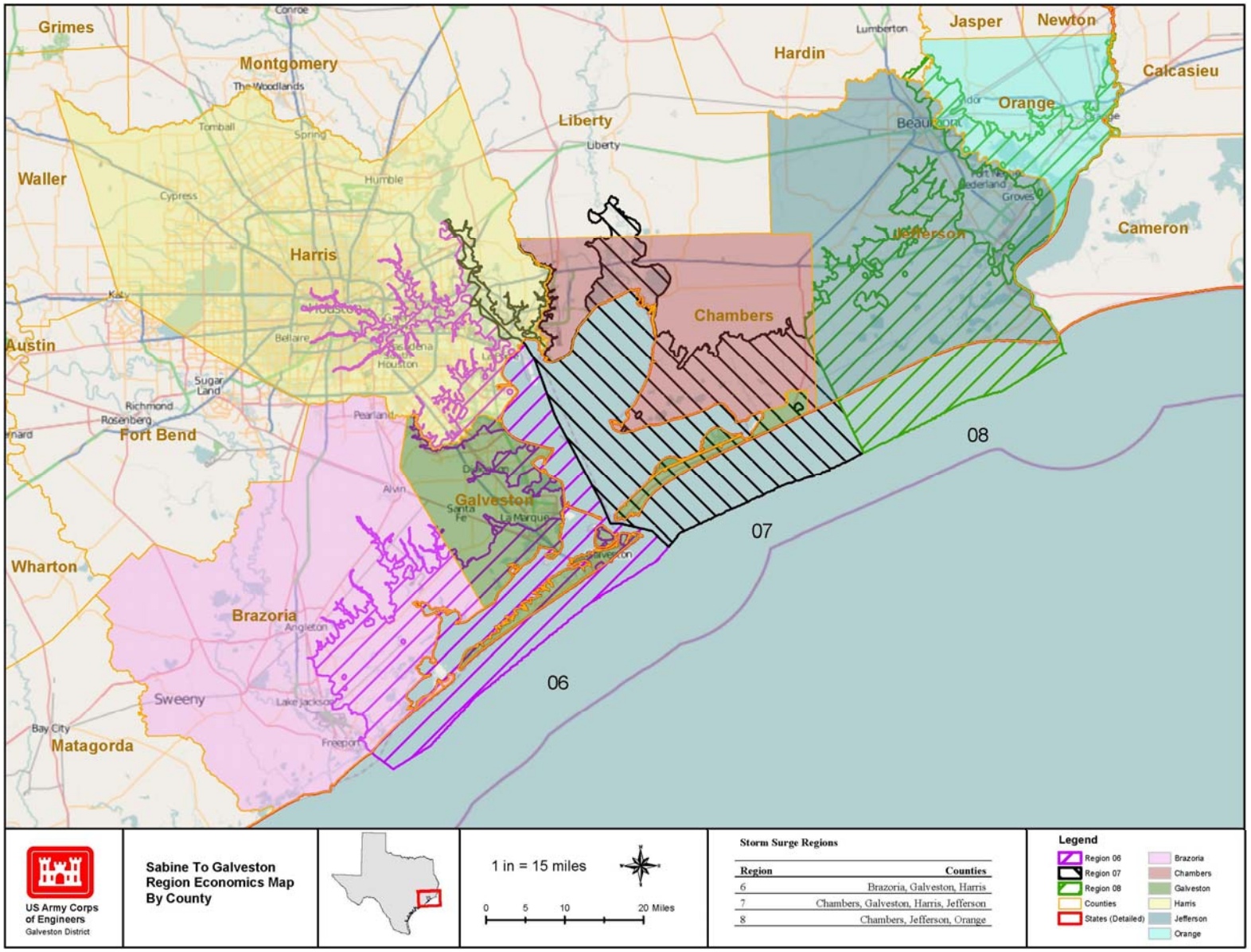

Figure 2-1. Study Area showing 100-year storm surge and Economic Regions for benefits

3 SUMMARY OF ALTERNATIVE ANALYSIS

3.1 INITIAL SCREENING OF MEASURES

3.1.1 Initial Screening of Measures Criteria

To evaluate and screen the initial measures to determine those that best meet the study and non-Federal sponsor objectives, an initial screening matrix was developed during the Planning Charette. Table 3-1 lists the screening criteria and metrics used in screening the measures.

Table 3-1. Initial Screening Criteria

Criteria	Metric
Damages reduced	Economic damages reduced based on water surface elevation
Environmental benefits	Acres habitat protected/restored by the plan
Implementation costs	Order of magnitude parametric (Class 5 cost estimates)

3.1.2 Initial Screening of Measures Prior to Alternative Formulation

After reformulation of the measures, each measure was evaluated to determine whether it would address one or more of the planning objectives, alone or in combination with other measures. Table 3-2 lists each measure that was eliminated from further consideration and the reason for elimination. If a measure could not meet at least one objective, the measure was dropped from further consideration in plan formulation.

Table 3-2. Measures Eliminated from Further Consideration

Measure Number	Measure Name	Reason for Elimination
Measure 3-4	County-Wide Protection System on Sabine River and East Bank of Neches River, Orange Co.	Reduces risk for Orange County only. Other measures retained that protected same areas while also protecting adjacent areas at risk in Jefferson and Orange County and Calcasieu Parish, Louisiana.
Measure 3-8	Orange Co. Industrial Complex Protection System, Orange Co.	Provides risk reduction for one industrial complex in Orange County. Does not reduce risk for other vulnerable areas of Orange or Jefferson County.
Measure 3-10.1	Local Surge Protection, Houston Ship Channel North, Harris Co.	Would be built in conjunction with Measure 3-10.2 and Measure 3-10.3. When combined, measures would reduce risk covered by Measure 2 but at higher cost.
Measure 3-10.2	Local Surge Protection, Houston Ship Channel South, Harris Co.	See Measure 3-10.1 Reason for Elimination
Measure 3-10.3	Local Surge Protection, Baytown, Harris Co.	See Measure 3-10.1 Reason for Elimination
Measure 3-10.4	Local Surge Protection, NASA, Harris Co.	Further examination of 100-year surge maps show only small undeveloped portion of NASA property would be impacted; therefore not expected to generate significant economic benefits

Table 3-2, continued

Measure Number	Measure Name	Reason for Elimination
Measure 3-10.5	Local Surge Protection, UTMB, Galveston Co.	UTMB area would be protected by Galveston ring levee or coastal barrier; therefore UTMB specific ring levee would be redundant. UTMB has also been undertaking measures to harden their facilities.
Measure 4-2.1	Raise State Highway 87 from Sabine Pass to High Island, Jefferson and Chambers Co.	Preferred measure for reach of coastline is to restore beach ridge (Measure 5-4) instead of rebuilding highway. Measure 5-4 reduces risk in same area but is much less expensive and restores natural feature.
Measure 4-2.2	Raise State Highway 87 from High Island to Port Bolivar, Galveston Co.	Houses in area behind reach are raised above level of protection provided by Measure 4-2.1. Minimal marsh area protected.
Measure 4-2.3	Raise Co. Road 257, Brazoria Co.	Measure is located on Follets Island from San Luis Pass to City of Freeport. TXGLO recently armored road. Little or no development exists north (bayside) of road; houses in area behind reach are raised above level of protection provided by measure; and natural barrier island system functioning well.
Measure 5-1	Chenier Ridge Restoration, Jefferson Co.	Considered to be technically infeasible and would not result in significant environmental risk reduction benefits.
Measure 5-2	BU of Dredged Material for Shoreline Nourishment at Texas Point, Jefferson Co.	Dredged material is fine-grained sediment and not expected to significantly reduce risk.
Measure 5-9	Segmented Nearshore Breakwaters, West Galveston Island to San Luis Pass	Segmented breakwaters were initially proposed along most of Gulf coastline within project area. Purpose of breakwaters was to retain sand and increase life of beach nourishment. Shoreline response with breakwaters is very sensitive to ambient climate, making it difficult to predict performance. Such large-scale application has never before been attempted. Therefore, measure was excluded from further consideration. Segmented breakwaters will be considered as part of beach nourishment design in places with extreme beach erosion, such as coast of Jefferson County.
Measure 5-15	Segmented Nearshore Breakwaters, San Luis Pass to Brazos River Diversion Channel, Brazoria Co.	See Measure 5-9 Reason for Elimination.
Measure 7-3	Island Restoration, Vingt-et-un, Chambers Co.	Measure would have restored former island (approximately 26 acres) off Smith Point. Eliminated because island provided little to no storm surge protection for mainland.

4 BASIS FOR CHOICE

As noted above, the measures were screened to determine if they adequately addressed the problems with Sabine to Galveston study and meet the objectives for this study. The remaining measures were then formed into arrays of alternatives plans, which were screened to determine the most effective alternatives. The screening consisted of three levels:

- Initial Array of Alternatives;
- Evaluation Array of Alternatives; and
- Final Array of Alternatives.

Each level consisted of more detailed analysis when compared to the previous level. The initial array was screened on a qualitative level, using screening criteria, scientific judgment from use of mapping and alternative footprints, as well as the professional expertise of the PDT to identify the implications of each alternative. No detailed environmental and economic analysis was included at this level. With the evaluation array, a screening matrix was developed, which included quantitative criteria such as quantities, costs, net excess benefits, environmental benefits and Benefit-to-Cost Ratios (BCRs). The final array of alternatives will be evaluated on more detailed calculations for BCRs and on their ability to effectively meet the four criteria in the P&G.

During analysis of the evaluation array of alternatives, a preliminary economic analysis was performed to calculate the net excess benefits and BCRs for each of the alternative plans.

The following are the methodology and evaluations that were used to develop the criteria used for screening the measures.

4.1 METHODOLOGY TO ANALYZE TECHNICAL CRITERIA

Technical criteria require reduction of CSRM while minimizing environmental impacts. These criteria require plans to comply with current USACE design standards for CSRM projects including future maintenance requirements. Technical criteria also require measures be compatible with the needs of Federal projects within the study areas.

The plans must consider specific environmental conditions of the area including soil conditions, topography, and terrestrial and aquatic ecosystems. Initial and evaluation screening of the alternatives was completed using existing information readily available and professional expertise and scientific judgment of the PDT. More detailed technical information (both historical data and specific information and analyses prepared for this project) will be used during screening of the final arrays of alternatives. Technical information with the corresponding screening level in which this information was used includes, but is not limited to, the following:

- Existing information prepared by others used by PDT to develop preliminary designs and quantities (all arrays);
- Aerial photography (all arrays);
- Previously published scientific reports related to the study area (all arrays);

- Marine and estuarine resource investigations (all arrays);
- Hydrodynamic Modeling (final array only);
- Salinity Modeling (final array only);
- RSLR Analysis (final array only);
- Storm Surge Modeling (final array only);
- Sediment and water quality analysis (final array only);
- 50-year life cycle (O&M requirements) (final array);
- Endangered and threatened species impact assessments (final array), and
- Habitat Evaluation Procedure/Habitat Suitability Models (final array only)

4.2 METHODOLOGY TO ANALYZE ECONOMIC CRITERIA

The economic criteria require that tangible benefits attributable to projects exceed project costs. Project benefits and costs are reduced to average annual equivalent values and related in a BCR. This ratio must exceed unity to meet the NED objective. Selected plans, whether structural, nonstructural, or a combination of both, should maximize excess benefits over costs; however, unquantifiable features must be addressed subjectively. These criteria are used to develop plans that achieve the objective of NED and provide a base condition for consideration of economically unquantifiable factors, which may impact project proposals.

The USACE planning guidelines required that the alternative that most reasonably maximizes net economic benefits, consistent with protecting the Nation's environment, be identified as the NED Plan. This NED Plan may be selected as the TSP. This process is addressed in more detail later in this report.

All structural and nonstructural measures for CSRM projects should be evaluated using the appropriate 50-year period of analysis beginning in 2017 and the applicable interest rate at the time of analysis. Total annual costs should include amounts for operation, maintenance, major replacements, and mitigation, as well as amortization and interest on the investment.

4.3 METHODOLOGY TO ANALYZE ENVIRONMENTAL CRITERIA

The general environmental criteria for projects are identified in Federal environmental statutes, executive orders, and planning guidelines. It is national policy that fish and wildlife resource conservation be given equal consideration with other study purposes in the formulation and evaluation of alternative plans. Care must be taken to preserve and protect significant ecological, aesthetic, and cultural values, and to conserve natural resources. These efforts also should provide the means to maintain and restore, as applicable, the desirable qualities of the human and natural environments. Alternative plans formulated to reduce the risk of damages from coastal storms should avoid damaging the environment to the extent practicable and contain measures to minimize or mitigate unavoidable environmental damages.

Throughout the study process, USACE Environmental Operating Principles (EOP) should be considered. The re-energized EOP principles, are considered at the same level as economic issues. The seven EOP principles are:

- Foster a culture of sustainability throughout the organization;
- Proactively consider environmental consequences of all USACE activities and act accordingly;
- Create mutually supporting economic and environmental solutions;
- Continue to meet our corporate responsibility and accountability under the law for activities undertaken by the USACE which may impact human and natural environments;
- Consider the environment in employing a risk management and systems approach throughout life cycles of projects and programs;
- Leverage scientific, economic, and social knowledge to understand the environmental context and effects of Corps actions in a collaborative manner; and
- Employ an open, transparent process that respects views of individuals and groups interested in USACE activities.

4.4 METHODOLOGY TO ANALYZE SOCIAL AND OTHER CRITERIA

Plans proposed for implementation should have an overall favorable impact on the social well-being of affected interests and have overall public acceptance. Structural and nonstructural alternatives must reflect close coordination with interested Federal and State agencies and the affected public. The effects of these alternatives on the environment must be carefully identified and compared with technical, economic, and social considerations and evaluated in light of public input.

4.5 KEY UNCERTAINTIES

The key uncertainties for this study are:

- Hydraulics and Hydrology (H&H) Modeling
- Environmental Impacts
- RSLR - While the future rate of RSLR in the study area is uncertain, it must be considered in project planning. RSLR consists of two components: global (eustatic) sea level rise and local subsidence. The uncertainty in the rates of eustatic sea level rise is evident in the variability of the different modeled rates given for the National Research Council (NRC, 1987) projections and the 2007 Intergovernmental Panel on Climate Change (IPCC). A similar degree of uncertainty exists with the rate of local subsidence although it is considered minor in this area of the coast.

5 INITIAL ARRAY OF ALTERNATIVE PLANS

Individual measures were developed and previously screened to satisfy the planning objectives in providing CSRM along the upper Texas Coast. Alternative plans were formulated through combinations of remaining management measures.

5.1 FUTURE WITHOUT-PROJECT CONDITION (NO ACTION ALTERNATIVE)

The No Action Alternative provides a baseline against which the benefits and impacts of action alternatives may be measured, and it is required by NEPA to be included among the alternative plans in the final array of alternatives. It is described in more detail in Section 3 of the main report.

5.2 INITIAL ARRAY OF ALTERNATIVES

In this phase, comprehensive alternative plans were formulated for each of the three regions in the six-county study area. This was done to make this task of formulating alternatives for such a large and diverse area more manageable. The alternatives are meant to be stand-alone plans that can be compared directly to one another. Alternatives have been included that are anchored to existing or proposed structural projects (or "hard" structures) as well as "soft" structural alternatives that could reduce impacts with ER or protection measures and improve the resiliency of the system. Some alternatives were intended to provide all-inclusive plans, and others were drafted to focus more closely on traditional structural or ER measures.

5.2.1 Sabine Region

The initial array of alternatives included eleven alternatives for the Sabine region, including alternatives which addressed CSRM and ER in combination and individually. These alternatives included plans to include evaluation of the existing HFP system, construction of additional levees to protect Orange County, the use of gated surge barrier structures in combination with the new levees, as well as environmental restoration measures such as beach and dune restoration, marsh and barrier island restoration, shoreline protection along the Gulf and the GIWW, nearshore breakwaters, and hydrologic restoration. Nonstructural alternatives were also considered.

The initial plans for the Sabine region are described in Table 5-1. These alternatives comprised the initial array of alternatives to which preliminary analyses were performed. Screening of the initial array of alternatives resulted in an evaluation array of alternative plans, which were carried forward for more detailed analysis and evaluation, and identification of a final array from which selection of the recommended plan was made. The evaluation array of alternative plans and its screening is presented in the next section of this report.

Table 5-1. Sabine Region, Initial Array of Alternative Plans

Alternative Number	Alternative Name	Description
S1	Sabine Inland Barrier All-Inclusive CSRM (Sabine & Neches Levees/HFP) and ER	Sabine and Neches Levees, Port Arthur HFP, beach and dune restoration, restore beach ridge, nearshore breakwaters, GIWW shoreline protection, marsh restoration on Neches River, Keith Lake and Texas Point, Salt Bayou hydrologic restoration
S2	Sabine Inland Barrier All-Inclusive CSRM (Neches Gate/Sabine Levees/HFP) and ER (without Salt Bayou measures)	Neches River Navigation Gate and Sabine Levees, Port Arthur HFP, beach and dune restoration, restore beach ridge, nearshore breakwaters, GIWW shoreline protection and barrier island restoration, marsh restoration on Neches River, Keith Lake, and Texas Point, Salt Bayou hydrologic restoration
S3	Sabine Inland Barrier All-Inclusive CSRM (Neches &Sabine Gates/Sabine Levees/HFP) and ER	Neches River Navigation Gate, Sabine Levees and Gate, Port Arthur HFP beach and dune restoration, restore beach ridge, nearshore breakwaters, GIWW shoreline protection, marsh restoration on Neches River, Keith Lake, and Texas Point, Salt Bayou hydrologic restoration
S4	Sabine Inland Barrier CSRM Focus (Sabine & Neches Levees/HFP)	Sabine and Neches Levees, Port Arthur HFP
S5	Sabine Inland Barrier CSRM Focus(Neches Gate/Sabine Levees/HFP)	Neches River Navigation Gate, Sabine Levees, Port Arthur HFP
S6	Sabine Inland Barrier CSRM Focus (Neches &Sabine Gates/Sabine Levees/HFP)	Neches River Navigation Gate, Sabine Levees and Sabine River Gate, Port Arthur HFP
S7	Sabine ER (without Neches River marsh restoration)	Sabine Living Shoreline, beach and dune restoration, restore beach ridge, nearshore breakwaters, GIWW shoreline protection Neches River to High Island, marsh restoration at Keith Lake and Texas Point, Salt Bayou hydrologic restoration
S8	Sabine ER (with surge barrier on upper Sabine River)	Beach and dune restoration, restore beach ridge, nearshore breakwaters, GIWW shoreline protection, marsh restoration on Neches River and at Keith Lake and Texas Point, Salt Bayou hydrologic restoration, Sabine River levees and gate
S9	Sabine Inland Barrier (Neches Gate/Sabine Levees/HFP) and ER	Neches River Navigation Gate and Sabine Levees, Port Arthur HFP, beach and dune restoration, restore beach ridge, GIWW shoreline protection Neches River to High Island, marsh restoration at Keith Lake and Texas Point, Salt Bayou hydrologic restoration
S10	Sabine GIWW Shoreline Protection	All GIWW shoreline protection measures
S11	Sabine Nonstructural Alternative	Buyouts and Lone Star-type Conservation Plan

5.2.2 Galveston Region

The initial array of alternatives included nine alternatives for the Galveston region, including alternatives which addressed CSRM and ER in combination and individually. These alternatives included plans to include evaluation of the existing HFP system, a coastal barrier, ring levees, gated surge barrier structures, as well as environmental restoration measures such as beach and dune restoration, marsh and barrier island restoration, shoreline protection along the Gulf and the GIWW, and nearshore breakwaters. Nonstructural alternatives were also considered.

Alternatives G1 and G4 (within the Galveston region) begin with the assumption that a new coastal barrier or new inland barrier, respectively, would be constructed and connected to raised roadways or an existing hurricane protection system to provide protection to all or part of the region. ER/CSRM measures are also included that would increase resiliency of the structural components. The alternatives are called all-inclusive because they contain every measure we believe would actively contribute to the effectiveness of the alternative. Alternatives G2 and G5 focus primarily on structural measures, while Alternative G7 focuses on ER measures. Some measures combine a more limited number of hard and soft structures in an attempt to identify more efficient alternatives. For example, Alternative G3 combines a hard structure (the Galveston Bay Coastal Barrier) with soft structures such as measures to reduce erosion of the GIWW and restore marshes, both of which would improve the resiliency of the barrier island on which the hard structure measure is located.

For Galveston Bay, the team included competing plans for large surge protection structures that have been proposed by Texas A&M University at Galveston and by the Severe Storm Prediction, Education, and Evacuation from Disasters (SSPEED) Center based at Rice University. The largest of the proposed structures would affect Galveston Bay, an economically important and environmentally sensitive bay system of almost 800 square miles. For Sabine Lake, the team also included a large surge protection plan that has been developed by Orange County, Texas and the Texas Water Development Board (TWDB). The proposed project closure structures are also equal to or larger than the Maeslantkering closure structure (Figure 5-1) located in the Netherlands and would be potentially constructed in multiple locations.

Figure 5-1. Maeslantkering Closure Structure, Netherlands

The PDT coordinated with Texas A&M University at Galveston, the SSPEED Center, and Orange County and utilized existing information and data during the initial evaluation of the project alternatives, including economic data and parametric cost estimates.

The initial plans for the Galveston region are described in Table 5-2. These alternatives comprised the initial array of alternatives to which preliminary analyses were performed. Screening of the initial array of alternatives resulted in an evaluation array of alternative plans, which were carried forward for more detailed analysis and evaluation, and identification of a final array from which selection of the recommended plan was made. The evaluation array of alternative plans and its screening is presented in the next section of this report.

Table 5-2. Galveston Region, Initial Array of Alternative Plans

Alternative Number	Alternative Name	Description
G1	Galveston Coastal Barrier All-Inclusive CSRM and ER (without GIWW Protection)	Coastal barrier and gates, and buyouts/relocations within a 500 ft buffer, beach and dune restoration, closing Rollover Pass, all marsh restoration, East Bay shoreline protection
G2	Galveston Coastal Barrier CSRM Focus	Coastal barrier and gates, and buyouts/relocations within a 500 ft buffer
G3	Galveston Coastal Barrier All-Inclusive CSRM and ER	Coastal barrier and gates, and buyouts/relocations within a 500 ft buffer, beach and dune restoration, closing Rollover Pass, all GIWW shoreline protection, all marsh restoration
G4	Galveston Inland Barriers Comprehensive CSRM and ER	Surge barrier and gates near Hartman Bridge, Texas City HFP, Galveston Ring Levee, Chocolate Bayou ring levee, Raise Hwy 146 and buyouts/relocations within a 500 ft buffer, beach and dune restoration, all GIWW shoreline protection, all marsh restoration, East Bay shoreline protection
G5	South Galveston Bay Inland Barriers CSRM Focus	Surge barrier and gates near Hartman Bridge, Texas City HFP, Galveston Ring Levee, Chocolate Bayou Ring Levee, Raise Hwy 146 and buyouts/relocations within a 500 ft buffer
G6	South Galveston Bay Local Protection CSRM Focus	Texas City HFP, Galveston Ring Levee, and Chocolate Bayou Ring Levee
G7	Galveston ER Barrier Island Protection	Beach and dune restoration, GIWW shoreline protection, marsh restoration, East Bay shoreline protection, closing Rollover Pass
G8	Galveston GIWW Shoreline Protection	All GIWW shoreline protection measures
G9	Galveston Nonstructural Alternative	Buyouts and Lone Star-like conservation plan

5.2.3 Brazoria Region

The initial array of alternatives included five alternatives for the Brazoria region, including alternatives which addressed CSRM and ER in combination and individually. These alternatives included plans to include evaluation of the existing HFP system, as well as environmental restoration measures such as beach and dune restoration, shoreline protection along the GIWW, and a groin. Nonstructural alternatives were also considered.

The initial plans for the Brazoria region are described in Table 5-3. These alternatives comprised the initial array of alternatives to which preliminary analyses were performed. Screening of the initial array of alternatives resulted in an evaluation array of alternative plans, which were carried forward for more detailed analysis and evaluation, and identification of a final array from which

selection of the recommended plan was made. The evaluation array of alternative plans and its screening is presented in the next section of this report.

Table 5-3. Brazoria Region, Initial Array of Alternative Plans

Alternative Number	Alternative Name	Description
B1	Brazoria Coastal Barrier All-Inclusive CSRM and ER	Freeport FHP, beach and dune restoration, groin, GIWW shoreline protection
B2	Brazoria Coastal Barrier CSRM Focus (revised)	Freeport HFP
B3	Brazoria ER	Beach and dune restoration, groin and GIWW shoreline protection
B4	Brazoria GIWW Shoreline Protection	All GIWW shoreline protection measures
B5	Brazoria Nonstructural Alternative	Buyouts and Lone Star-type conservation plan

5.3 INITIAL SCREENING CRITERIA

The Initial Alternatives were screened using three quantitative criteria (economic benefits, environmental benefits and implementation costs) and one qualitative criterion (environmental impacts) (Table 5-4) to develop the Evaluation Array of Alternatives.

Table 5-4. Criteria for Screening Initial Array

Criteria	Metric
Damages reduced	Economic damages reduced based on water surface elevation
Environmental benefits	Acres habitat protected/restored by the plan
Implementation costs	Order of magnitude parametric (Class 5 cost estimates)
Environmental Impacts	Qualitative Analysis using construction impacts on wetlands and sensitive habitat, system-wide hydrologic impacts, and endangered species impacts

5.3.1 Economic Benefit Criterion

It was assumed that economic benefits would equal the cost of storm damages that could be prevented by each measure. The footprint and flood depths of a 100-year storm event in the six-county region were determined using FEMA's ADCIRC models of the upper Texas coast. Economic damages were estimated by linking Hazus and HEC-FIA (Flood Impact Analysis). Hazus is standardized FEMA methodology for estimating potential losses from hurricanes and other natural disasters. HEC-FIA is a software package developed by the USACE Hydrologic Engineering Center that analyzes the consequences a flood events. These damages are roughly equivalent to insured losses, and do not include damages to the economy as a whole. The benefits for each measure in an alternative will be summed to calculate the total economic benefits for the alternative.

5.3.2 Environmental Benefit Criterion

It was assumed that environmental benefits would be equal to the acres protected from storm surge damages, and further that this acreage would be equivalent to the total acres of wetlands protected by each structural measure, or restored/protected by marsh restoration or erosion control measures. The benefits for each measure in an alternative were summed to calculate the environmental benefits for the alternative. The same impact footprint of a 100-year event that was used to develop the Economic benefits was used as the future without-project condition for the environmental analysis. Wetland acres protected by each measure were determined by clipping measure footprints from the 2012 National Wetlands Inventory.

5.3.3 Implementation Costs Criterion

Rough order of magnitude costs were refined for some measures with new information developed during this phase. Where no additional information was obtainable, costs provided by proponents were used. In general, costs used to select the final array equivalent to Class 5 or conceptual costs. All measure costs for both structural and ER measures were added together and compared to total economic benefits to develop the net excess benefits estimate in Table 5-5, Table 5-6, and Table 5-7 below. This is not customary; generally, costs for only those measures for which economic benefits have been calculated would be compared to economic benefits. This non-traditional approach was used in an effort to identify the strongest performing alternatives.

5.3.4 Environmental Impacts Criterion

This qualitative criterion was intended to provide information about the relative environmental impacts that could result from the implementation of each alternative. This is needed because the environmental benefit analysis does not consider either construction impacts or impacts to the environment that could occur during the period of analysis. Alternatives were scored as potentially having high, medium, or low environmental impacts based on the best professional judgment of the PDT and input from the resource agencies.

5.4 INITIAL SCREENING OF ALTERNATIVES

The economic and cost criteria were applied to screen the alternatives as shown in Table 5-5, Table 5-6, and Table 5-7. Table 5-8, Table 5-9, and Table 5-10 summarize the results of the economic and cost screening and rank the alternatives by net excess benefits.

The Environmental benefits criterion (acres protected) was used to inform decisions to retain or eliminate alternatives in the final array. For example, Alternatives S5 and G2 were retained, in part, because they have the potential to beneficially affect very large areas of significant coastal wetland habitats. Additional study is needed, as described below, to determine if the environmental effects of these surge barriers will be positive or negative.

Table 5-5. Sabine Region Initial Alternatives Array

Alternative Number	Measure Number	Measure Name	Total Cost ($)	Economic Benefits ($)	Net Excess Benefits ($)	BCR	Env Benefits (wetland acres)	
S1	**Sabine Inland Barrier All-Inclusive CSRM (Sabine & Neches Levees/HFP) and ER**							
	3-1	Port Arthur and Vicinity, Texas Hurricane Flood Protection	64,148,000	4,446,704,000	4,382,556,000	69.32	0	
	3-5	Co.-Wide Protection System on Sabine River and East Bank of Neches River, Orange Co.	1,743,500,000	1,535,553,000	-207,947,000	0.88	7,400	
	5-3	Dune Restoration and Beach Nourishment, Sabine Pass to High Island, Jefferson and Chambers Counties	3,351,642,000				65,500	
	5-4	Restore Beach Ridge, Sabine Pass to High Island, Jefferson and Chambers Co.	33,027,000	83,752,000	50,725,000	2.54	65,500	*
	5-5	Segmented Nearshore Breakwaters, Sabine Pass to High Island, Jefferson and Chambers Counties	226,676,000				65,500	*
	6-1.1	GIWW Breakwater at Old River Cove, Orange County	20,480,000				50	
	6-1.2	GIWW Barrier Island Restoration, Old River and Hickory Coves, Orange County	10,215,000				131	
	6-2	GIWW Breakwaters, Neches River to High Island, Jefferson County	181,509,000				761	
	6-3	GIWW Barrier Island Restoration, North Pleasure Island, Jefferson County	3,542,000				64	
	8-1	Marsh Restoration, Bessie Heights East , Orange County	177,687,000				2,076	
	8-2	Marsh Restoration, Old River Cove , Orange County	23,805,000				1,210	
	8-3	Marsh Restoration, Rose City East , Orange County	25,833,000				568	
	8-5.1	Marsh Restoration, South of Keith Lake, Jefferson County	65,631,000				4,132	*
	8-5.2	Marsh Restoration, Texas Point NWR, Jefferson County	80,098,000				5,172	*
	9-1	Salt Water Control Structure, Keith Lake Fish Pass, Jefferson County	7,254,000				10,100	*
	9-2	Inverted Siphons Under GIWW, Jefferson County	11,711,000				10,100	*
		Total Alt S1	**6,026,758,000**	**6,066,009,000**	**39,251,000**	**1.01**	**77,760**	
S2	**Sabine Inland Barrier All-Inclusive CSRM (Neches Gate/Sabine Levees/HFP) and ER (without Salt Bayou measures**							
	3-1	Port Arthur and Vicinity, Texas Hurricane Flood Protection	64,148,000	4,446,704,000	4,382,556,000	69.32	0	
	3-6	County-Wide Protection System with Neches River Closure and Port Arthur Levee Tie-In, Orange County and Part of Jefferson County	1,549,463,000	1,849,554,000	300,091,000	1.19	31,500	
	5-3	Dune Restoration and Beach Nourishment, Sabine Pass to High Island, Jefferson and Chambers Counties	3,351,642,000				65,500	
	5-4	Restore Beach Ridge, Sabine Pass to High Island, Jefferson and Chambers Co.	33,027,000	83,752,000	50,725,000	2.54	65,500	*
	5-5	Segmented Nearshore Breakwaters, Sabine Pass to High Island, Jefferson and Chambers Counties	226,676,000				65,500	*
	6-1.1	GIWW Breakwater at Old River Cove, Orange County	20,480,000				50	
	6-1.2	GIWW Barrier Island Restoration, Old River and Hickory Coves, Orange County	10,215,000				131	
	6-2	GIWW Breakwaters, Neches River to High Island, Jefferson County	181,509,000				761	
	6-3	GIWW Barrier Island Restoration, North Pleasure Island, Jefferson County	3,542,000				64	
	8-1	Marsh Restoration, Bessie Heights East , Orange County	177,687,000				2,076	*

Table 5-5, continued

Alternative Number	Measure Number	Measure Name	Total Cost ($)	Economic Benefits ($)	Net Excess Benefits ($)	BCR	Env Benefits (wetland acres)	
	8-2	Marsh Restoration, Old River Cove , Orange County	23,805,000				1,210	*
	8-3	Marsh Restoration, Rose City East , Orange County	25,833,000				568	*
	8-5.1	Marsh Restoration, South of Keith Lake, Jefferson County	65,631,000				4,132	*
	8-5.2	Marsh Restoration, Texas Point NWR, Jefferson County	80,098,000				5,172	*
	9-1	Salt Water Control Structure, Keith Lake Fish Pass, Jefferson County	7,254,000				10,100	*
	9-2	Inverted Siphons Under GIWW, Jefferson County	11,711,000				10,100	*
		Total Alt S2	**5,832,721,000**	**6,380,010,000**	**547,289,000**	**1.09**	**98,006**	
S3	**Sabine Inland Barrier All-Inclusive CSRM (Neches Gate/Sabine Levees/HFP) and ER**							
	3-1	Port Arthur and Vicinity, Texas Hurricane Flood Protection	64,148,000	4,446,704,000	4,382,556,000	69.32	0	
	3-7	Sabine River Crossing, Orange County and Calcasieu Parish	1,842,580,000	1,869,790,000	27,210,000	1.01	37,000	
	5-3	Dune Restoration and Beach Nourishment, Sabine Pass to High Island, Jefferson and Chambers Counties	3,351,642,000				65,500	
	5-4	Restore Beach Ridge, Sabine Pass to High Island, Jefferson and Chambers Co.	33,027,000	83,752,000	50,725,000	2.54	65,500	*
	5-5	Segmented Nearshore Breakwaters, Sabine Pass to High Island, Jefferson and Chambers Counties	226,676,000				65,500	*
	6-1.1	GIWW Breakwater at Old River Cove, Orange County	20,480,000				50	
	6-1.2	GIWW Barrier Island Restoration, Old River and Hickory Coves, Orange County	10,215,000				131	
	6-2	GIWW Breakwaters, Neches River to High Island, Jefferson County	181,509,000				761	
	6-3	GIWW Barrier Island Restoration, North Pleasure Island, Jefferson County	3,542,000				64	
	8-1	Marsh Restoration, Bessie Heights East , Orange County	177,687,000				2,076	*
	8-2	Marsh Restoration, Old River Cove , Orange County	23,805,000				1,210	*
	8-3	Marsh Restoration, Rose City East , Orange County	25,833,000				568	*
	8-5.1	Marsh Restoration, South of Keith Lake, Jefferson County	65,631,000				4,132	*
	8-5.2	Marsh Restoration, Texas Point NWR, Jefferson County	80,098,000				5,172	*
	9-1	Salt Water Control Structure, Keith Lake Fish Pass, Jefferson County	7,254,000				10,100	*
	9-2	Inverted Siphons Under GIWW, Jefferson County	11,711,000				10,100	*
		Total Alt S3	**6,125,838,000**	**6,400,246,000**	**274,408,000**	**1.04**	**103,506**	*****
S4	**Sabine Inland Barrier CSRM Focus (Sabine & Neches Levees/HFP)**							
	3-1	Port Arthur and Vicinity, Texas Hurricane Flood Protection	64,148,000	4,446,704,000	4,382,556,000	69.32	0	
	3-5	County-Wide Protection System on Sabine River and East Bank of Neches River, Orange County	1,743,500,000	1,535,553,000	(207,947,000)	0.88	7,400	
		Total Alt S4	**1,807,648,000**	**5,982,257,000**	**4,174,609,000**	**3.31**	**7,400**	

Table 5-5, continued

Alternative Number	Measure Number	Measure Name	Total Cost ($)	Economic Benefits ($)	Net Excess Benefits ($)	BCR	Env Benefits (wetland acres)	
S5	**Sabine Inland Barrier CSRM Focus(Neches Gate/Sabine Levees/HFP)**							
	3-1	Port Arthur and Vicinity, Texas Hurricane Flood Protection	64,148,000	4,446,704,000	4,382,556,000	69.32	0	
	3-6	County-Wide Protection System with Neches River Closure and Port Arthur Levee Tie-In, Orange County and Part of Jefferson County	1,549,463,000	1,849,554,000	300,091,000	1.19	31,500	
		Total Alt S5	**1,613,611,000**	**6,296,258,000**	**4,682,647,000**	**3.90**	**31,500**	
S6	**Sabine Inland Barrier CSRM Focus (Neches & Sabine Gates/Sabine Levees/HFP)**							
	3-1	Port Arthur and Vicinity, Texas Hurricane Flood Protection	64,148,000	4,446,704,000	4,382,556,000	69.32	0	
	3-7	Sabine River Crossing, Orange County and Calcasieu Parish	1,842,580,000	1,869,790,000	27,210,000	1.01	37,000	
		Total Alt S6	**1,906,728,000**	**6,316,494,000**	**4,409,766,000**	**3.31**	**37,000**	
S7	**Sabine ER (without Neches River marsh restoration)**							
	5-3	Dune Restoration and Beach Nourishment, Sabine Pass to High Island, Jefferson and Chambers Counties	3,351,642,000				65,500	
	5-4	Restore Beach Ridge, Sabine Pass to High Island, Jefferson and Chambers Co.	33,027,000	83,752,000	50,725,000	2.54	65,500	*
	5-5	Segmented Nearshore Breakwaters, Sabine Pass to High Island, Jefferson and Chambers Counties	226,676,000				65,500	*
	6-2	GIWW Erosion Protection, Neches River to High Island, Jefferson County	181,509,000				761	
	8-5.1	Marsh Restoration, South of Keith Lake, Jefferson County	65,631,000				4,132	*
	8-5.2	Marsh Restoration, Texas Point NWR, Jefferson County	80,098,000				5,172	*
	9-1	Salt Water Control Structure, Keith Lake Fish Pass, Jefferson County	7,254,000				10,100	*
	9-2	Inverted Siphons Under GIWW, Jefferson County	11,711,000				10,100	*
		Total Alt S7	**3,957,548,000**	**83,752,000**	**NA**	**NA**	**72,006**	
S8	**Sabine ER (with surge barrier on upper Sabine River)**							
	5-3	Dune Restoration and Beach Nourishment, Sabine Pass to High Island, Jefferson and Chambers Counties	3,351,642,000				65,500	
	5-4	Restore Beach Ridge, Sabine Pass to High Island, Jefferson and Chambers Co.	33,027,000	83,752,000	50,725,000	2.54	65,500	*
	5-5	Segmented Nearshore Breakwaters, Sabine Pass to High Island, Jefferson and Chambers Counties	226,676,000				65,500	*
	6-1.1	GIWW Erosion Protection at Old River Cove, Orange County	20,480,000				50	
	6-1.2	GIWW Barrier Island Restoration, Old River and Hickory Coves, Orange County	10,215,000				131	
	6-2	GIWW Erosion Protection, Neches River to High Island, Jefferson County	181,509,000				761	
	6-3	GIWW Barrier Island Restoration, North Pleasure Island, Jefferson County	3,542,000				64	
	8-1	Marsh Restoration, Bessie Heights East , Orange County	177,687,450				2,076	*
	8-2	Marsh Restoration, Old River Cove , Orange County	23,805,000				1,210	*

Table 5-5, continued

Alternative Number	Measure Number	Measure Name	Total Cost ($)	Economic Benefits ($)	Net Excess Benefits ($)	BCR	Env Benefits (wetland acres)	
	8-3	Marsh Restoration, Rose City East , Orange County	25,833,000				568	*
	8-5.1	Marsh Restoration, South of Keith Lake, Jefferson County	65,631,000				4,132	*
	8-5.2	Marsh Restoration, Texas Point NWR, Jefferson County	80,098,000				5,172	*
	9-1	Salt Water Control Structure, Keith Lake Fish Pass, Jefferson County	7,254,000				10,100	*
	9-2	Inverted Siphons Under GIWW, Jefferson County	11,711,000				10,100	*
	10	Sabine River Levee and Gate	293,117,000	20,236,000	NA		5,500	
		Total Alt S8	**4,512,227,000**	**103,988,000**	**NA**	**NA**	**72,006**	
S9	**Sabine Inland Barrier (Neches Gate/Sabine Levees/HFP) and ER**							
	3-1	Port Arthur and Vicinity, Texas Hurricane Flood Protection	64,148,000	4,446,704,000	4,382,556,000	69.32	0	
	3-6	County-Wide Protection System with Neches River Closure and Port Arthur Levee Tie-In, Orange County and Part of Jefferson County	1,549,463,000	1,849,554,000	300,091,000	1.19	31,500	
	5-3	Dune Restoration and Beach Nourishment, Sabine Pass to High Island, Jefferson and Chambers Counties	3,351,642,000				65,500	
	5-4	Restore Beach Ridge, Sabine Pass to High Island, Jefferson and Chambers Co.	33,027,000	83,752,000	50,725,000	2.54	65,500	*
	6-2	GIWW Erosion Protection, Neches River to High Island, Jefferson County	181,509,000				761	
	8-5.1	Marsh Restoration, South of Keith Lake, Jefferson County	65,631,000				4,132	*
	8-5.2	Marsh Restoration, Texas Point NWR, Jefferson County	80,098,000				5,172	*
	9-1	Salt Water Control Structure, Keith Lake Fish Pass, Jefferson County	7,254,000				10,100	*
	9-2	Inverted Siphons Under GIWW, Jefferson County	11,711,000				10,100	*
		Total Alt S9	**5,344,483,000**	**$6,380,010,000**	**1,035,527,000**	**1.19**	**97,761**	
S10	**Sabine GIWW Shoreline Protection**							
	6-1.1	GIWW Erosion Protection at Old River Cove, Orange County	20,480,000	NA			50	
	6-1.2	GIWW Barrier Island Restoration, Old River and Hickory Coves, Orange County	10,215,000	NA			131	
	6-2	GIWW Erosion Protection, Neches River to High Island, Jefferson County	181,509,000	NA			761	
	6-3	GIWW Barrier Island Restoration, North Pleasure Island, Jefferson County	3,542,000	NA			64	
		Total Alt S11	**215,746,000**				**1,006**	
S11	**Sabine Nonstructural Alternative**							
	10-1.1	Buy-outs in Sabine Region (to be developed)	TBD					
	10-2.1	Lone Star Recreation and Conservation Area (to be developed)	TBD					

* Not included in total acreage because of overlap in Environmental Benefits for some measures

Table 5-6. Galveston Region Initial Alternatives Array

Alternative Number	Measure Number	Measure Name	Total Cost ($)	Economic Benefits ($)	Net Excess Benefits ($)	BCR	Env Benefits (wetland ac)	
G1	**Galveston Coastal Barrier All-Inclusive CSRM and ER (without GIWW Protection)**							
	1	Galveston Bay Coastal Barrier, Chambers, Galveston and Harris Co.	6,232,500,000	14,042,424,000	7,809,924,000	2.25	121,000	
	5-6	Dune Restoration and Beach Nourishment, High Island to Galveston East Jetty, Galveston County	1,660,837,000				530	
	5-7	Beach Nourishment, East Galveston Island Seawall, Galveston Island	453,368,000				235	
	5-8	Dune Restoration and Beach Nourishment, West Galveston Island, Galveston County	1,201,816,000				420	
	5-10	Closing of Rollover Pass, Galveston County	6,873,000				42	
	7-1	Shoreline Protection, East Bay, Chambers County	137,121,000				600	*
	8-4.1	Marsh Restoration, Pepper Grove Cove, Galveston County	17,047,000				294	*
	8-4.2	Marsh Restoration, Long Point Marsh, Galveston County	45,561,000				1,661	*
	8-6.1	Marsh Restoration, Pierce Marsh, Galveston County	52,173,000				2,076	*
	8-6.2	Marsh Restoration, IH-10 Causeway, Galveston County	21,478,000				633	*
	8-6.3	Marsh Restoration, Greens Lake, Galveston County	70,718,000				3,293	*
	8-7.1	Marsh Restoration, Gangs to Oxen Bayou, Galveston County	7,662,000				176	*
	8-7.2	Marsh Restoration, Oxen to Mantel Bayou, Galveston County	15,679,000				390	*
	8-7.3	Marsh Restoration, Dana Cove, Galveston County	12,301,000				213	*
	8-7.4	Marsh Restoration, Jumbile Cove, Galveston County	14,652,000				316	*
	8-7.5	Marsh Restoration, Bird Island to Maggies Cove, Galveston County	22,174,000				467	*
	8-7.6	Marsh Restoration, Snake Island Cove, Galveston County	19,711,000				457	*
	8-7.7	Marsh and Bayou Restoration, Sweetwater Preserve, Galveston County	7,257,000				447	*
		Total Alt G1	**9,998,928,000**	**14,042,424,000**	**4,043,496,000**	**1.40**	**122,227**	
G2	**Galveston Coastal Barrier CSRM Focus**							
	1	Galveston Bay Coastal Barrier, Chambers, Galveston and Harris Counties	6,232,500,000	14,042,424,000	7,809,924,000	2.25	121,000	
		Total Alt G2	**6,232,500,000**	**14,042,424,000**	**7,564,224,000**	**2.17**	**121,000**	
G3	**Galveston Coastal Barrier All-Inclusive CSRM and ER**							
	1	Galveston Bay Coastal Barrier, Chambers, Galveston and Harris Counties	6,232,500,000	14,042,424,000	7,809,924,000	2.25	121,000	
	5-6	Dune Restoration and Beach Nourishment, High Island to Galveston East Jetty, Galveston County	1,660,837,000				530	
	5-7	Beach Nourishment, East Galveston Island Seawall, Galveston Island	453,368,000				235	
	5-8	Dune Restoration and Beach Nourishment, West Galveston Island, Galveston County	1,201,816,000				420	
	5-10	Closing of Rollover Pass, Galveston County	6,873,000				42	
	6-4.1	GIWW Breakwaters, Bolivar Peninsula, Galveston County	141,782,000				867	*

Table 5-6, continued

Alternative Number	Measure Number	Measure Name	Total Cost ($)	Economic Benefits ($)	Net Excess Benefits ($)	BCR	Env Benefits (wetland ac)	
	6-4.2	GIWW Barrier Island Restoration, Bolivar Peninsula, Galveston County	10,017,000				246	*
	6-5.1	GIWW Breakwaters, West Bay, Galveston County	43,406,000				222	*
	6-5.2	GIWW Barrier Island Restoration, West Bay 1, Galveston County	9,764,000				112	*
	6-5.3	GIWW Barrier Island Restoration, West Bay 2, Galveston County	4,037,000				35	*
	6-6.2	GIWW Barrier Island Restoration, West Bay, Brazoria County	18,202,000				215	*
	8-4.1	Marsh Restoration, Pepper Grove Cove, Galveston County	17,047,000				294	*
	8-4.2	Marsh Restoration, Long Point Marsh, Galveston County	45,561,000				1,661	*
	8-6.1	Marsh Restoration, Pierce Marsh, Galveston County	52,173,000				2,076	*****
	8-6.2	Marsh Restoration, IH-10 Causeway, Galveston County	21,478,000				633	*****
	8-6.3	Marsh Restoration, Greens Lake, Galveston County	70,718,000				3,293	*****
	8-7.1	Marsh Restoration, Gangs to Oxen Bayou, Galveston County	7,662,000				176	*
	8-7.2	Marsh Restoration, Oxen to Mantel Bayou, Galveston County	15,679,000				390	*
	8-7.3	Marsh Restoration, Dana Cove, Galveston County	12,301,000				213	*
	8-7.4	Marsh Restoration, Jumbile Cove, Galveston County	14,652,000				316	*
	8-7.5	Marsh Restoration, Bird Island to Maggies Cove, Galveston County	22,174,000				467	*
	8-7.6	Marsh Restoration, Snake Island Cove, Galveston County	19,711,000				457	*
	8-7.7	Marsh and Bayou Restoration, Sweetwater Preserve, Galveston County	7,257,000				447	*
		Total Alt G3	**10,089,015,000**	**14,042,424,000**	**3,953,409,000**	**1.39**	**122,227**	
G4	**Galveston Inland Barriers Comprehensive CSRM and ER**							
	2	Surge Gate and Barrier at Hartman Bridge, Harris County	801,842,000	3,054,181,000	2,252,339,000	3.81	3,200	
	3-2	Texas City, Texas Hurricane Flood Protection	36,985,000	2,139,339,000	2,102,354,000	57.84	0	
	3-9	Galveston Ring Levee, Galveston County	556,116,000	3,296,295,000	2,740,179,000	5.93	300	
	3-10.6	Local Surge Protection, Chocolate Bayou, Brazoria County	472,997,000	5,109,000	(467,888,000)	0.01	125	
	4-1	Raise State Highway 146, Galveston and Harris Counties	563,090,000	3,073,296,000	2,510,206,000	5.46	2,900	
	5-6	Dune Restoration and Beach Nourishment, High Island to Galveston East Jetty, Galveston County	1,660,837,000				530	
	5-7	Beach Nourishment, East Galveston Island Seawall, Galveston Island	453,368,000				235	
	5-8	Dune Restoration and Beach Nourishment, West Galveston Island, Galveston County	1,201,816,000				420	
	6-4.1	GIWW Breakwaters, Bolivar Peninsula, Galveston County	141,782,000				867	
	6-4.2	GIWW Barrier Island Restoration, Bolivar Peninsula, Galveston County	10,017,000				246	
	6-5.1	GIWW Breakwaters, West Bay, Galveston County	43,406,000				222	
	6-5.2	GIWW Barrier Island Restoration, West Bay 1, Galveston County	9,764,000				112	
	6-5.3	GIWW Barrier Island Restoration, West Bay 2, Galveston County	4,037,000				35	

Table 5-6, continued

Alternative Number	Measure Number	Measure Name	Total Cost ($)	Economic Benefits ($)	Net Excess Benefits ($)	BCR	Env Benefits (wetland ac)	
	6-6.2	GIWW Barrier Island Restoration, West Bay, Brazoria County	18,202,000				215	
	7-1	Shoreline Protection, East Bay, Chambers County	137,121,000				600	
	8-4.1	Marsh Restoration, Pepper Grove Cove, Galveston County	17,047,000				294	
	8-4.2	Marsh Restoration, Long Point Marsh, Galveston County	45,561,000				1,661	
	8-6.1	Marsh Restoration, Pierce Marsh, Galveston County	52,173,000				2,076	
	8-6.2	Marsh Restoration, IH-10 Causeway, Galveston County	21,478,000				633	
	8-6.3	Marsh Restoration, Greens Lake, Galveston County	70,718,000				3,293	
	8-7.1	Marsh Restoration, Gangs to Oxen Bayou, Galveston County	7,662,000				176	
	8-7.2	Marsh Restoration, Oxen to Mantel Bayou, Galveston County	15,679,000				390	
	8-7.3	Marsh Restoration, Dana Cove, Galveston County	12,301,000				213	
	8-7.4	Marsh Restoration, Jumbile Cove, Galveston County	14,652,000				316	
	8-7.5	Marsh Restoration, Bird Island to Maggies Cove, Galveston County	22,174,000				467	
	8-7.6	Marsh Restoration, Snake Island Cove, Galveston County	19,711,000				457	
	8-7.7	Marsh and Bayou Restoration, Sweetwater Preserve, Galveston County	7,257,000				447	
		Total Alt G4	**6,417,793,000**	**11,568,220,000**	**5,150,427,000**	**1.80**	**20,431**	
G5	**South Galveston Bay Inland Barriers CSRM Focus**							
	2	Surge Gate and Barrier at Hartman Bridge, Harris County	801,842,000	3,054,181,000	2,252,339,000	3.81	3,200	
	3-2	Texas City, Texas Hurricane Flood Protection	36,985,000	2,139,339,000	2,102,354,000	57.84	-	
	3-9	Galveston Ring Levee, Galveston County	556,116,000	3,296,295,000	2,740,179,000	5.93	300	
	3-10.6	Local Surge Protection, Chocolate Bayou, Brazoria County	472,997,000	5,109,000	-467,888,000	0.01	125	
	4-1	Raise State Highway 146, Galveston and Harris Counties	563,090,000	3,073,296,000	2,510,206,000	5.46	2,900	
		Total Alt G5	**2,431,030,000**	**11,568,220,000**	**9,137,190,000**	**4.76**	**6,525**	
G6	**South Galveston Bay Local Protection CSRM Focus**							
	3-9	Galveston Ring Levee, Galveston County	36,985,000	2,139,339,000	2,102,354,000	57.84	-	
	3-2	Texas City, Texas Hurricane Flood Protection	556,116,000	3,296,295,000	2,740,179,000	5.93	300	
	3-10.6	Local Surge Protection, Chocolate Bayou, Brazoria County	472,997,000	5,109,000	-467,888,000	0.01	125	
		Total Alt G6	**1,066,098,000**	**5,440,743,000**	**4,374,645,000**	**5.10**	**425**	
G7	**Galveston ER Barrier Island Protection**							
	5-6	Dune Restoration and Beach Nourishment, High Island to Galveston East Jetty, Galveston County	1,660,837,000				530	
	5-7	Beach Nourishment, East Galveston Island Seawall, Galveston Island	453,368,000				235	

Table 5-6, continued

Alternative Number	Measure Number	Measure Name	Total Cost ($)	Economic Benefits ($)	Net Excess Benefits ($)	BCR	Env Benefits (wetland ac)	
	5-8	Dune Restoration and Beach Nourishment, West Galveston Island, Galveston County	1,201,816,000				420	
	5-10	Closing of Rollover Pass, Galveston County	6,873,000				42	
	6-4.1	GIWW Breakwaters, Bolivar Peninsula, Galveston County	141,782,000				867	
	6-4.2	GIWW Barrier Island Restoration, Bolivar Peninsula, Galveston County	10,017,000				246	
	6-5.1	GIWW Breakwaters, West Bay, Galveston County	43,406,000				222	
	6-5.2	GIWW Barrier Island Restoration, West Bay 1, Galveston County	9,764,000				112	
	6-5.3	GIWW Barrier Island Restoration, West Bay 2, Galveston County	4,037,000				35	
	6-6.2	GIWW Barrier Island Restoration, West Bay, Brazoria County	18,202,000				215	
	7-1	Shoreline Protection, East Bay, Chambers County	137,121,000				600	
	8-4.1	Marsh Restoration, Pepper Grove Cove, Galveston County	17,047,000				294	
	8-4.2	Marsh Restoration, Long Point Marsh, Galveston County	45,561,000				1,661	
	8-7.1	Marsh Restoration, Gangs to Oxen Bayou, Galveston County	7,662,300				176	
	8-7.2	Marsh Restoration, Oxen to Mantel Bayou, Galveston County	15,679,000				390	
	8-7.3	Marsh Restoration, Dana Cove, Galveston County	12,301,200				213	
	8-7.4	Marsh Restoration, Jumbile Cove, Galveston County	14,652,000				316	
	8-7.5	Marsh Restoration, Bird Island to Maggies Cove, Galveston County	22,174,000				467	
	8-7.6	Marsh Restoration, Snake Island Cove, Galveston County	19,711,000				457	
	8-7.7	Marsh and Bayou Restoration, Sweetwater Preserve, Galveston County	7,257,000				447	
		Total Alt G7	**3,849,267,500**	**NA**	**NA**	**NA**	**7,946**	
G8		**Galveston GIWW Shoreline Protection**						
		6-4.1	GIWW Breakwaters, Bolivar Peninsula, Galveston County	141,782,000				867	
		6-4.2	GIWW Barrier Island Restoration, Bolivar Peninsula, Galveston County	10,017,000				246	
		6-5.1	GIWW Breakwaters, West Bay, Galveston County	43,406,000				222	
		6-5.2	GIWW Barrier Island Restoration, West Bay 1, Galveston County	9,764,000				112	
		6-5.3	GIWW Barrier Island Restoration, West Bay 2, Galveston County	4,037,000				35	
		6-6.2	GIWW Barrier Island Restoration, West Bay, Brazoria County	18,202,000				215	
			Total Alt G9	**227,208,000**	**NA**	**NA**	**NA**	**1,698**	
G9		**Galveston Nonstructural Alternative**						
		10-1.2	Buy-outs in Galveston Region (to be developed)	TBD					
		10-2.2	Lone Star Recreation and Conservation Area (to be developed)	TBD					

* Not included in total acreage because of overlap in Environmental Benefits for some measures

Table 5-7. Brazoria Region Initial Alternatives Array

Alternative Number	Measure Number	Measure Name	Total Cost ($)	Economic Benefits ($)	Net Excess Benefits ($)	BCR	Env Benefits (wetland ac)
B1	**Brazoria Coastal Barrier All-Inclusive CSRM and ER**						
	3-3	Freeport and Vicinity, Texas Hurricane Flood Protection	123,784,000	2,195,837,000	2,072,053,000	17.74	0
	5-11	Dune Restoration and Beach Nourishment, San Luis Pass to Surfside, Brazoria County	667,903,000				500
	5-12	Dune Restoration and Beach Nourishment, Surfside to Brazos River, Brazoria County	247,862,000				45
	5-13	Dune Restoration and Beach Nourishment, Brazos River to Brazos River Diversion channel, Brazoria County	409,410,000				540
	5-16	Groin at State Highway 332, Brazoria County	4,010,000				50
	6-6.1	GIWW Erosion Protection, Brazoria County	219,877,000				1,110
	7-2	Shoreline Protection, Bastrop Bay , Brazoria County	20,420,000				40
		Total Alt B1	**1,693,266,000**	**2,195,837,000**	**502,571,000**	**1.30**	**2,285**
B2	**Brazoria Coastal Barrier CSRM Focus (revised)**		-	-	-	-	-
	3-3	Freeport and Vicinity, Texas Hurricane Flood Protection	123,784,000	2,195,837,000	2,072,053,000	17.74	0
		Total Alt B2	**123,784,000**	**2,195,837,000**	**2,072,053,000**	**17.74**	
B3	**Brazoria ER and Coastal Marsh Protection**						
	5-11	Dune Restoration and Beach Nourishment, San Luis Pass to Surfside, Brazoria County	667,903,000	-			500
	5-12	Dune Restoration and Beach Nourishment, Surfside to Brazos River, Brazoria County	247,862,000	-			45
	5-13	Dune Restoration and Beach Nourishment, Brazos River to Brazos River Diversion channel, Brazoria County	409,410,000	-			540
	5-16	Groin at State Highway 332, Brazoria County	4,010,000				50
	6-6.1	GIWW Erosion Protection, Brazoria County	219,877,000				1,110
	7-2	Shoreline Protection, Bastrop Bay , Brazoria County	20,420,000				40
		Total Alt B3	**1,569,482,000**	**NA**	**NA**	**NA**	**2,285**
B4	**Brazoria GIWW Shoreline Protection**						
	6-6.1	GIWW Erosion Protection, Brazoria County	219,877,000				1,110
	7-2	Shoreline Protection, Bastrop Bay , Brazoria County	20,420,000				40
		Total Alt B4	**240,297,000**	**NA**	**NA**	**NA**	**1,150**
B5	**Brazoria Nonstructural Alternative**						
	10-1.3	Buy-outs in Brazoria (to be developed)	TBD				
	10-2.3	Lone Star Recreation and Conservation Area (to be developed)	TBD				
		Total Alt B5					

Table 5-8. Ranking by Net Excess Benefits for Sabine Region Initial Array

Alternative Number	Description	Total Cost ($)	Economic Benefits ($)	Net Excess Benefits ($)	BCR	Env Benefits (wetland ac.)
S5	Sabine Inland Barrier CSRM Focus(Neches Gate/Sabine Levees/HFP)	1,613,611,000	6,296,258,000	4,682,647,000	3.90	31,500
S6	Sabine Inland Barrier CSRM Focus (Neches &Sabine Gates/Sabine Levees/HFP)	1,906,728,000	6,316,494,000	4,409,766,000	3.31	37,000
S4	Sabine Inland Barrier CSRM Focus (Sabine & Neches Levees/HFP)	1,807,648,000	5,982,257,000	4,174,609,000	3.31	7,400
S9	Sabine Inland Barrier (Neches Gate/Sabine Levees/HFP) and ER	5,344,483,000	6,380,010,000	1,035,527,000	2.54	97,761
S2	Sabine Inland Barrier All-Inclusive CSRM (Neches Gate/Sabine Levees/HFP) and ER (without Salt Bayou measures)	5,832,721,000	6,380,010,000	547,289,000	1.09	98,006
S3	Sabine Inland Barrier All-Inclusive CSRM (Neches &Sabine Gates/Sabine Levees/HFP) and ER	6,125,838,000	6,400,246,000	274,408,000	1.04	103,506
S1	Sabine Inland Barrier All-Inclusive CSRM (Sabine & Neches Levees/HFP) and ER	6,026,758,000	6,066,009,000	39,251,000	1.01	77,760
S10	Sabine GIWW Shoreline Protection	215,746,000	NA	NA	NA	1,006
S7	Sabine ER (without Neches River marsh restoration)	3,957,548,000	83,752,000	NA	NA	66,261
S8	Sabine ER (with surge barrier on upper Sabine River)	4,512,227,000	103,988,000	NA	NA	72,006
S11	Sabine Nonstructural Alternative	TBD				

Table 5-9. Ranking by Net Excess Benefits for Galveston Region Initial Array

Alternative Number	Description	Total Cost ($)	Economic Benefits ($)	Net Excess Benefits ($)	BCR	Env Benefits (wetland ac)
G5	South Galveston Bay Inland Barriers CSRM Focus	2,495,830,000	11,568,219,620	9,072,389,620	4.64	6,525
G2	Galveston Coastal Barrier CSRM Focus	6,478,200,000	14,042,424,000	7,564,224,000	2.17	121,000
G4	Galveston Inland Barriers Comprehensive CSRM and ER	6,417,793,000	11,568,220,000	5,150,427,000	1.80	20,431
G6	South Galveston Bay Local Protection CSRM Focus	966,298,000	5,440,742,620	4,474,444,620	5.63	425
G1	Galveston Coastal Barrier All-Inclusive CSRM and ER (without GIWW Protection)	9,998,928,000	14,042,424,000	4,043,496,000	1.40	122,227
G3	Galveston Coastal Barrier All-Inclusive CSRM and ER	10,089,015,000	14,042,424,000	3,953,409,000	1.39	122,227
G8	Galveston Bay GIWW Shoreline Protection	227,208,000	NA	NA	NA	1,698
G7	Galveston Bay ER	3,809,994,500	NA	NA	NA	7,904
G9	Galveston Bay Nonstructural Alternative	TBD				

Table 5-10. Ranking by Net Excess Benefits for Brazoria Region Initial Array

Alternative Number	Description	Total Cost ($)	Economic Benefits ($)	Net Excess Benefits ($)	BCR	Env Benefits (wetland ac)
B2	Brazoria Coastal Barrier CSRM Focus (revised)	123,784,337	2,195,837,080	2,072,052,743	17.74	0
B1	Brazoria Coastal Barrier All-Inclusive CSRM and ER	1,693,266,337	2,195,837,080	502,570,743	1.30	2,140
B4	Brazoria GIWW Shoreline Protection	240,297,000	0	-240,297,000	0.00	1,160
B3	Brazoria ER	1,569,482,000	NA	NA	NA	2,140
B5	Brazoria Nonstructural Alternative	TBD				

The qualitative environmental impacts criterion was utilized to screen the initial array of alternatives to determine if any contained significant environmental impacts which could not be mitigated or which could render an alternative non-implementable (Table 5-11, Table 5-12, and Table 5-13). None of the alternatives would have construction footprint impacts that could not be mitigated. While several alternatives potentially cause significant changes to salinity, tidal circulation, sediment transport, aquatic organism access and erosion, further analysis will be needed to determine the extent of these changes and whether they have positive or negative effects. For example, all alternatives scored as "high" impacts for System-wide Hydrologic Effects contain Measure 1 (Galveston Bay Coastal Barrier) which could decrease the cross-sectional area of the mouth of the Galveston Bay, creating a reduction in the volume of the tidal prism and reducing salinity. Depending on the amount of salinity reduction, this could have a beneficial effect on the estuary. Furthermore, the PDT believed that all of the surge barrier measures can potentially be designed to minimize effects on the tidal prism, circulation and erosion. Endangered species impacts were evaluated to determine if construction could jeopardize the continued existence of any endangered species in the study area. It was determined that construction impacts could be minimized, but that small areas of piping plover critical habitat would be impacted by alternatives including Measure 1. It is assumed that construction and critical habitat impacts could be mitigated. Therefore, none of the alternatives was screened out on the basis of this criterion.

All of the ER Alternatives (S8, G9, B3) were retained because it is assumed that some mix of these measures will be needed to increase the sustainability of structural measures or the landforms they protect. None of the individual measures was eliminated at this phase because incremental analysis is needed to evaluate the most cost-effective and efficient mix of the measures included in the alternatives. Ecological modeling proposed for the TSP phase will quantify the ecological benefits of the measures, so that the most efficient array of measures in each alternative can be identified.

5.5 EVALUATION ARRAY OF ALTERNATIVE PLANS CARRIED FORWARD

The initial screening discussed above resulted in the identification of the evaluation array of alternatives to be carried to the next screening. Table 5-14, Table 5-15, and Table 5-16 list the Initial Array of alternative plans and summarized the reasons for eliminating alternative plans or carrying alternative plans forward to the Evaluation Array of Alternative Plans. Alternative plans determined to be the most viable plans to carry forward to the Evaluation Plans Array based on the four criteria in Section 5.3 are indicated by shading. The Evaluation Array of Alternative Plans comprises 10 alternatives (three from Sabine region, four from Galveston region, and three from Brazoria region) to be evaluated in more detail in the Section 6.0.

Table 5-11. Qualitative Analysis of Environmental Impacts Sabine Region

Alternative Number	Description	Environmental Impacts (Qualitative Analysis)			Impact Description
		Construction Impacts to Wetlands and Sensitive Habitats	System-wide Hydrologic Impacts	Endangered Species Impacts	
S5	Sabine Inland Barrier CSRM Focus(Neches Gate/Sabine Levees/HFP)	Medium	Medium	Low	Construction of navigation gate and barrier across Neches River would impact small area of river bottom and navigation channel, but construction of south Orange County and Sabine River west bank surge barriers would impact moderate amount of wetlands. Neches River gate has potential to adversely affect tidal circulation, sediment transport, aquatic organism access and erosion in lower Neches River watershed. No impacts on endangered species are anticipated.
S6	Sabine Inland Barrier CSRM Focus (Neches &Sabine Gates/Sabine Levees/HFP)	Medium	Medium	Low	Construction of Neches and Sabine River gates would impact small area of river bottom, but construction of south Orange County surge barrier, Sabine River surge barrier, and barrier extension into Calcasieu Parish would impact moderate amount of wetlands. Neches River gate has potential to adversely affect tidal circulation, sediment transport, aquatic organism access and erosion in lower Neches River watershed. Sabine River gate could have small effect on normal tidal circulation, while preventing storm surge impacts on about 5,500 acres of cypress-tupelo swamp in Sabine Island WMA. No impacts on endangered species are anticipated.
S4	Sabine Inland Barrier CSRM Focus (Sabine & Neches Levees/HFP)	Medium	Low	Low	Construction of surge barriers along Neches River south bank, high terrace of Neches River north bank, south Orange County and Sabine River south bank would impact moderate amount of wetlands. No impacts on endangered species are anticipated.
S9	Sabine Inland Barrier (Neches Gate/Sabine Levees/HFP) and ER	Medium	Medium	Low	Construction of Neches River gate would impact small area of river bottom, but construction of south Orange County and Sabine River west bank surge barriers would impact moderate amount of wetlands. Neches River gate has potential to adversely affect tidal circulation, sediment transport, aquatic organism access and erosion in lower Neches River watershed. Beach and dune restoration, beach ridge restoration, GIWW shoreline protection from Neches River to High Island, marsh restoration at Keith Lake and Texas Point, and Salt Bayou hydrologic restoration are all ER measures; impacts of construction are outweighed by overall benefit. No impacts on endangered species are anticipated.
S2	Sabine Inland Barrier All-Inclusive CSRM (Neches Gate/Sabine Levees/HFP) and ER (without Salt Bayou measures)	Medium	Medium	Low	Construction of navigation gate and barrier across Neches River would impact small area of river bottom and navigation channel, but construction of Orange County and Sabine River west bank levees would impact moderate amount of wetlands. Neches River gate has potential to adversely affect tidal circulation, sediment transport, aquatic organism access and erosion in lower Neches River watershed. Beach and dune restoration, beach ridge restoration, all GIWW shoreline protection, regional marsh restoration, and Salt Bayou hydrologic restoration are all ER measures; impacts of construction are outweighed by overall benefits. No impacts on endangered species are anticipated.
S3	Sabine Inland Barrier All-Inclusive CSRM (Neches &Sabine Gates/Sabine Levees/HFP) and ER	Medium	Medium	Low	Construction of Neches and Sabine River gates would impact small area of river bottom, but construction of south Orange County surge barrier, Sabine River surge barrier, and barrier extension into Calcasieu Parish would impact moderate amount of wetlands. Neches River gate has potential to adversely affect tidal circulation, sediment transport, aquatic organism access and erosion in lower Neches River watershed. Sabine River gate could have small effect on normal tidal circulation, while preventing storm surge impacts on about 5,500 acres of cypress-tupelo swamp in Sabine Island WMA. Beach and dune restoration, beach ridge restoration, GIWW shoreline protection, regional marsh restoration, and Salt Bayou hydrologic restoration are all ER measures; impacts of construction are outweighed by overall benefits. No impacts on endangered species are anticipated.
S1	Sabine Inland Barrier All-Inclusive CSRM (Sabine & Neches Levees/HFP) and ER	Medium	Low	Low	Construction of surge barriers along Neches River south bank, high terrace of Neches River north bank, and Sabine River south bank would impact moderate amount of wetlands. Beach and dune restoration, beach ridge restoration, all GIWW shoreline protection, regional marsh restoration, and Salt Bayou hydrologic restoration are all ER measures; impacts of construction are outweighed by overall benefits. No impacts on endangered species are anticipated.

Table 5-11, continued

Alternative Number	Description	Environmental Impacts (Qualitative Analysis)			Impact Description
		Construction Impacts to Wetlands and Sensitive Habitats	System-wide Hydrologic Impacts	Endangered Species Impacts	
S10	Sabine GIWW Shoreline Protection	Low	Low	Low	Construction impacts would likely be limited to submerged edge of GIWW, footprint of breakwaters or other ER erosion control structures. Structures are expected to slow shoreline erosion and not expected to have effect on larger system. No endangered species impacts are anticipated.
S7	Sabine ER (without Neches River marsh restoration)	Low	Low	Low	Beach and dune restoration, beach ridge restoration, GIWW shoreline protection from Neches River to High Island, marsh restoration at Keith Lake and Texas Point, and Salt Bayou hydrologic restoration are all ER measures; impacts of construction are outweighed by overall benefits. No impacts on endangered species are anticipated.
S8	Sabine ER (with surge barrier on upper Sabine River)	Low	Low	Low	Sabine Island Swamp surge barrier and gate would prevent storm surge impacts to about 5,500 acres of cypress-tupelo swamp in Sabine Island Wildlife Management Area. Beach and dune restoration, beach ridge restoration, GIWW shoreline protection, regional marsh restoration, and Salt Bayou hydrologic restoration are all ER measures; impacts of construction are outweighed by overall benefits. No impacts on endangered species are anticipated.
S11	Sabine Nonstructural Alternative	Low	Low	Low	Conservation of natural landscapes would have beneficial long-term environmental effects.

Table 5-12. Qualitative Analysis of Environmental Impacts Galveston Region

Alternative Number	Description	Environmental Impacts (Qualitative Analysis)			Impact Description
		Construction Impacts to Wetlands and Sensitive Habitats	System-wide Hydrologic Impacts	Endangered Species Impacts	
G5	South Galveston Bay Inland Barriers CSRM Focus	Low	Med	Low	With exception of Chocolate Bayou, construction right-of-way would be located primarily in developed areas, so few wetlands or sensitive habitats would be affected. Surge gate and barrier at Hartman Bridge has potential to adversely affect tidal circulation, sediment transport, aquatic organism access, and erosion in lower San Jacinto and Buffalo Bayou watersheds. Construction would not jeopardize continued existence of endangered species, but construction would impact small areas of piping plover critical habitat. It is assumed that impacts could be mitigated.
G2	Galveston Coastal Barrier CSRM Focus	Medium	High	Medium	Construction right-of-way would be located on existing highways; minor wetlands impacts would be expected along expanded right-of-way. Gate structures would be located in natural passes and navigation channels; impacts to natural bottom and oyster reef would be expected. 65-mile long barrier and gates have potential to adversely affect tidal circulation, salinity, sediment transport, aquatic organism access, erosion and oyster reefs in greater Galveston Bay and lower San Jacinto and Buffalo Bayou watersheds. Construction would not jeopardize continued existence of endangered species, but construction would impact small areas of piping plover critical habitat. It is assumed that impacts could be mitigated.
G4	Galveston Inland Barriers Comprehensive CSRM and ER	Low	Med	Low	With exception of Chocolate Bayou, construction right-of-way would be located primarily in developed areas, so few wetlands or sensitive habitats would be affected. Surge gate and barrier at Hartman Bridge has potential to adversely affect tidal circulation, sediment transport, aquatic organism access and erosion in lower San Jacinto and Buffalo Bayou watersheds. Beach and dune restoration would temporarily impact piping plover critical habitat, but would stabilize habitat over the long-term. Beach and dune restoration, GIWW shoreline protection, marsh restoration, and East Bay shoreline protection are all ER measures; impacts of construction are outweighed by overall benefits.
G6	South Galveston Bay Local Protection CSRM Focus	Low	Low	Low	With exception of Chocolate Bayou, construction right-of-way would be located primarily in developed areas, so few wetlands or sensitive habitats would be affected. Texas City HFP is existing project that would be upgraded; no wetland impacts anticipated. Construction of levees around Chocolate Bayou facilities would impact small amount of wetlands. Local systems would have no effect on Galveston Bay hydrology and there would be no endangered species impacts.
G1	Galveston Coastal Barrier All-Inclusive CSRM and ER (without GIWW Protection)	Low	High	Medium	Coastal barrier construction right-of-way would be located on existing highways; minor wetlands impacts would be expected along the expanded right-of-way. 65-mile long barrier and gates have potential to adversely affect tidal circulation, salinity, sediment transport, aquatic organism access, erosion and oyster reefs in greater Galveston Bay and lower San Jacinto and Buffalo Bayou watersheds. Beach and dune restoration would temporarily impact piping plover critical habitat, but would stabilize habitat over long-term. Beach and dune restoration, marsh restoration, and East Bay shoreline protection are all ER measures; impacts of construction are outweighed by overall benefits. Construction would not jeopardize continued existence of endangered species, but construction would impact small areas of piping plover critical habitat. It is assumed that impacts could be mitigated.
G3	Galveston Coastal Barrier All-Inclusive CSRM and ER	Low	High	Medium	Coastal barrier construction right-of-way would be located on existing highways; minor wetlands impacts would be expected along expanded right-of-way. 65-mile long barrier and gates have potential to adversely affect tidal circulation, salinity, sediment transport, aquatic organism access, erosion and oyster reefs in greater Galveston Bay and lower San Jacinto and Buffalo Bayou watersheds. Beach and dune restoration would temporarily impact piping plover critical habitat, but would stabilize habitat over long-term. Beach and dune restoration, marsh restoration, and East Bay shoreline protection are all ER measures; impacts of construction are outweighed by overall benefits. Construction would not jeopardize the continued existence of endangered species, but construction would impact small areas of piping plover critical habitat. It is assumed that impacts could be mitigated.

Table 5-12, continued

Alternative Number	Description	Environmental Impacts (Qualitative Analysis)			Impact Description
		Construction Impacts to Wetlands and Sensitive Habitats	System-wide Hydrologic Impacts	Endangered Species Impacts	
G8	Galveston Bay GIWW Shoreline Protection	Low	Low	Low	Construction impacts would likely be limited to submerged edge of GIWW, footprint of erosion protection (e.g. breakwaters) or other living shoreline erosion control structures. Structures are expected to slow shoreline erosion and not expected to have effect on larger system. No endangered species impacts are anticipated.
G7	Galveston Bay ER	Low	Low	Low	Beach and dune restoration would temporarily impact piping plover critical habitat, but would stabilize habitat over the long-term. Beach and dune restoration, marsh restoration, and East Bay shoreline protection are all ER measures; impacts of construction are outweighed by overall benefits.
G9	Galveston Bay Nonstructural Alternative	Low	Low	Low	Conservation of natural landscapes would have beneficial long-term environmental effects.

Table 5-13. Qualitative Analysis of Environmental Impacts Galveston Region

Alternative Number	Description	Environmental Impacts (Qualitative Analysis)			Impact Description
		Construction Impacts to Wetlands and Sensitive Habitats	System-wide Hydrologic Impacts	Endangered Species Impacts	
B2	Brazoria Coastal Barrier CSRM Focus (revised)	Low	Low	Low	Reconstruction of existing Freeport HFP would not impact wetlands or sensitive habitats. Alterations to lower Brazos River system are existing conditions and no changes would results from reconstruction of HFP. No endangered species impacts are anticipated.
B1	Brazoria Coastal Barrier All-Inclusive CSRM and ER	Low	Low	Low	Reconstruction of existing Freeport HFP would not impact wetlands or sensitive habitats. Alterations to lower Brazos River system are existing conditions and no changes would results from reconstruction of HFP. Beach and dune restoration would temporarily impact piping plover critical habitat, but would stabilize habitat over long-term. Beach and dune restoration, groin construction, and GIWW shoreline protection are all ER measures; impacts of construction are outweighed by overall benefits.
B4	Brazoria GIWW Shoreline Protection	Low	Low	Low	Construction impacts would likely be limited to submerged edge of GIWW, footprint of breakwaters or other living shoreline erosion control structures. Structures are expected to slow shoreline erosion and not expected to have effect on larger system. No endangered species impacts are anticipated.
B3	Brazoria ER	Low	Low	Low	Beach and dune restoration would temporarily impact piping plover critical habitat, but would stabilize habitat over long-term. Beach and dune restoration, groin construction, and GIWW shoreline protection are all ER measures; impacts of construction are outweighed by overall benefits.
B5	Brazoria Nonstructural Alternative	Low	Low	Low	Conservation of natural landscapes would have beneficial long-term environmental effects.

Table 5-14. Summary of Screening of Sabine Region Alternatives for Evaluation Array*

Alternative Number	Alt Name / Description	Reason Eliminated or Carried Forward to Evaluation Array
S5	Sabine Inland Barrier CSRM Focus(Neches Gate/Sabine Levees/HFP)	Carried Forward to Evaluation Array because of highest net excess benefits
S6	Sabine Inland Barrier CSRM Focus (Neches &Sabine Gates/Sabine Levees/HFP)	Eliminated because of lower net excess benefits than S5. Sabine gate has complex interstate issues and not known if GLO can fund project that would be in LA. Sabine gate is carried forward in S8 as a separate measure to allow in to be further studied.
S4	Sabine Inland Barrier CSRM Focus (Sabine & Neches Levees/HFP)	Eliminated because of lower net excess benefits than S5. Longer lines of defense at higher cost.
S9	Sabine Inland Barrier (Neches Gate/Sabine Levees/HFP) and ER	Eliminated because of lower net excess benefits than S5 due to the costs of the ER measures. CSRM measures same as S5. Considered redundant as ER measures carried forward in S8.
S2	Sabine Inland Barrier All-Inclusive CSRM (Neches Gate/Sabine Levees/HFP) and ER (without Salt Bayou measures)	Eliminated because implementation costs are high. Considered redundant as ER measures carried forward in S8.
S3	Sabine Inland Barrier All-Inclusive CSRM (Neches &Sabine Gates/Sabine Levees/HFP) and ER	Eliminated for same reasons as S6 (Sabine Gate in LA) and S2 (ER measures carried forward in S8).
S1	Sabine Inland Barrier All-Inclusive CSRM (Sabine & Neches Levees/HFP) and ER	Eliminated because of lower net excess benefits. Long lines of defense at higher costs. ER measures carried forward under S8.
S10	Sabine GIWW Shoreline Protection	Eliminated because of lack of significant economic benefits. GIWW shoreline protection carried forward as part of S8.
S7	Sabine ER (without Neches River marsh restoration)	Eliminated because of lack of significant economic benefits. ER measures are also in S8 and will be evaluated further under S8.
S8	Sabine ER (with surge barrier on upper Sabine River)	Carried forward as ER Alternative Plan. Carrying forward one ER plan with all ER measures rolled into it allows PDT to refine ER benefits during next study phase. Based on refined benefits, PDT can perform incremental analysis and ER plan can then be reformulated to maximize ER benefits.
S11	Sabine Nonstructural Alternative	Carried forward to develop during next phase of study. Assumed some level of buyouts and Lone Star-type of Conservation plan will be part of recommended plan.

* Listed in order of Economic Benefits

Table 5-15. Summary of Screening of Galveston Region Alternatives for Evaluation Array*

Alternative Number	Alt Name / Description	Reason Eliminated or Carried Forward to Evaluation Array
G5	South Galveston Bay Inland Barriers CSRM Focus	Carried Forward to Evaluation Array because of high net excess benefits.
G2	Galveston Coastal Barrier CSRM Focus	Carried Forward to Evaluation Array because of high net excess benefits.
G4	Galveston Inland Barriers Comprehensive CSRM and ER	Eliminated due to lower net excess benefits than G5 or G2. High Implementation Costs associated with the ER measures. Surge reduction measures same as G5. ER measures carried forward under Alternative G7.
G6	South Galveston Bay Local Protection CSRM Focus	Eliminated due to not provide any benefits for Harris or Chambers Counties and does not reduce risk for the Houston Ship Channel and associated industry.
G1	Galveston Coastal Barrier All-Inclusive CSRM and ER (without GIWW Protection)	Eliminated due to extremely high implementation costs due to the addition of all ER measures. The surge reduction measures are the same as G2. ER measures are carried forward under Alternative G7.
G3	Galveston Coastal Barrier All-Inclusive CSRM and ER	Eliminated for same reasons as G1. GIWW measures are also carried forward under G7.
G8	Galveston Bay GIWW Shoreline Protection	Eliminated due to lack of significant economic benefits. GIWW shoreline protection carried forward as part of G7.
G7	Galveston Bay ER	Carried forward as ER Alternative Plan. Carrying forward one ER plan with all ER measures rolled into it allows PDT to refine ER benefits during next study phase. Based on refined benefits, PDT can perform incremental analysis and ER plan can then be reformulated to maximize ER benefits.
G9	Galveston Bay Nonstructural Alternative	Carried forward to develop during next phase of study. Assumed some level of buyouts and Lone Star-type of Conservation plan will be part of recommended plan.

* Listed in order of Economic Benefits

Table 5-16. Summary of Brazoria Region Alternatives Eliminated or Carried Forward to Evaluation Array*

Alternative Number	Alt Name / Description	Reason Eliminated or Carried Forward to Evaluation Array
B2	Brazoria Coastal Barrier CSRM Focus (revised)	Carried Forward because of highest economic benefit of all Brazoria alternatives.
B1	Brazoria Coastal Barrier All-Inclusive CSRM and ER	Eliminated due to high implementation costs associated with ER measures. ER measures are carried forward as part of alternative B3.
B4	Brazoria GIWW Shoreline Protection	Eliminated due to lack of significant economic benefits. GIWW shoreline protection carried forward as part of B3.
B3	Brazoria ER	Carried forward as ER Alternative Plan. Carrying forward one ER plan with all ER measures rolled into it allows PDT to refine ER benefits during next study phase. Based on refined benefits, PDT can perform incremental analysis and ER plan can then be reformulated to maximize ER benefits.
B5	Brazoria Nonstructural Alternative	Carried forward to develop during next phase of study. Assumed some level of buyouts and Lone Star-type of Conservation plan will be part of recommended plan.

* Listed in order of Economic Benefits

6 EVALUATION ARRAY OF ALTERNATIVE PLANS

6.1 EVALUATION ARRAY OF ALTERNATIVES

The Evaluation Array of Alternatives was identified from the screening of the Initial Array of Alternatives. Table 6-1 described this evaluation array.

Table 6-1. Evaluation Array of Alternatives

Alternative Number	Alternative Name	Description
S5	Sabine Inland Barrier CSRM Focus(Neches Gate/Sabine Levees/HFP)	Neches River Navigation Gate, Sabine Levees, Port Arthur HFP
S8	Sabine ER (with surge barrier on upper Sabine River)	Beach and dune restoration, restore beach ridge, nearshore breakwaters, GIWW shoreline protection, marsh restoration on Neches River and at Keith Lake and Texas Point, Salt Bayou hydrologic restoration, Sabine River levees and gate
S11	Sabine Nonstructural Alternative	Buyouts and Lone Star-type conservation plan
G2	Galveston Coastal Barrier CSRM Focus	Coastal barrier and gates, and buyouts/relocations within a 500 ft buffer
G5	South Galveston Bay Inland Barriers CSRM Focus	Surge barrier and gates near Hartman Bridge, Tx City HFP, Galveston Ring Levee, Chocolate Bayou ring levee, Raise Hwy 146 and buyouts/relocations within a 500 ft buffer
G7	Galveston Bay ER	Beach and dune restoration, GIWW shoreline protection, marsh restoration, East Bay shoreline protection, closing Rollover Pass
G9	Galveston Bay Nonstructural Alternative	Buyouts and Lone Star-like conservation plan
B2	Brazoria Coastal Barrier CSRM Focus (revised)	Freeport HFP
B3	Brazoria ER	Beach and dune restoration, groin, and GIWW shoreline protection
B5	Brazoria Nonstructural Alternative	Buyouts and Lone Star-like conservation plan

6.2 EVALUATION SCREENING OF ALTERNATIVES

The Evaluation Screening of Alternatives was used as the decision point for this analysis to determine whether the data collected and utilized for this analysis is sufficient to make the determination of which alternative (S5-Gate/ S8-No-Gate) to carry forward for detailed analysis. In order to make this comparison between these two alternatives, it was decided that the S8 Alternative was configured to provide the same level of protection as that provided by the S5 Alternative. This level of protection would be assumed to provide roughly the same amount of benefits, as evidenced by the inundation patterns of the two alternatives compared to inundation for the without-project condition shown in the figures below. Therefore, since the benefits are roughly the same, the primary determining factor becomes cost, allowing the alternative with the lowest cost to be the alternative to be carried forward into more detailed evaluation. If the two

alternative costs were not significantly different, both alternatives would require additional detailed evaluation before either could be ruled out.

6.2.1 Development of Alternative Alignments

The Gate Alternative consists of a protection system utilizing the existing Port Arthur Hurricane Flood Protection (HFP) levee with construction of a navigation gate across the Neches River and new levees along the west bank of the Sabine River. Figure 6-1 shows the Gate Alternative alignment as previously developed for the initial screening analysis. The No-Gate Alternative consists of a protection system utilizing the existing Port Arthur Hurricane Flood Protection (HFP) levee with extension of the levees along the west bank of the Neches River, as well as new levees along the east bank of the Neches River and the west bank of the Sabine River. Figure 6-2 shows the No-Gate Alternative alignment also from the previously developed initial screening.

The levee alignments for both of the alternatives in this analysis were based on alignments from the Orange County Flood Protection Planning Study (Orange Report), which was 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. Additional effort was taken to avoid disruptions to major pipeline corridors and to identify opportunities for potential buyouts. The alignment for the closure gate at the mouth of the Neches River also originated from the Orange County Study. This alignment was refined to minimize impacts on the environment and navigation and to identify specific location for a pumping station that would be used to reduce the risk of inland flows impacting gate operation. This pumping station would need to have the ability to pump discharge from the inland Neches River into Sabine Lake, when the gate structure was closed.

The area that would be protected by the Gate Alternative is roughly 290 square miles in size (186,500 acres). The western boundary of the protected area is approximately 20 miles long, stretching from Interstate Highway 10 (IH 10) at the northern end to the southern end of the existing Port Arthur HFPS near the intersection of the Gulf Intracoastal Waterway (GIWW) and the Sabine Neches Waterway. The eastern boundary extends roughly 11 miles from IH 10 at its northern extent to the mouth of the Sabine River at the northeastern corner of Sabine Lake to the south. At its maximum width, the area is approximately 22 miles wide along the IH 10 corridor. This area encompasses the lower 18 and lower 11 river miles of the Neches and Sabine Rivers, respectively.

The area that would be protected by the No-Gate Alternative is the same general location, with the exception of the Neches River bottomland and some flood prone uplands that would be open to hurricane storm surge flooding without the surge gate at the mouth of the Neches River. West of the Neches River, the area protected by the proposed levee/floodwall system would be approximately 62 square miles (63,000 acres) in size. East of the Neches River and West of the Sabine River, the area protected would be approximately 100 square miles (66,000 acres) in size.

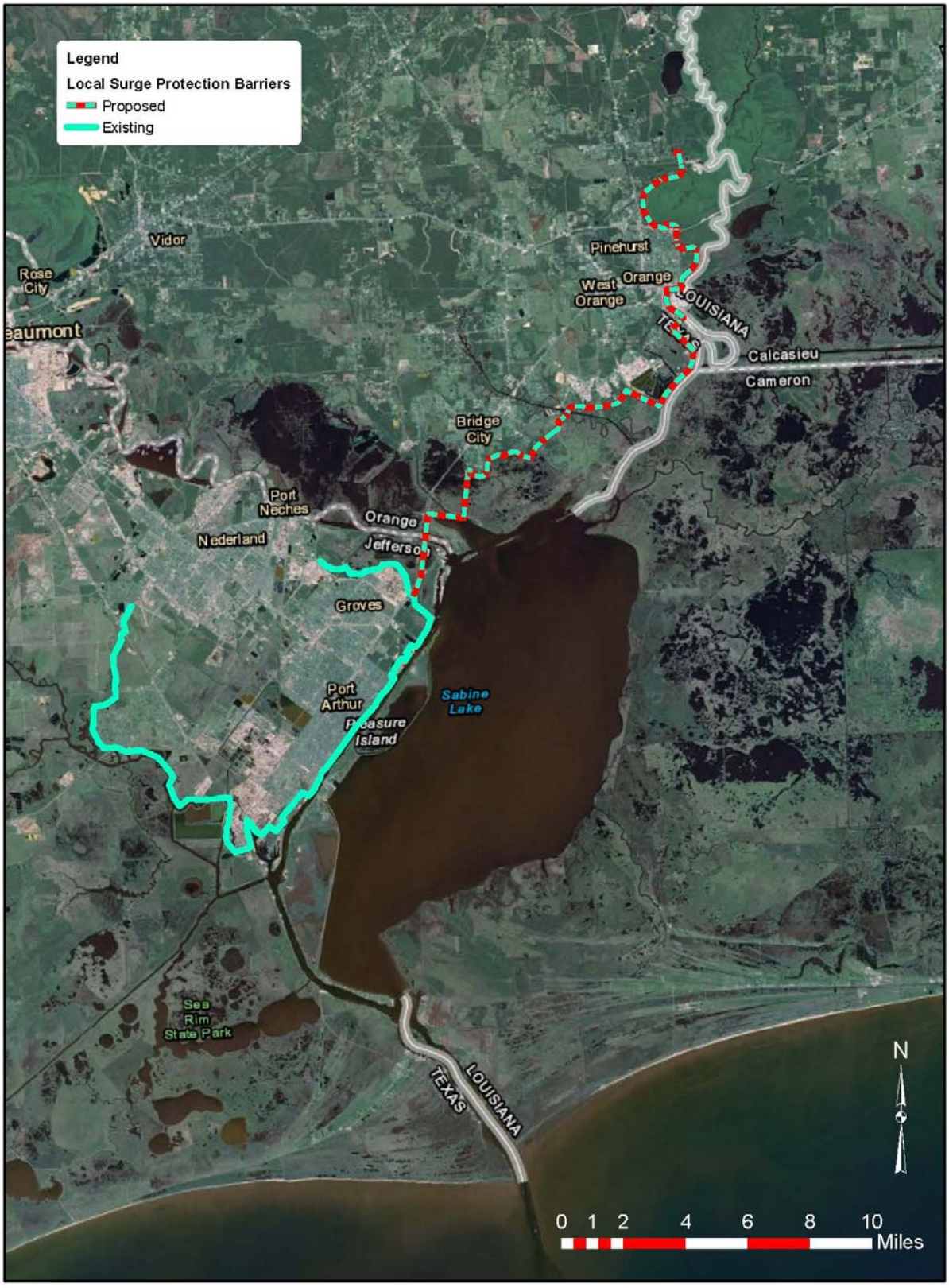

Figure 6-1. Gate Alternative

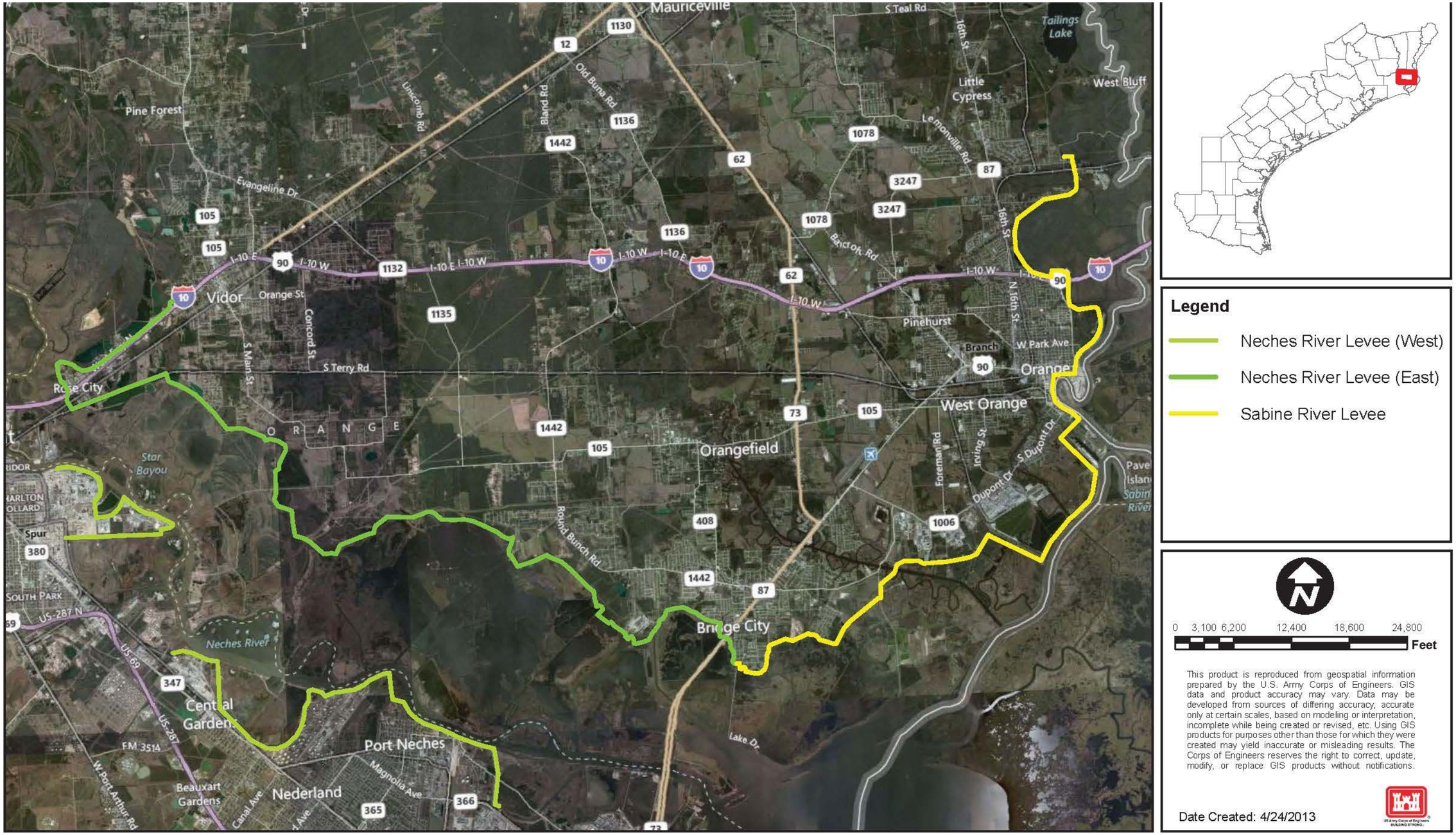

Figure 6-2. No-Gate Alternative

Together, the protected areas total approximately 162 square miles (129,000 acres). The layout of the levee/floodwall system has been placed on the upland margins to the greatest extent possible, and therefore wetland areas protected from storm surge impacts are much smaller than the Gate Alternative, covering roughly 7,000 acres.

6.2.2 Hydraulic and Hydrology (H&H) Analysis

For the H&H analysis to compare these two alternatives, inundation for the 100-year event was developed. Figure 6-3, Figure 6-4, and Figure 6-5 show the inundation pattern of the 100-year event for the without-project, and for the No-Gate Alterative and the Gate Alternative. Note that the levee and gate alignments were slightly refined from the original alternative figures.

A joint probability analysis of riverine discharge and storm surge on the Neches River was conducted to assist with preliminary screening of the Neches gate alternative. The analysis calculates the probability of discharge with respect to extreme water level.

The nearest gage measuring river discharge is a USGS gage at the Neches River Saltwater Barrier. The nearest gage measuring water level is a NOAA gage at the mouth of the Neches River. Data gathered from the NOAA and USGS gages was 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. Frank and empirical Copula bivariate distribution functions were then fit to the data to calculate the distribution. Figure 6-6 plots the probability distribution calculated with the Frank (top) and empirical (bottom) Copula functions. The colors and contours show probability in return period.

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

- The 100-year return period the Neches River discharge could reach a maximum level of 40,000 cubic feet per second (cfs) for events that could occur during gate closure.
- There would be some storage volume in the Neches River basin behind the gate. This storage volume reduces the amount of Neches River flow the pump would need to discharge.
- Coincident analysis and historical data indicate that a flow between 20,000 cfs and 30,000 cfs would be expected during an event that requires gate closure.
- During Hurricane Rita (2005), the flow in the Neches River varied between 15,000 cfs and 22,000 cfs during the time when gate closure would be necessary due to high water levels.
- Based on the joint probability analysis, basin storage volume, and historical data a pump with a minimum discharge capacity of approximately 20,000 cfs is recommended.
- 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.

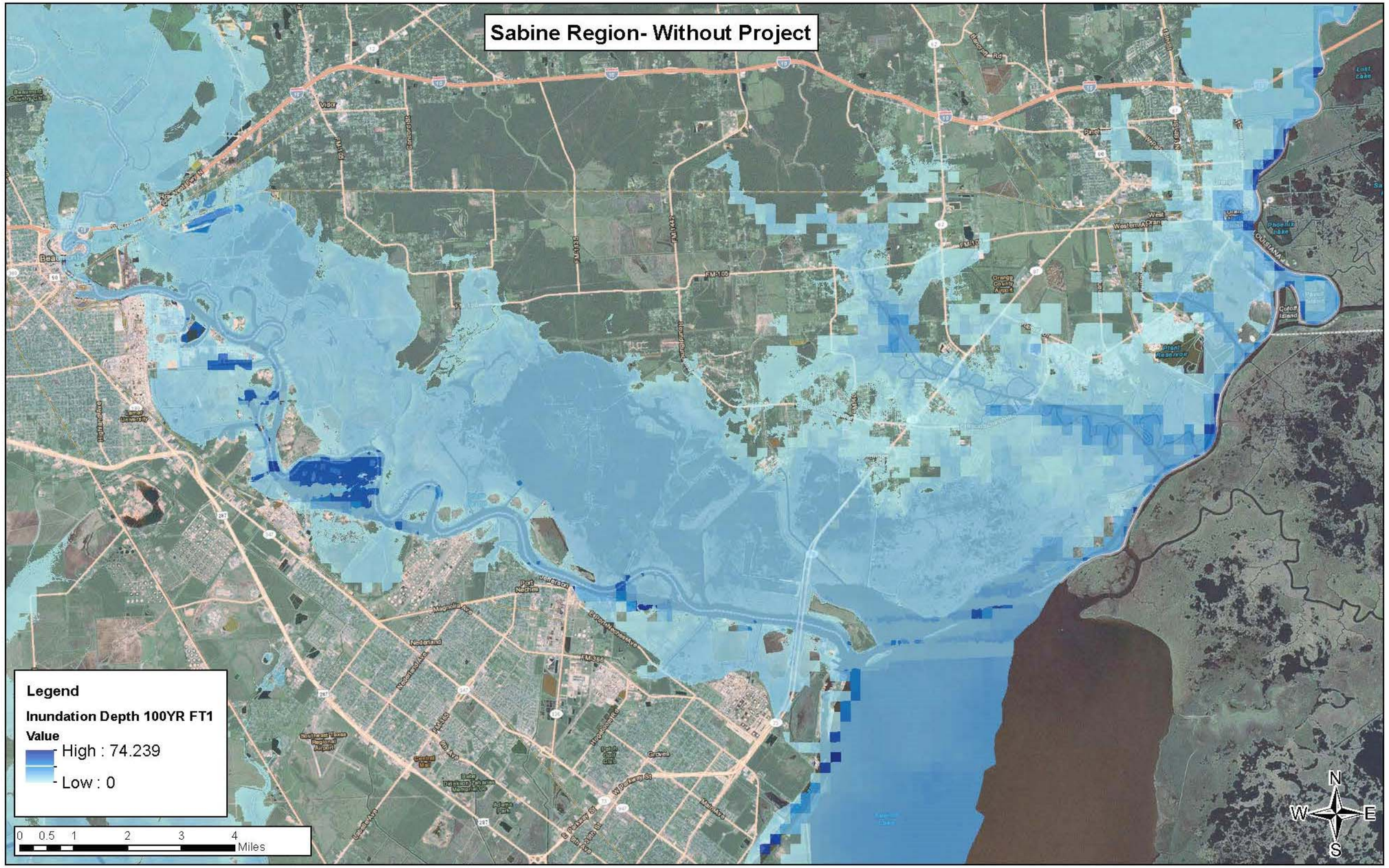

Figure 6-3. Sabine Region 100-Year Flood Inundation – Without-Project Condition

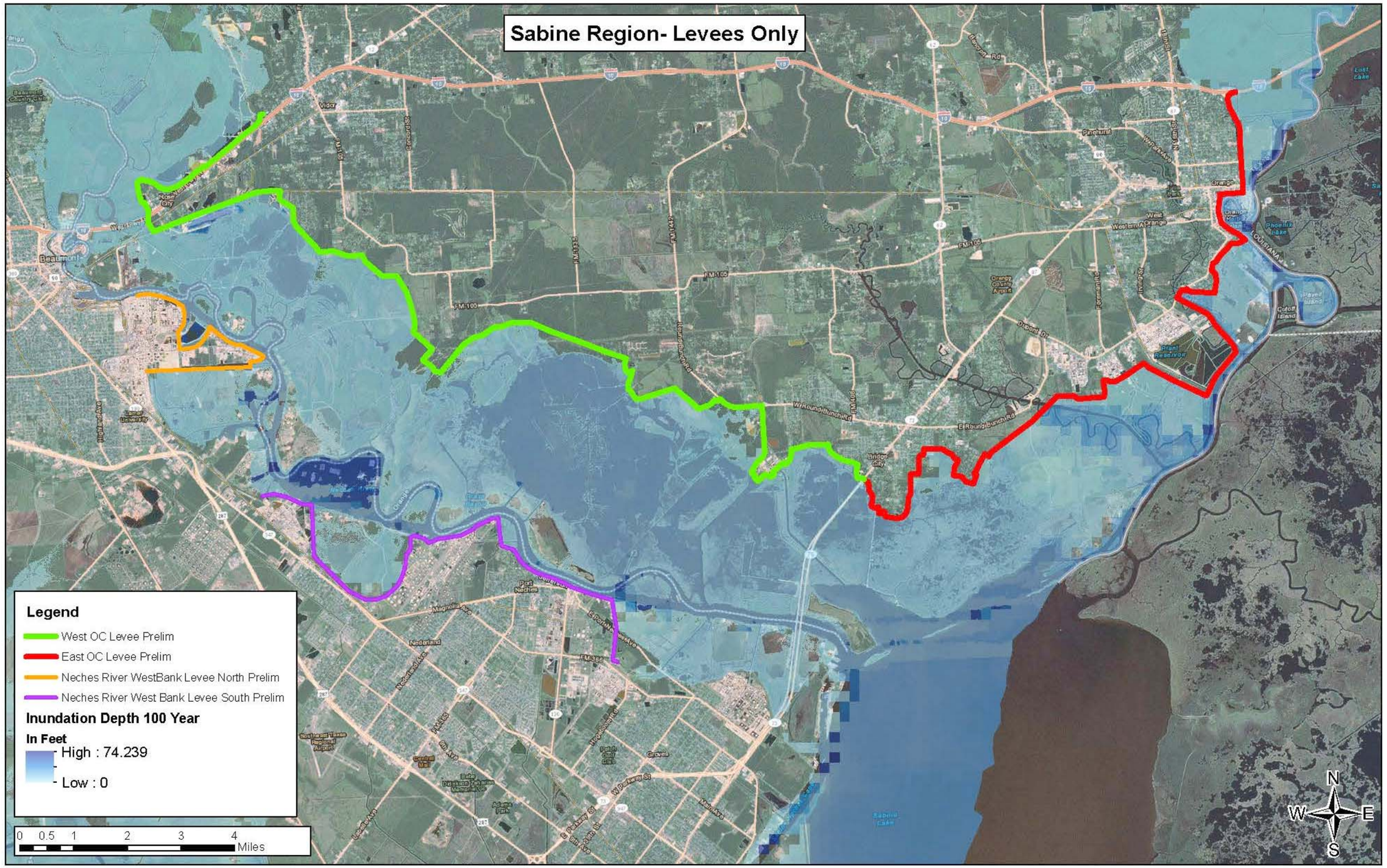

Figure 6-4. Sabine Region – No-Gate Alternative

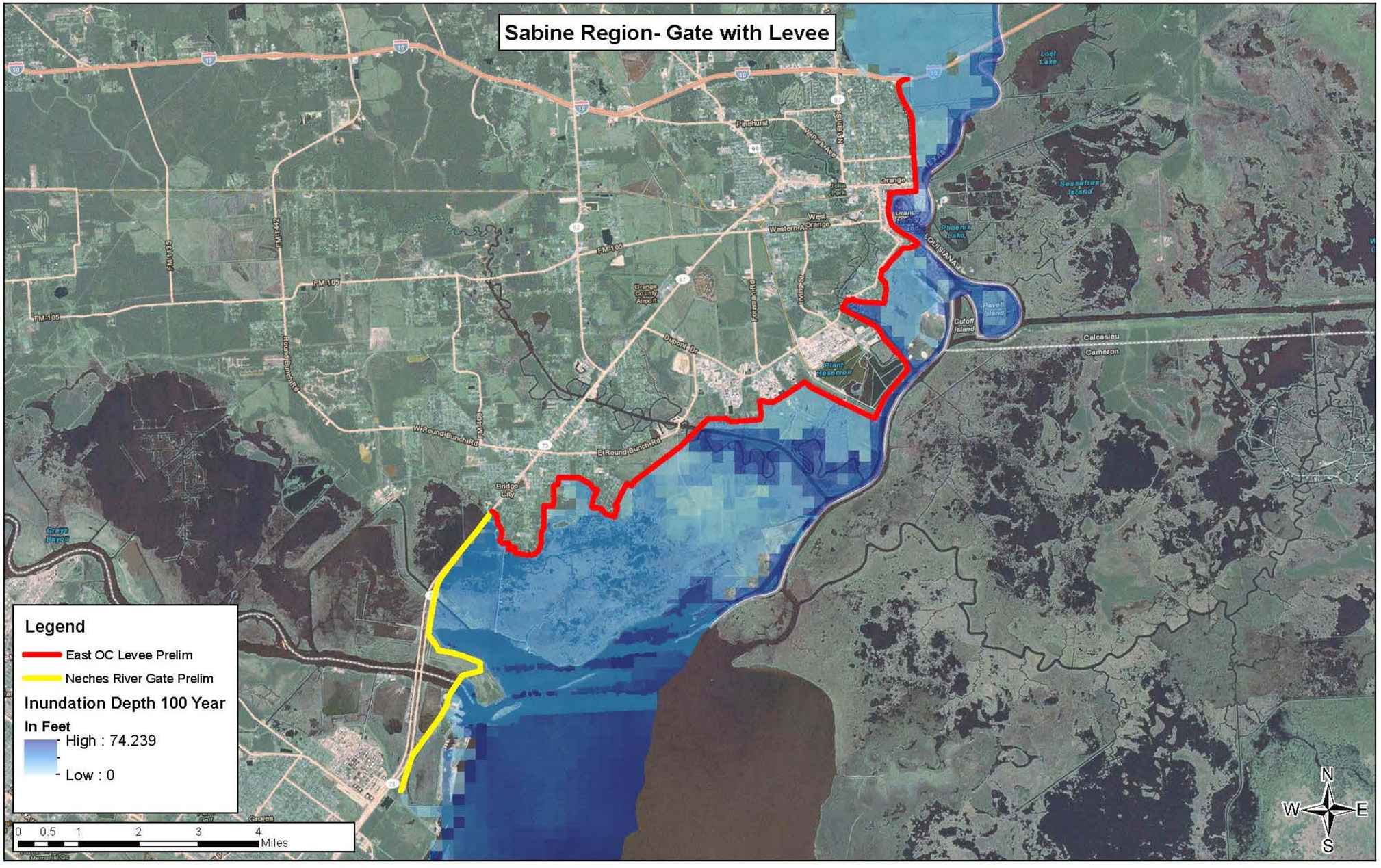

Figure 6-5. Sabine Region – Gate Alternative

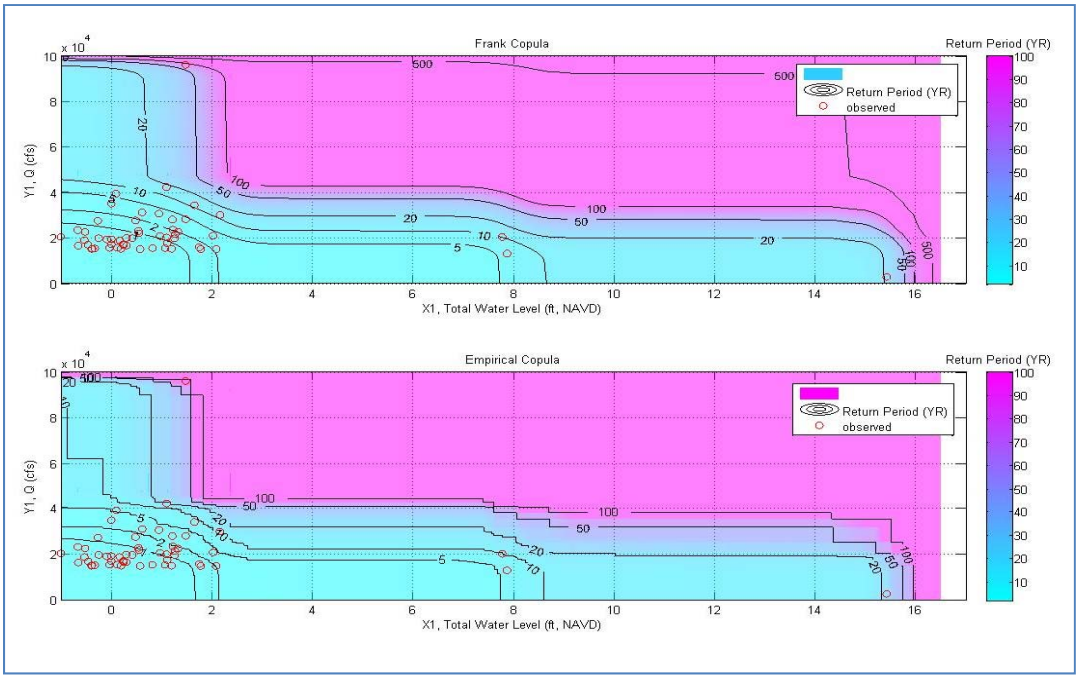

Figure 6-6. Joint probability of discharge (Q) and water level.

6.2.3 Geotechnical and Structures Analysis

A Geotechnical and Structural analysis was performed and consisted of a preliminary assessment of the proposed alignment in conjunction with H&H and Environmental analysis. The alignment was then reviewed to delineate the different reaches of floodwall and levee. The preliminary floodwall section designs were based on the Industrial Canal floodwall sections from the reconstruction of the New Orleans system. The levee sections were considered to be 15 feet in height with a 15 feet crown width and 1V:4H side slopes. The overall lengths of floodwall and levee were provided to cost. Drainage and closure structures were not separated out. The gate and pump station locations were also provided to the PDT.

6.2.4 Environmental Impacts

The construction of a flood protection system in the vicinity of Orange and north Jefferson Counties would have a high potential of impacting tidally influenced marshes and forested wetlands, cultural resources, and hazardous, toxic, or radioactive waste (HTRW) sites. The region is highly industrialized with numerous, large petrochemical refineries and other industries. Natural habitats in the area affected by the Neches River Gate and No-Gate Alternatives include the lower reaches of the Sabine and Neches Rivers, fringing marshes, bottomland hardwoods and swamps, and adjacent upland areas.

6.2.5 Wetlands and Hydrology

Wetland areas protected by the Gate Alternative from storm surge impacts cover roughly 30,000 acres. These areas include extensive tidal (fresh, intermediate, brackish, and saline) marsh along the Neches and Sabine River bottoms, as well as cypress-tupelo swamp and bottomland

hardwoods. The forested wetlands occupy an intricate network of sloughs and sandy ridges formed within the rivers' relict meander belts. They tend to be located in slightly higher elevations intermediate between the marshes and the Pleistocene terrace uplands and are found scattered throughout the affected area. A large navigable surge gate in the Neches River could potentially block some of the normal tidal flow into the system, depending upon how much of the gate is constructed within the river banks. It has been assumed that the impacts on flow could be minimized by the gate design, but residual impacts could remain. Smaller-scale navigable surge gates on Cow and Adams Bayous could have similar impacts. If reduction of the tidal prism is sizable, the smaller tidal prism could reduce daily flooding of marshes and swamps, potentially leading to changes in marsh and swamp extent. The smaller cross-section could also reduce fish and shellfish larvae access to the marsh nursery areas. Although these effects cannot be quantified for this preliminary screening, they would be systemic and have the potential for significant impacts to wetlands and nursery habitat in the Neches River system.

Habitats types protected by the No-Gate Alternative are the same as those protected by the Gate Alternative. The No-Gate Alternative would leave the Neches River floodplain open to the effects of storm surge flooding. These effects can be both positive and negative. The existing floodplain has developed under the influence of the existing tidal regime, which includes periodic flooding during storm surge events. These periodic floods bring sediments to renourish marshes. The river also provides access for estuarine organisms to reach nursery areas in the extensive marsh systems along the river bottoms. On the other hand, storm surges also scour marsh and increase salinities in areas not accustomed to higher salinity. The effects of the salinity stress varies, depending upon how long the area takes to drain high salinity surge waters after the storm, and the extent of rainfall events to help flush the system after the storm.

Direct construction impacts of both alternatives have been estimated with a GIS analysis. The classification of wetlands in the area was provided by USGS and is illustrated in Figure 6-7 and Figure 6-8. The levee/floodwall alignments were buffered to cover a total of 650 feet. This is conservatively large because it is much wider than necessary for the floodwall segments. The wetland impacts for each alternative are shown in Table 6-1 below. Overall, the No-Gate Alternative has much higher direct construction impacts than the Gate Alternative, with the exception of the brackish marsh class, for which impacts are roughly equal. However, these impacts do not include the potential indirect impacts on wetlands and nursery habitat in the Neches River system that might be caused by the large gate's obstruction of a portion of the normal tidal flow.

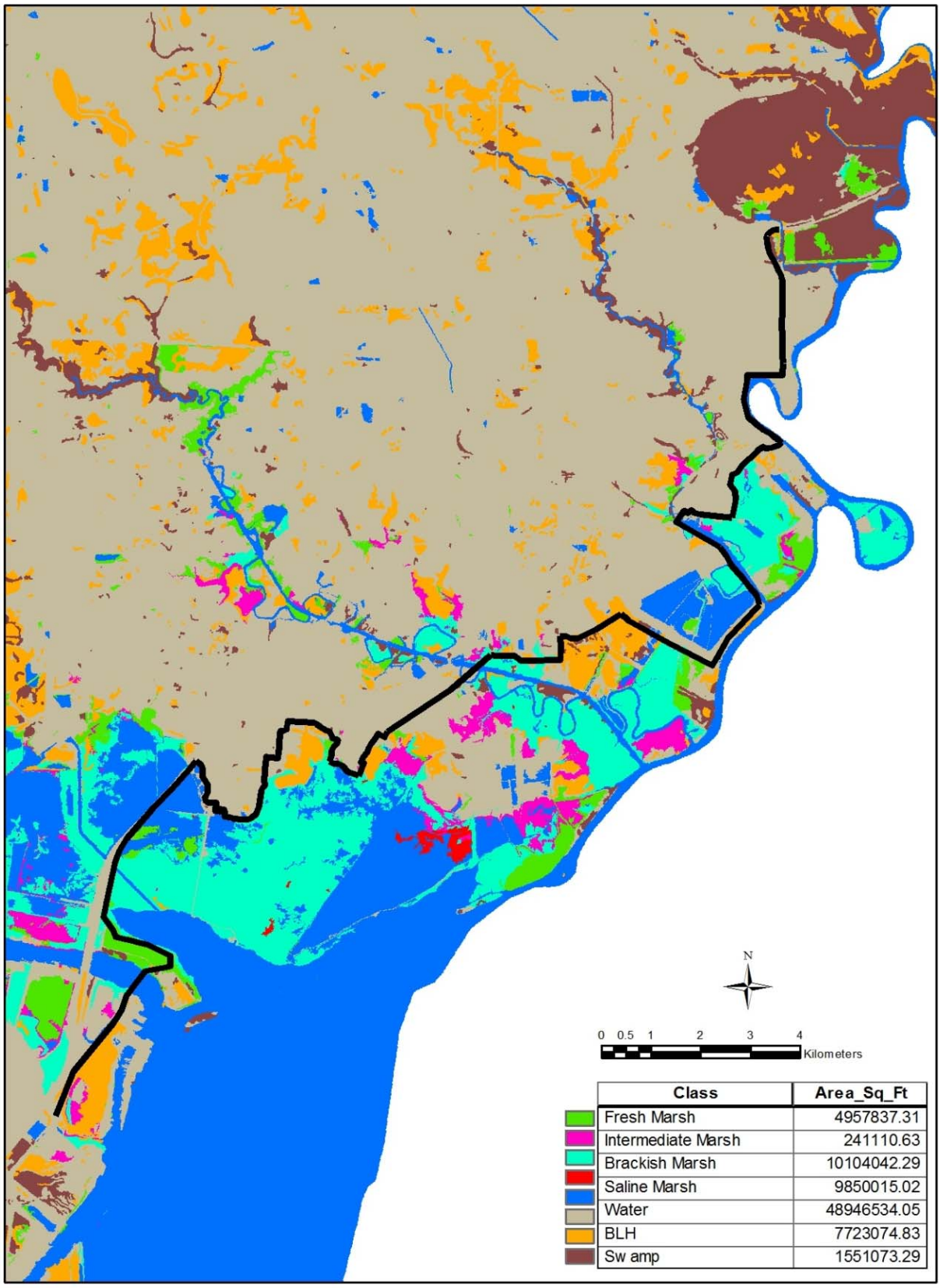

Figure 6-7. Impact of Wetlands with Gate Alternative

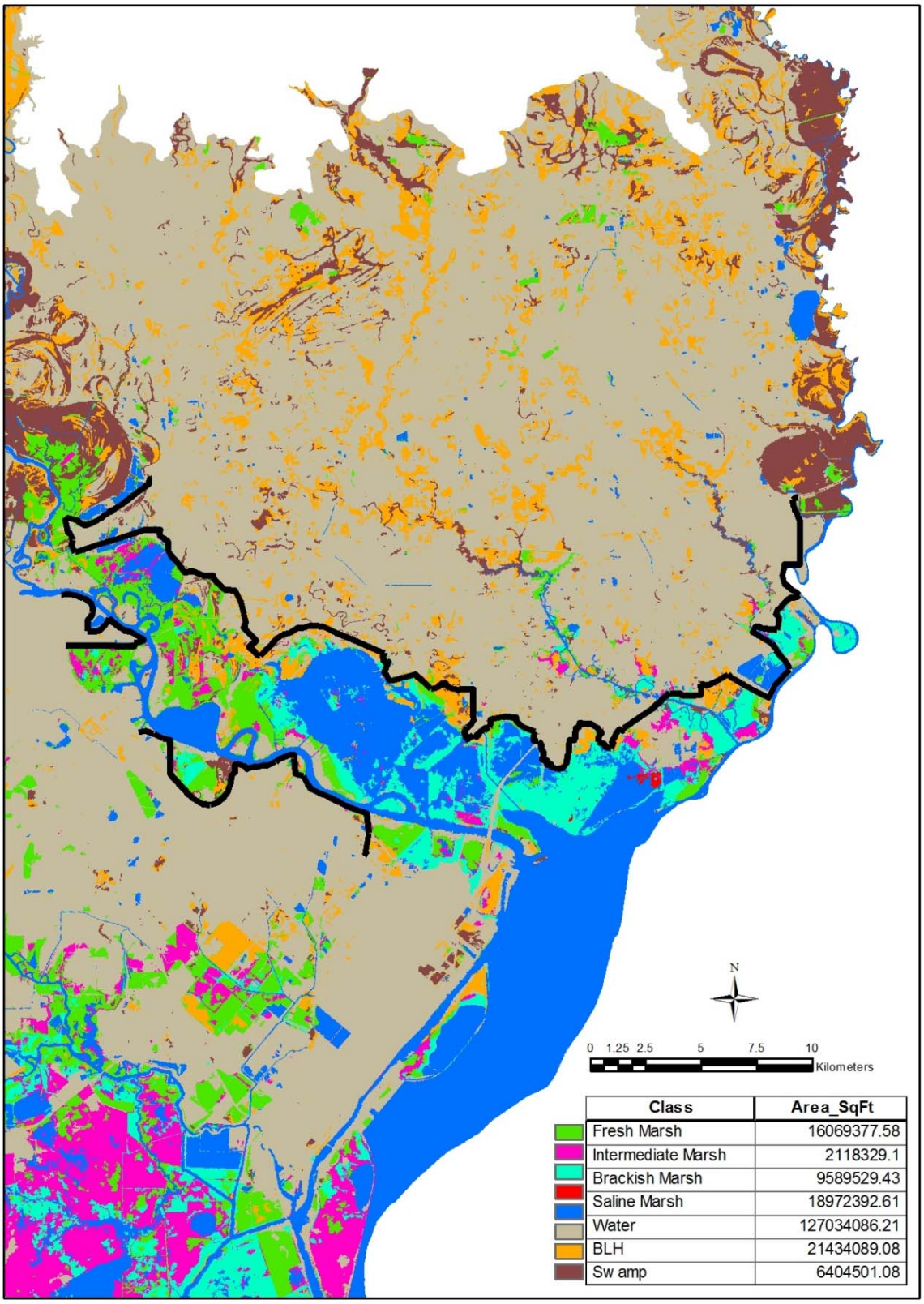

Figure 6-8. Impact of Wetlands with No-Gate Alternative

Table 6-2. Wetland Impacts Comparison of Potential Construction Impact Areas Neches River Gate and No-Gate Alternatives

Wetland Class	Gate (ac)	No-Gate (ac)
Fresh Marsh	114	369
Intermediate Marsh	6	49
Brackish Marsh	232	220
Saline Marsh	226	436
Bottomland Hardwood	177	492
Swamp	36	147
Total Emergent Vegetation	791	1713
Water	1124	2916
Total	1915	4629

The Orange County report's estimate of total wetlands that would be impacted by each alternative is very close to the USACE-USGS estimate, and therefore it is reasonable to use that report's mitigation estimates for this preliminary analysis. The Orange County report assumed that mitigation would be in-kind to the greatest extent possible and that mitigation would be performed through purchase of credits in mitigation banks. No impacts on endangered species or designated critical habitat are expected with either alternative. The estimated costs described below are included in the costs per linear foot that were used by Cost Estimating to prepare estimates for each alternative, and therefore there is no line item cost for environmental mitigation in cost comparison presented below.

Mitigation estimates in the Orange County report account for only the direct constructions impacts of these alternatives. The total mitigation cost estimated for the Gate Alternative is $69 million, while mitigation costs for the No-Gate Alternative are estimated to be $157 million. Mitigation costs for direct construction impacts appear to be much higher for the No-Gate Alternative. However, these costs do not include an estimate of mitigation for indirect impacts on the Neches River system. Potential impacts on the hydrology of the Neches River system from a large surge gate in the Neches River, and associated effects on tidally influenced wetlands and estuarine organism access were not described in the Orange County report and mitigation costs are not included in the for the Gate Alternative. Therefore, it is not possible to determine with this preliminary analysis which alternative would require the most mitigation. In either case, however, costs for mitigation are likely to be dwarfed by construction costs, and so are not likely to affect plan selection.

6.2.6 HTRW

Because of the highly industrial nature of the project area, new levee alignments have the potential to disturb HTRW sites in the project vicinity. The Orange County analysis obtained information from a one-mile radius of the new levee segments in each alternative from Banks Environmental Data, and thus over counts by a large margin the number of sites that would actually be affected by construction. The regulatory data search identified locations of HTRW sites that are regulated

by CERCLA and RCRA, as well as sites with potential environmental health and safety concerns. The number of sites that could be impacted by each alternative is roughly equal, and therefore the costs to avoid or remediate affected sites are also assumed to be roughly equal. A total of 429 sites were identified within one mile of the Gate Alternative and a total of 452 sites were identified within one mile of the No-Gate Alternative.

The Orange County HTRW analysis did not include a reevaluation of the existing Port Arthur HFPS, and therefore no analysis of potential HTRW sites adjacent to these levees and floodwalls was included in that report. USACE assumes that potential sites exist as the HFPS system passes through and adjacent to a large refinery south of Port Arthur and by other industrial facilities as well. No database search was conducted for this analysis because reevaluation of the existing HFPS is part of both alternatives and any cost associated with avoidance or remediation would be the same in both cost estimates.

Cultural Resources - A preliminary assessment of the cultural resources was conducted using a desktop review of the databases maintained by the Texas Historical Commission. The assessment looked at a 700-foot corridor for both the No-Gate and Gate Alternatives. The No-Gate Alternative overlaps with eleven archaeological sites, one National Register District, four cemeteries, and two historic markers. Ten of the archaeological sites are prehistoric and the final site has both prehistoric and historic components. None of the archeological sites has been evaluated for NRHP eligibility. The Navy Park Historic District in Orange, Texas, is the only historic property currently listed that overlaps with the project area. This is a residential neighborhood with approximately 203 contributing elements. The cemeteries include the Hollywood Community, Adcock, Sullivan, and one unknown cemetery. Both the Adcock and Sullivan cemeteries date to the early Twentieth Century and it is unknown if they are in current use. The Hollywood Community cemetery is primarily an African-American cemetery and dates to the late Nineteenth Century through the present. The two historic markers were placed in 1969 and 1986 and are likely not eligible for inclusion in the NRHP. The Gate Alternative overlaps with nine archaeological sites, the Navy Park Historic District, the Hollywood Community cemetery, and one historic marker. The nine archeological sites are also unevaluated for NRHP eligibility; however one of the sites is reported to have prehistoric human interments. The historic marker in this alternative is the same marker as above constructed in 1986. A total of 37 archeological investigations overlap with the two alternatives, however these only cover a small percentage of the total project area. Intensive historic properties investigations will likely be required in all areas with a moderate to high probability for cultural resources to occur. The cultural resource records search has determined that each alternative is likely to affect roughly the same number of archaeological sites, and therefore National Register assessment and data recovery costs would be roughly the same for each alternative.

6.2.7 Real Estate Analysis

The Real Estate (RE) analysis of the two alternatives was formulated using data from the August 2012 Final Draft of the Orange Report. RE costs were included in the cost per linear foot for the construction of the levee for both options. The only additional RE cost estimate developed was for the Neches River Crossing (NRX) segment for the Gate Option. Two elements were taken under consideration to calculate the RE cost for the NRX segment for the Gate Option; Right of

Way (ROW) acquisition and condemnation costs. When determining the ROW for the NRX, it was assumed that the width of the ROW will vary from 60 feet to 700 feet. The cost for ROW acquisition was developed by multiplying the acreage of the proposed alignment segments by the cost per acre of the ROW type provided by the Orange Report. It is assumed that 10 percent of the proposed acquisitions will be contested; therefore, condemnation actions are anticipated. Condemnation costs were calculated by taking 10 percent of the total number of affected tracts multiplied by the average cost of the condemnation process, or $70,000. The condemnation cost was provided by the Orange Report. Based upon this analysis, the RE cost estimate for the NRX segment of the Gate Option is $2,600,000.

6.2.8 Economic Analysis

A qualitative and semi-quantitative assessment for any potential disparities between the potential benefits associated with either the Gate or No-Gate alternatives was conducted utilizing ArcMap, HAZUS-MH, and parcel data from the Orange and Jefferson Counties Appraisal Districts. Inundation rasters were created from ADCIRC data points for the 100- and 500-year events in order to identify areas that could be impacted by either of these events. For this exercise, the 100-year event was used to identify a without-project damage area, which is depicted in Figure 6-3. The "dollar exposure" for this area's development was pulled from HAZUS-MH for those census blocks that intersect the 100-year inundation grid. This development is listed in Table 6-3 below by county.

Table 6-3. 100-Year HAZUS-MH Development by County (1,000s)

	Res.	Comm.	Ind.	Ag.	Rel.	Govt.	Edu.	Total
Jefferson	$166,119	$18,992	$4,024	$424	$4,828	$0	$2,450	$196,837
Orange	$154,723	$21,145	$7,766	$694	$3,640	$245	$3,546	$191,759
Total	$320,842	$40,137	$11,790	$1,118	$8,468	$245	$5,996	$388,596

The levee alignments, based on the Orange Report alignment done in 2012, were refined in some areas to increase potential benefits, reduce costs and potential environmental impacts, and to protect critical infrastructure. Additional effort was taken to avoid disruptions to major pipeline corridors and to identify opportunities for potential buyouts. The alignment for the closure gate at the mouth of the Neches River also originated from the Orange Report. This alignment was also refined to minimize impacts to the environment and navigation and to identify a potential location for a pumping station. This pumping station would need to have the ability to pump discharge from the inland Neches River into Sabine Lake.

Potential benefits for the Gate and No-Gate Alternatives were identified by trimming the 100-year inundation raster behind those areas that would be protected by each alternative. Since the decision is whether the surge gate should be ruled out from further consideration, the No-Gate Alternative was configured to provide the same level of protection as what would be provided by the Gate alternative. "Benefits" would therefore be that development removed from behind the protected areas for both alternatives. These benefits are depicted graphically for each alternative in Figure 6-4 and Figure 6-5. These reductions in monetary exposure (i.e., "Benefits") are depicted in Table

6-4 below. The assumption is that the two alternatives provide roughly the same amount of benefits.

Table 6-4. 100-Year HAZUS-MH "Benefits" by County
(1,000s)

Orange	**Res.**	**Comm.**	**Ind.**	**Ag.**	**Rel.**	**Govt.**	**Edu.**	**Total**
Without Project	$154,723	$21,145	$7,766	$694	$3,640	$245	$3,546	$191,759
Gate	$92,407	$12,236	$7,148	$694	$1,312	$245	$3,546	$117,588
No-Gate	$92,817	$14,504	$6,322	$694	$3,640	$245	$3,546	$121,768
Jefferson	**Res.**	**Comm.**	**Ind.**	**Ag.**	**Rel.**	**Govt.**	**Edu.**	**Total**
Without Project	$166,119	$18,992	$4,024	$424	$4,828	$0	$2,450	$196,837
Gate	$918	$0	$0	$0	$0	$0	$0	$918
No-Gate	$918	$0	$0	$0	$0	$0	$0	$918

For Orange County, relatively small differences exist between the Gate and No-Gate Alternative in the monetary benefits. Graphically, the protected areas for both are essentially identical. The monetary benefits for Jefferson County are identical between the two alternatives. Graphically, the No-Gate Alternative does not cut off surge going up the Neches. Because of this, the Gate Alternative showed the potential to offer greater protection since more census blocks could be impacted by the No-Gate Alternative. A closer examination however showed no additional development being unprotected by this alternative.

From this analysis, the assumption holds that the two alternatives offer roughly the same level of protection. This is supported by the inundation patterns of the two alternatives compared to inundation for the without project condition and from this qualitative/semi-quantitative assessment based on reductions in monetary exposure. The primary factor then determining the decision between the Gate and No-Gate Alternatives becomes cost.

6.2.9 Cost Estimates

Cost estimates were prepared for both alternatives in the Sabine Region:

- Gate Alternative, and
- No-Gate Alternative

These cost estimates are not representative of the overall total costs but rather are just screening level costs. The order of magnitude for these two alternatives is comparable. Both plans contain an earthen levee along the Sabine River. The Gate Option contains earthen levee, floodwalls, a Sector gate across the Neches River, and a 20,000 CFS Pump Station. The No-Gate Alternative contains earthen levee, and floodwalls. Quantities and design features were developed by the Galveston District (SWG) Engineering Branch.

For purpose of this estimate the cost for the earthen levee construction was developed by averaging the levee cost per linear foot from the Orange County Report. In doing so, these cost per linear

foot capture the cost for the construction of the levee and any incidental costs associated with the levee construction such as real estate, mitigation, pipeline relocation, culverts, road closures, etc. The cost for the floodwall was developed from the cost provided by New Orleans District. The Neches gate cost was derived by extrapolating from the gate costs in the Ike Dike Report, and the cost for the new pump station was derived from the Orange Report. No contingencies were added to the cost for this effort.

For the Engineering and Design, a flat 15 percent was applied to the construction cost. In addition, for the Construction Management, a flat 7.5 percent was added to the construction cost. See Table 6-5 below for the estimated cost summary of each alternative.

Table 6-5. Estimated Total Cost (For Each Alternative)

	Cost ($)	
Item	**Gate Alternative**	**No-Gate Alternative**
Levees & Floodwalls	762,856,000	1,550,187,000
Gate	1,296,000,000	0
Pump Station	233,182,000	0
RE Cost	2,600,000	*
Engineering & Design	342,306,000	255,405,000
Const Management	171,153,000	127,703,000
TOTAL COST	2,798,097,000	1,933,295,000

*RE costs included in the cost per linear foot of the flood wall.

6.2.10 Port of Beaumont: Evaluation of Storm Surge Impacts on Functionality and Operations of Port

A preliminary investigation was conducted by USACE to evaluate the vulnerability of the Beaumont area to storm surge, and what, if any, level of protection the proposed Neches River gate would provide to the Port and its functionality.

The representative from the Port of Beaumont stated that surge in the Port did occur during Hurricane Ike but caused only minor damage to docks and electrical systems. The Port of Beaumont was fully operable two to three days after Hurricane Ike passed. Hurricane Rita caused almost no surge or damage at the Port. Damages from Rita in the Beaumont area were almost entirely due to wind. The local floodplain administrator 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. The Sabine Neches Navigation District reported considerable damages along Taylors Bayou caused by Hurricane Ike. They have since constructed a large diversion culvert to route water around the area and prevent flood damages on Taylors Bayou. The Water Utilities

Department noted the salt water barrier intake on the Neches River was damaged during Ike, but the cost of repair was minimal.

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 (which would be protected under either alternative currently being considered). During surge events water is almost entirely contained within the undeveloped Neches floodplain in the vicinity of Beaumont. Historically the Port and associated Neches River navigable waterway have been fully functional two to three days after a major storm surge event.

6.2.11 Conclusion of Gate/No-Gate Screening

Analysis for both alternatives was developed to offer roughly the same level of economic protection in order to use the costs of both to compare the Gate and No-Gate Alternatives. The cost of the Gate Alternative is approximately $865 million more expensive than the No-Gate Alternative. This cost difference is significant and further refinement and detailed analyses would not be expected to reduce this difference. Therefore, it is recommended that the Gate Alternative be dropped from further consideration in the study.

6.3 SCOPING OF STUDY UNDER 3X3X3 GUIDELINES

Recent USACE planning modernization has resulted the 3x3x3 guidelines under which this study was being developed. Therefore, a scope was developed for completion of the study that would evaluate the final array of structural and non-structural alternatives in the six-county study area and that would be completed in three years for $3 million.

One practical option available to the PDT was to develop only programmatic information, identification of projects for future studies, within the 3-year window. However, this programmatic information would not recommend a project for authorization that would reduce storm surge damages and was not supported by the non-Federal sponsor. Additionally, after coordination with the VT, it was determined that the level of effort and associated risk for the large and complex regional study was too high and other options should be developed for consideration.

A key to minimizing the study budget across all study alternatives is limiting data collection costs. Therefore, the availability of technical data has guided the PDT's approach in sequencing feasibility assessments for the upper Texas coast. The PDT would rely on technical information and assessments obtained following recent hurricanes. For example, hurricane surge data was collected at coastal levees throughout the study region after Hurricanes Rita (2006) and Ike (2008). Comprehensive storm surge modeling along the Texas coast was completed by FEMA in 2012 using modern probabilistic techniques. USACE Risk Management Center (RMC) and ERDC are conducting Potential Failure Mode Analysis (PFMA) and I-wall assessments, respectively, of existing coastal levee infrastructure in the Brazoria County region, including recommendations for improving level of performance, reliability, and resiliency. The PDT would maximize use of technical data developed by local stakeholders. In the Sabine region, Orange County and the Texas

Water Development Board have developed a planning report proposing enhanced storm surge protection infrastructure. In the Brazoria region, Velasco Drainage District has completed a storm surge assessment and collected extensive geotechnical data to support levee assessment and improvements. In the Galveston region, planning efforts have begun at multiple research agencies, including Texas A&M University at Galveston and the SSPEED Center. Additionally, the Gulf Coast Community Protection and Recovery District (GCCPRD) has begun an effort to collect existing technical data within the study area using a $3.9 million grant from GLO. Order of magnitude economic benefit and cost data exist for projects throughout the entire six-county study region.

Despite extensive data available, the VT has determined that there remain substantial data gaps, which introduce high to moderate risk in study completion for large-scale, complex engineering projects over an extensive geographic area. Therefore, the level of risk associated with the engineering and environmental decisions for the full scope to be made for completion of this $3 million study is considerable and was considered to be unacceptable by the VT.

The USACE Galveston District (SWG) developed an option for completing the study in a manner that was low to moderate risk and requested an exemption from the 3x3x3 guidelines to complete this study. The recommendation was to pursue a $4.4 million programmatic assessment of the six-county study area and focused evaluation on two sub-regions, Sabine and Brazoria, within the study area as the first interim study for CSRM project implementation. This first interim feasibility study would be followed by future studies recommending CSRM projects in the Galveston region, as well as ER opportunities throughout the entire six-county region. Future feasibilities will leverage studies, data, and models currently under development by others in the Galveston region. The exemption request was approved by USACE Headquarters and the recommended focus of the study in the Sabine and Brazoria regions continued into the final array of alternative plans.

6.4 IDENTIFICATION OF FINAL ARRAY OF ALTERNATIVES

From the combination of the evaluation screening of alternatives and exemption request approval, the gate structures in the Sabine region, all alternatives in the Galveston Region, and the ER alternatives in the entire study area were dropped from further consideration. The final array of alternatives was identified and is presented in Table 6-6. These alternatives will be evaluated in detail in the Final Screening of Alternatives to determine the TSP.

Table 6-6. Final Array of Alternatives

Alternative Number	Alternative Name	Description
S8	Sabine ER (with surge barrier on upper Sabine River)	Beach and dune restoration, restore beach ridge, nearshore breakwaters, GIWW shoreline protection, marsh restoration on Neches River and at Keith Lake and Texas Point, Salt Bayou hydrologic restoration, Sabine River levees and gate
S11	Sabine Nonstructural Alternative	Buyouts and Lone Star-type conservation plan
B2	Brazoria Coastal Barrier CSRM Focus (revised)	Freeport HFP
B5	Brazoria Nonstructural Alternative	Buyouts and Lone Star-like conservation plan

7 COMPARISON OF FINAL ARRAY OF ALTERNATIVE PLANS AND DECISION CRITERIA

7.1 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 with this array not including ER measures because those are to be included in future interim feasibility studies, along with the Galveston region.

In accordance with the exemption request approval, the Sabine and Brazoria CSRM measures have been carried forward into detailed feasibility analysis. A navigable surge gate structure on the Neches River in the Sabine region was screened out primarily because levees performed better economically. The Lone Star-like conservation plan non-structural alternative was also screened out, as it was not implementable by USACE. The remaining alternatives became the final array of alternatives. The final array of alternatives is presented in Table 7-1. These alternatives were evaluated in detail in the final evaluation to determine the Tentatively Selected Plan (TSP).

The Final Array of Alternatives are generally listed in Table 7-1. This list is considered a project area for the remainder of the discussion of the evaluation and comparison of the final array. The "Optimization Alternatives" embedded in the project areas listed in Table 7-1 are the actual final array evaluated and compared to determine the TSP. In the final evaluation, it became necessary to redefine the names for the Final Array of Alternatives. For example, the S5 Alternative was split into two individual alternatives: 1) Orange-Jefferson CSRM; and 2) Port Arthur and Vicinity CSRM. The project areas are listed by their name in Table 5-4.

Table 7-1. Final Array of Alternatives

Alternative Number	Description
No Action	No Action or Future Without Project (FWOP)
S5	Orange-Jefferson CSRM
S5	Port Arthur and Vicinity CSRM
B2	Freeport and Vicinity CSRM
S11 & B5	Brazoria and Sabine Nonstructural

The Optimization Alternatives are defined in Table 7-2. The Optimization Alternatives were defined by Alternative Reaches discussed in the updated FWOP described in Section 3.1.2 of the main report. The Alternative Reaches are included in the table for reference. The No Action Alternative is not listed in the table since it is the FWOP condition for each of the project areas. Brazoria and Sabine Nonstructural are also not listed because Alternative Reaches were not required for the nonstructural evaluation.

Table 7-2. Relationship with Project Area, Alternative Reaches and Optimization Alternatives

Project Area	Alternative Reaches	Optimization Alternatives
Orange-Jefferson CSRM	Orange 1	11-, 12-, 13-, and 14-foot New Levee
	Orange 2	11-, 12-, 13-, and 14-foot New Levee
	Orange 3	11-, 12-, 13-, and 14-foot New Levee
	Jefferson Main	11-, 12-, 13-, and 14-foot New Levee
	Beaumont A	11-, 12-, 13-, and 14-foot New Levee
	Beaumont B	11-, 12-, 13-, and 14-foot New Levee
	Beaumont C	11-, 12-, 13-, and 14-foot New Levee
Port Arthur and Vicinity CSRM	8- to10-foot I-Wall	No Fail, 1-foot Raise, 2-foot Raise
	Closure Structure	No Fail, 1-foot Raise, 2-foot Raise
	I-Wall Near Valero	No Fail, 1-foot Raise, 2-foot Raise
	I-Wall Near Tank Farm	No Fail, 1-foot Raise, 2-foot Raise
Freeport and Vicinity CSRM	DOW Barge Canal	Levee Rehabilitation; Gate Structure
	Oyster Creek Levee	No Fail, 1-foot Raise, 2-foot Raise
	East Storm Levee	No Fail, 1-foot Raise, 2-foot Raise
	South Storm Levee	1-foot Raise, 2-foot Raise
	Freeport Dock Floodwall	Partial Fail, No Fail, 1-foot Raise
	Old River Levee at DOW Thumb	No Fail, 1-foot Raise, 2-foot Raise
	Tide Gate I-Wall	No Fail, 1-foot Raise, 2-foot Raise

7.1.1 Final Screening Criteria

In order to select a plan from the final array, screening criteria were developed that align with the objectives of the study (See Table 4-1, Section 4.2.3 of the main report) and listed below.

- Objective 1: Reduce economic damages to business, residents and infrastructure for the Sabine and Brazoria region for the 50-year period of analysis.
- Objective 2: Reduce risk to human life from storm surge impacts for the Sabine and Brazoria region for the 50-year period of analysis.
- Objective 3: Maintain and/or restore coastal habitat that contributes to storm surge attenuation where feasibility for the 50-year period of analysis.
- Objective 4: Enhance energy security and reduce economic impacts of petrochemical supply-related interruption for the Sabine and Brazoria region for the 50-year period of analysis.
- Objective 5: Reduce risk to critical infrastructure (e.g. medical centers, ship channels, schools, transportation) for the Sabine and Brazoria region for the 50-year period of analysis.
- Objective 6: Identify opportunities to enhance functionality of existing hurricane protection system including evaluation of impacts due to sea level rise for the 50-year period of analysis.

The planning objectives were aligned with the four accounts: NED, EQ, RED, and OSE. The Optimization Alternatives were evaluated in detail, then compared against each other to identify

which plan contributes most to the objectives. These screening criteria are different than the screening process used in the Initial and Evaluation Array of Alternatives. The Optimization Alternatives were evaluated first for the NED objectives (Objectives 1, 4 and 6) using the HEC-FDA model. The EADs presented in this report use storm surge levels without considering sea level rise scenarios for the 20-, 50- and 100-year sea level rise scenarios. Alternative Reaches were defined in the FWOP; this condition is the baseline to show reductions in EAD and to identify which plan reasonably maximizes net economic benefits (i.e., the NED plan). The compilation of each NED plan from the project areas are considered for the TSP. The screening criteria for RED and OSE objectives are qualitative (Objectives 4 and 2, respectively). For RED, critical infrastructure impacts are discussed qualitatively with focus on the effect of transportation disruptions after storms and the number of critical facilities and evacuation routes for which risk is reduced. For OSE, alternative performance is measured based on the number of people for which risk is reduced. This is discussed qualitatively for the final array. Another means to measure reduction in life-safety risk is to utilize a quantitative model. The HEC-FIA model has not been used to evaluate the final array. The final array evaluation results are described first in terms of economic performance (i.e., the net benefits are displayed for each Optimization Alternative). The net benefits were developed by comparing the Optimization Alternatives to the FWOP EADs. The qualitative discussion of life-safety, critical infrastructure, and consideration of RSLC is provided in Section 7.1.8.

7.1.2 Final Array Evaluation Results

The following sections present the results of the evaluation of the final array. This section focuses on a description of the Optimization Alternatives and the economic evaluation results. Additional description of the Optimization Alternatives is provided in Appendix D, Section 1.9, and the detailed economic evaluation results is provided in Appendix C, Economics. Project Area

The regions were further refined in the study within the Sabine and Brazoria regions located in Orange, Jefferson and Brazoria counties into project areas. These project areas were defined for the final array to show more detail on the FWOP conditions storm surge flood risk. The project areas generally align with the 0.2% Annual Chance Exceedance (ACE) (500-year floodplain) and locations of structures analyzed in the study. Figure 7-1 and 7-2 show the project areas. The Orange-Jefferson CSRM and Port Arthur and Vicinity CSRM projects areas are in the same general vicinity. In Figure 7-1, the highlighted areas shown in red are located on Orange County side and structure in yellow on the Jefferson County side. The Orange-Jefferson CSRM focus on inundation of structure on the Orange and Jefferson County side, while the Port Arthur and vicinity focus on the Jefferson County side.

7.1.3 FWOP Conditions Updates for the Final Array of Alternatives

The conditions described here focus on summarizing the technical engineering and economic evaluations that drive the flood risk analysis for this study. Flood risk is described in terms of life-safety risk, economic damages, and impacts on infrastructure with national significance. These items are important in comparison of plans evaluated to address the storm surge problems and meet the study objectives.

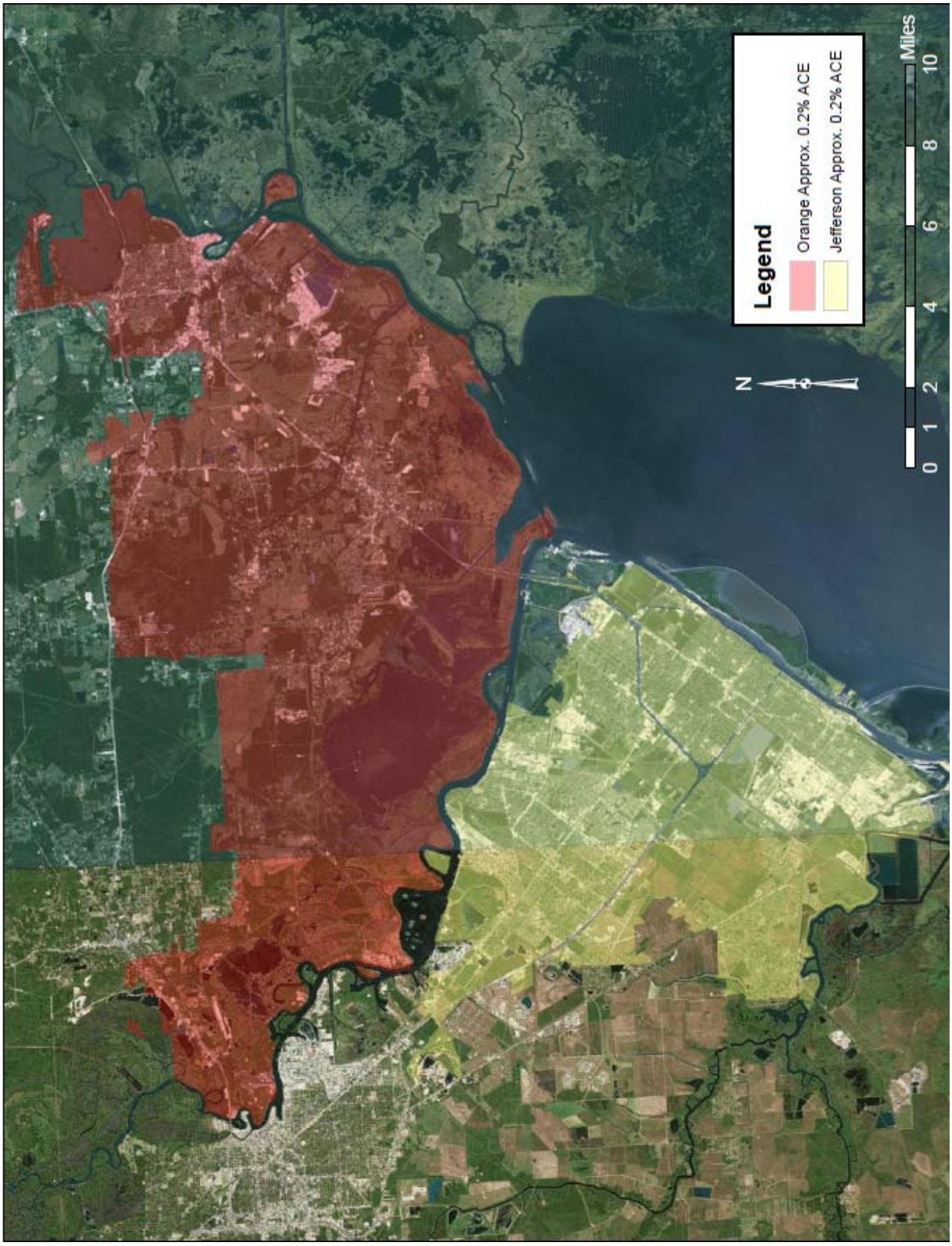

Figure 7-1. Orange-Jefferson CSRM and Port Arthur and Vicinity CSRM Project Areas

Figure 7-2. Freeport and Vicinity CSRM Project Areas

In order to define the conditions for life-safety, economic damages and infrastructure under the FWOP, a description of the existing HFPPs is required. This includes a description of the existing facilities in place and the known vulnerabilities in those systems. The following is a brief description of the existing projects in place, including two Federal projects (Freeport HFPP and Port Arthur HFPP). Other projects in the vicinity are noted, but were not originally built by USACE. Additional detail of the existing projects is included in the engineering appendix (Appendix D).

As noted in Section 1.9 of the main report, the Port Arthur and the Freeport HFPPs were constructed by USACE. The local sponsors responsible for operation and maintenance are the Jefferson Country Drainage District No. 7, and the Velasco Drainage District (VDD), respectively. There is no existing USACE HFPP in the Orange-Jefferson CSRM project area. The following describes the existing projects in place for each project area.

7.1.4 Existing Hurricane Flood Protection Facilities

Orange-Jefferson CSRM
A known existing flood protection facility located in the Orange-Jefferson CSRM project area is a wall surrounding the Exxon Mobil industrial facilities as indicated in Figure 7-3. This facility was constructed by local industry around the Exxon Mobil plant.

Port Arthur and Vicinity CSRM
The system protects the Port Arthur region from coastal storm surge events coming from the Gulf of Mexico. It also protects from flooding from the Sabine River. 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 (Texas Coastal I-Wall study). There is also a wave barrier on Pleasure Island. The system was designed and constructed for a 1% ACE.

The Port Arthur and Vicinity CSRM project area has an existing USACE HFPP that has a preliminary Levee Safety Action Classification (LSAC) that has resulted in the 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 lists the major engineering concerns for the Port Arthur and Vicinity CSRM:

- Potential failure due to I-wall stability (locations of concern shown in Figure 7-4); and
- Currently the system would suffer a catastrophic failure during a future hydraulic loading roughly equivalent to 0.6% ACE (150-year event).

The existing system at Port Arthur is considered “minimally acceptable” under the USACE’ P.L. 84-99 program. A Periodic Inspection was completed for the Port Arthur system in 2012. The sponsor was provided a list of items to correct. The sponsor is in the process of correcting these items. The potential failure issues addressed in this study are not considered an O&M responsibility. The existing Port Arthur HFPP is certifiable for FEMA accreditation under CFR 65.10 so the local sponsor has no current plans to address the risk drivers for the engineering

Figure 7-3. Existing Floodwall in the Orange-Jefferson CSRM Project Areas

Figure 7-4. Port Arthur and Vicinity CSRM Failure Locations

Figure 7-5. Existing HFPP in Freeport and Vicinity CSRM

concerns in the FWOP condition. It is assumed in the FWOP condition, no other actions to reduce the risk will take place by others.

Freeport and Vicinity CSRM
The existing HFPP at Freeport consists of approximately 43 miles of levees and wave barriers, seven 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.

The Freeport and vicinity system has a preliminarily LSAC that has resulted in the RMC conducting an SQRA to define the systems risk. This classification was 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 (i.e., high probability of overtopping).

- Steady state seepage analysis for the levees and foundation areas that have a high sand content show high potential for levee failure at top of levee loading;
- Potential failure of the I-wall at the tide gate due to stability; and
- System capacity corresponds to around a 0.7% ACE (130-year event) with significant consequences.

Currently the system is "unacceptable" in the PL 84-99 program and not certifiable for FEMA accreditation under CFR 65.10; therefore, the local sponsor has a System-Wide Improvement Framework (SWIF) plan in place to address the deferred maintenance issues and issues impeding CFR 65.10 accreditation. The sponsor has no current plans to address the structural risk drivers for the LSAC rating due to the performance concerns coming at a more significant hydraulic loading event than the requirements under CFR 65.10. 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 to a 0.7% ACE event.

7.1.5 Economic Evaluation

Structure files for the project areas were developed to determine the potential flood damages to properties based on estimated storm surge events. Estimated Annual Damages (EAD) under the FWOP conditions were calculated using the risk and uncertainty within HEC-FDA version 1.2.5, through integration of frequency-damage data. Based on the characteristics of the floodplain, the project areas were split into damage reaches. The damage reach determinations were based on hydraulic, geotechnical, social and environmental considerations as appropriate, and defined within the respective project area sections below. The EADs for the FWOP conditions are presented for each alternative reach along with the engineering inputs and assumptions into the model. Tables displaying structure and content values by reach, and additional detail regarding development of the structure file is provided in Appendix C.

The effort for estimating EAD estimates for each damage reach used a different methodology than what was employed for the initial screening of alternatives. The initial screening 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 incorporated a risk-based analysis in compliance with ER-1105-2-101.

Still water levels were used to determine the overall economic efficiency of the final array alternatives since low-probability wave run-up and/or overtopping do not incorporate a reliable means of determining high-level overall economic efficiency. Design considerations for wave run-up and overtopping will be analyzed later and applied to specific locations where it is applicable. This includes along the levee/floodwall system, and necessary interior drainage analysis on the final feasibility-level design of the recommended plan.

Fragility curves were developed for use in the HEC-FDA model for specific locations along the Port Arthur and Freeport 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 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, USACE work on erosion for Herbert Hover Dike, Interagency Performance Evaluation Task Force (IPET) report, Engineering Technical Letter (ETL) 1110-2-575 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 anticipated structural performance of the I-walls along with erosion from overtopping of embankments and at wall embankment tie-in locations and reflect uncertainty in storm duration, size, landfall location, and wind driven wave height. Additional detail of the fragility curve development for the economic evaluation for the FWOP condition and the with-project conditions discussed in the subsequent sections are included in Appendix D, Geotechnical Section.

Orange-Jefferson CSRM

To estimate EADs, the system was set up with three major components based on their location. This was primarily due to initial configurations of new levees based on alignments from the Orange County Flood Protection Planning Study (Orange Report), completed in 2012. The following lists the major features.

- Orange 1, Orange 2, and Orange 3;
- Jefferson Main;
- Beaumont A, Beaumont B, and Beaumont 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 that 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. Figure 7-6 presents the Orange-Jefferson damage reaches. The “with-project” levee and floodwall alignments are included in this figure although this discussion is only supposed to present the reaches.

Fragility curves for use within the HEC-FDA model were not required since there was no existing HFPP in this project area. The FWOP condition EADs for the Orange-Jefferson CSRM were

based on Hydrology and Hydraulic (H&H) and structure file inputs, and described in detail in Appendix C.

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 eight 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 total number of structures in the Orange-Jefferson CSRM is 27,125 (Orange County) and 26,605 (Jefferson Country). The total structure and content values of inventoried structures (2015 price and levels of development) for the Orange-Jefferson CSRM, in Orange County is $6,147,511,000 ($3,170,490,000 structure value, and $2,977,021,000 in content value). Total structure and content values of inventoried structures (2015 price and levels of development) for the Orange-Jefferson CSRM, in Jefferson County is $8,120,438,000 ($3,998,788,000 structure value, and $4,121,650,000 in content value).

Table 7-3 estimates the FWOP EADs for the damage reaches in the Orange-Jefferson CSRM. Damage categories are defined as the following; *Comm*. (commercial), Ind. (industrial), *MFR* (multi-family residential), *MR* (mobile residences), *Public* (public), *POV* (personal occupancy vehicles), and *SFR* (single-family residential).

Port Arthur and Vicinity CSRM

The draft findings of the SQRA for the Freeport system were applied to the plan formulation for the Port Arthur because one has not yet been done for this system. For the Port Arthur HFPP, 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 for the Port Arthur system at this time.

The FWOP conditions 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 7-7 displays the Port Arthur HFPP failure locations. These locations were included in the plan formulation where improvements would positively impact the system's capacity for protection. The following lists the reaches at Port Arthur.

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

The FWOP condition EADs for the Port Arthur and Vicinity CSRM were based on fragility curves, Hydrology and Hydraulic (H&H) and structure file inputs, and described in detail in Appendix C.

Figure 7-6. Orange-Jefferson Alternative Reaches

Table 7-3. Expected Annual Damages Future Without-Project Condition for Orange-Jefferson CSRM (2015 price level)

	Damage Categories							
Reach	**Commercial**	**Industrial**	**MFR**	**MR**	**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

Figure 7-7. Port Arthur and Vicinity Failure Locations

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

There are 43,968 structures included in the structure file for the Port Arthur and Vicinity CSRM. The total structure and content values of inventoried structures (2015 price and levels of development) for the Port Arthur and Vicinity CSRM is $19,195,051,000 ($7,869,963,000 structure value, and $11,625,088,000 in content value).

Table 7-4 estimates the FWOP EADs for the damage reaches in the Port Arthur and Vicinity CSRM. Damage categories are defined as the following; *Comm*. (commercial), Ind. (industrial), *MFR* (multi-family residential), *MR* (mobile residences), *Public* (public), *POV* (personal occupancy vehicles), and *SFR* (single-family residential).

Freeport and Vicinity CSRM

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 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 7-8). 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

The FWOP condition EADs for the Freeport and Vicinity CSRM were based on fragility curves, Hydrology and Hydraulic (H&H) and structure file inputs, and described in detail in Appendix C.

Table 7-4. Expected Annual Damages Future Without-Project Conditions for Port Arthur and Vicinity CSRM (2015 price level)

	Damage Categories							
Reach	**Commercial**	**Industrial**	**MFR**	**MR**	**Public**	**POV**	**SFR**	**Total**
Port Arthur and Vicinity CSRM								
Port Arthur 8ft-10ft I-Wall	$19,302,000	$560,000	$83,000	$0	$368,000	$275,000	$2,824,000	$23,413,000
Port Arthur Closure Structure	$3,128,000	$86,000	$13,000	$0	$59,000	$44,000	$453,000	$3,784,000
Port Arthur I-Wall Near Valero	$50,798,000	$1,587,000	$228,000	$0	$975,000	$726,000	$7,553,000	$61,867,000
Port Arthur Tank Farm	$31,139,000	$1,012,000	$143,000	$0	$599,000	$446,000	$4,670,000	$38,009,000

Figure 7-8. Freeport and Vicinity CSRM Failure Locations

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

There are 23,326 structures included in the structure file for the Freeport and Vicinity CSRM. The total structure and content values of inventoried structures (2015 price and levels of development) is approximately $16,700,000,000. Estimates could be higher based on additional structures in the lower reaches outside the Dow Barge Canal structure file inventory.

Table 7-5 estimates the FWOP EADs for the damage reaches in the Freeport and Vicinity CSRM. Damage categories are defined as the following; *Comm*. (commercial), Ind. (industrial), *MFR* (multi-family residential), *MR* (mobile residences), *Public* (public), *POV* (personal occupancy vehicles), and *SFR* (single-family residential).

7.1.6 Life Safety

The population at risk broken down by project area is included in Table 7-6. These populations at risk were developed based on the 2010 census blocks that intersect the damageable properties in the project areas. This population reflects the residential population that could be exposed to flood risk. This does not include transportation routes for population evacuating or those at work in commercial or industrial areas.

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. Orange and Jefferson Counties, as well as Brazoria County, have emergency management departments that engage their respective cities including specific evacuation plans and processes.

7.1.7 Critical Infrastructure

The following is a description of 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 was developed from information derived from the Homeland Security Infrastructure Program (HSIP), which is an infrastructure geospatial data inventory. The critical infrastructure is

Table 7-5. Expected Annual Damages Future Without-Project Conditions for Freeport and Vicinity CSRM (2015 price level)

	Damage Categories							
Reach	**Commercial**	**Industrial**	**MFR**	**MR**	**Public**	**POV**	**SFR**	**Total**
Freeport and Vicinity 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 7-6. Population at Risk by Project Area

Population at Risk	
Orange-Jefferson CSRM	
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 and Vicinity CSRM	116,762
Freeport and Vicinity CSRM	16,559

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 included in Appendix C, Economic Analysis. The project areas are discussed 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
- 3 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. A detailed description of each critical facility is not provided here; however, to explain one in some detail, Exxon Mobil is located near downtown Beaumont, Texas on the Neches River. The refinery processes 345,000 barrels of crude oil per day and produces 2.5 billion gallons of gasoline annually (Exxon Mobil, 2015).

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
- 3 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. A detailed description of each critical facility is not provided here; however, to explain one in some detail, Motiva is the largest petroleum refinery in the United States, with a capacity of approximately 600,000 barrels of crude oil (Beaumont Enterprise, 2014).

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 (Dow, 2015).

In summary, the critical infrastructure located in the project areas could be impacted during a flood. Of note, if the refineries were closed down due to flood events, there could be significant impacts on gas supplies and multiplier effects to the economy, e.g., increase in transportation costs. Local roadways and major thoroughfares in the project areas were not evaluated in detail for the FWOP condition. Although it is included in the objectives for this study, they are considered ancillary benefits, so they are only covered in this context in the report.

7.1.8 Relative Sea Level Change

USACE expectations of climate change and relative seas level change, and their impact is an important component of the FWOP condition. The planning horizon of 50 years is used in this

study; however, RSLC is estimated beyond that to 100 years. Some key expectations for RSLC in a feasibility study 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.

Tables 7-7 through 7-9 present the estimated RSLC in the project areas for the 20-, 50- and 100-year project life for the Low, Intermediate and High scenarios. Additional information on how the estimates were developed are included in Appendix D. The Sabine Pass, TX row corresponds to the sea level rise estimates for the Orange-Jefferson CSRM and Port Arthur and Vicinity CSRM; and the Freeport, TX row corresponds to the Freeport and Vicinity CSRM project areas.

Table 7-7. Estimated RSLC over the First 20 Years of the Project Life (2030-2050)

Tidal 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
Freeport, TX	4.35 mm/yr	0.29	0.46	1.00

Table 7-8. Estimated RSLC over the First 50 Years of the Project Life (2030-2080)

Tidal 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
Freeport, TX	4.35 mm/yr	0.72	1.27	3.05

Table 7-9. Estimated RSLC over the First 100 Years of the Project Life (2030-2130)

Tidal 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
Freeport, TX	4.35 mm/yr	1.43	2.99	7.95

The EAD tables presented for the FWOP condition for the final array did not include estimates for the 20-50- and 100-year sea level rise scenarios. The TSP from the final array was measured against sea level rise scenarios to show performance against the various scenarios.

7.2 FINAL ARRAY EVALUATION RESULTS

7.2.1 Orange-Jefferson CSRM

The following section describes the proposed Orange-Jefferson CSRM Optimization Alternatives. The plans in this project area include a combination of new levees and floodwalls at varying

heights to address the storm surge flood risk. The Optimization Alternatives run along the north side of the Neches River and the west bank of the Sabine River. Figure 7-9 shows the location of the Optimization Alternatives listed below.

- Orange 1 consists of approximately 27,000 linear feet (LF) of levee and 16,500 LF of floodwall (total of 8.2 miles); levee heights evaluated include 11-foot, 12-foot, 13-foot and 14-foot;
- Orange 2 consists of approximately 34,600 LF of levee (6.6 miles); levee heights evaluated include 11-foot, 12-foot, 13-foot and 14-foot;
- Orange 3 consists of a combination of 113,600 LF of levee and 29,800 LF of floodwall (total of 27 miles); levee heights evaluated include 11-foot, 12-foot, 13-foot and 14-foot;
- Jefferson Main runs along the south side of the Neches River and consists of approximately 41,700 LF of levee and 16,200 LF of floodwall (11 miles); levee heights evaluated include 11-foot, 12-foot, 13-foot and 14-foot;
- Beaumont A is combination of 3,100 LF of levee and 200 LF of floodwall (0.6 mile); levee heights evaluated include 11-foot, 12-foot, 13-foot and 14-foot;
- Beaumont B is 2,500 LF of levee (0.5 mile); levee heights evaluated include 11-foot, 12-foot, 13-foot and 14-foot; and
- Beaumont C is 6,800 LF of levee (1.3 mile); levee heights evaluated include 11-foot, 12-foot, 13-foot and 14-foot.

Economic Evaluation

The economic evaluation of the alternatives for the Orange-Jefferson CSRM damage reaches are presented in Tables 7-10 through 7-12. Fish and wildlife mitigation costs were included in the economic evaluation. The approved WVA was used to quantify habitat impacts for a conservatively wide footprint of the alignment's construction right-of-way. Estimated mitigation costs (first costs and monitoring/adaptive management costs) were developed based upon conceptual mitigation plans. The same mitigation cost was applied to all height alternatives in each segment as the impacts and mitigation would be similar for all heights and the cost variation among them would be small. When compared to other cost elements, estimated fish and wildlife mitigations costs were not large enough to affect plan selection.

Figure 7-9. Location of Optimization Alternatives in the Orange-Jefferson CSRM Project Area

Table 7-10. Economic Performance of New Levees at Orange and Jefferson Counties

(FY 2015 Price Level/3.375% interest rate)

	Orange 1				Orange 2				Orange 3			
	11 - Foot	**12 - Foot**	**13 - Foot**	**14 - Foot**	**11 - Foot**	**12 - Foot**	**13 - Foot**	**14 - Foot**	**11 - Foot**	**12 - Foot**	**13 - Foot**	**14 - Foot**
INVESTMENT												
Estimated First Cost	$46,617,000	$60,935,000	$75,252,000	$89,570,000	$41,088,000	$49,305,000	$57,523,000	$65,740,000	$246,811,000	$288,284,000	$329,762,000	$371,237,000
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	$2,377,000	$3,108,000	$3,838,000	$4,568,000	$2,095,000	$2,515,000	$2,934,000	$3,353,000	$12,587,000	$14,702,000	$16,818,000	$18,933,000
Investment Cost	$48,995,000	$64,043,000	$79,090,000	$94,138,000	$43,183,000	$51,820,000	$60,456,000	$69,093,000	$259,398,000	$302,986,000	$346,580,000	$390,169,000
Interest	$1,654,000	$2,161,000	$2,669,000	$3,177,000	$1,457,000	$1,749,000	$2,040,000	$2,332,000	$8,755,000	$10,226,000	$11,697,000	$13,168,000
Amortization	$388,000	$508,000	$627,000	$746,000	$342,000	$411,000	$479,000	$548,000	$2,056,000	$2,402,000	$2,747,000	$3,093,000
OMRR&R ($/year)*									$4,084,000	$4,084,000	$4,084,000	$4,084,000
TOTAL ANNUAL COSTS	**$2,042,000**	**$2,669,000**	**$3,296,000**	**$3,923,000**	**$1,800,000**	**$2,160,000**	**$2,520,000**	**$2,880,000**	**$14,895,000**	**$16,711,000**	**$18,528,000**	**$20,345,000**
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	$39,000	$23,000	$12,000	$6,000	$26,000	$20,000	$16,000	$11,000	$5,242,000	$3,044,000	$1,654,000	$832,000
Storm Reduction Benefits	$273,000	$289,000	$300,000	$306,000	$42,000	$48,000	$52,000	$57,000	$24,745,000	$26,943,000	$28,333,000	$29,155,000
TOTAL BENEFITS	**$273,000**	**$289,000**	**$300,000**	**$306,000**	**$42,000**	**$48,000**	**$52,000**	**$57,000**	$24,745,000	$26,943,000	$28,333,000	$29,155,000
NET BENEFITS	**($1,769,000)**	**($2,380,000)**	**($2,996,000)**	**($3,617,000)**	**($1,757,000)**	**($2,112,000)**	**($2,467,000)**	**($2,822,000)**	**$9,851,000**	**$10,232,000**	**$9,804,000**	**$8,810,000**
BENEFIT-COST RATIO	**0.13**	**0.11**	**0.09**	**0.08**	**0.02**	**0.02**	**0.02**	**0.02**	**1.66**	**1.61**	**1.53**	**1.43**

*****For Mitigation

Note: Tables may not add up exactly due to rounding.

Table 7-11. Economic Performance of New Levees at Orange and Jefferson Counties

(FY 2015 Price Level/3.375% interest rate)

	Beaumont A				Beaumont B				Beaumont C		
	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	**2.00**	**1.97**	**1.89**	**1.79**	**0.23**	**0.19**	**0.17**	**0.14**	**0.36**	**0.36**	**0.31**

Note: Tables may not add up exactly due to rounding.

Table 7-12 Economic Performance of New Levees at Orange and Jefferson Counties

(FY 2015 Price Level/3.375% interest rate)

	Jefferson Main			
	11 - Foot	**12 - Foot**	**13 - Foot**	**14 - Foot**
INVESTMENT				
Estimated First Cost	$65,726,000	$87,674,000	$104,747,000	$121,814,000
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	$3,352,000	$4,471,000	$5,342,000	$6,212,000
Investment Cost	$69,078,000	$92,145,000	$110,089,000	$128,027,000
Interest	$2,331,000	$3,110,000	$3,715,000	$4,321,000
Amortization	$548,000	$730,000	$873,000	$1,015,000
OMRR&R ($/year)*	$371,000	$371,000	$371,000	$371,000
TOTAL ANNUAL COSTS	**$3,250,000**	**$4,212,000**	**$4,960,000**	**$5,707,000**
Without Project EAD	$28,231,000	$28,231,000	$28,231,000	$28,231,000
Residual EAD	$2,520,000	$1,440,000	$776,000	$401,000
Flood Reduction Benefits	$25,711,000	$26,791,000	$27,456,000	$27,831,000
TOTAL BENEFITS	**$25,711,000**	**$26,791,000**	**$27,456,000**	**$27,831,000**
NET BENEFITS	**$22,461,000**	**$22,580,000**	**$22,496,000**	**$22,123,000**
BENEFIT-COST RATIO	**7.91**	**6.36**	**5.54**	**4.88**

* For Mitigation

Note: Tables may not add up exactly due to rounding.

7.2.2 Port Arthur and Vicinity

The following section describes the proposed Port Arthur and Vicinity CSRM Optimization Alternatives. The plans include modifications to the existing HFPP at Port Arthur. Figure 7-10 shows the location of the Optimization Alternatives listed below.

- 8- to 10-foot I-Wall
  - No fail: 3,500 LF of 15-foot-wide 6-inch scour pad
  - 1-foot raise: 7,500 LF of 15-foot-wide 6-inch scour pad. 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 1 foot and providing overtopping erosion protection.
  - 2-foot raise: 7,500 LF of 15-foot-wide 6-inch scour pad. Additional 60,000 LF of levee raising 2 feet along with raising the highway 87 and highway 73 levee crossings. Floodwalls at two 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 one gravity drainage structure and one vehicle closure structure.

- *Closure Structure*
  - No fail: Construction of 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 likely hood of a brittle failure if the systems' capacity is exceeded.
  - 1-foot raise: This includes replacement of the closure structure gate that is 12 feet height by 30 feet width. It also includes 2,300 LF of 100-foot-wide 6-inch scour pad, one on each side of the structure to provide erosion protection to reduce the likelihood of a brittle failure if the systems' capacity is exceeded. This option also included raising 12,000 LF of levee 1 foot.
  - 2-foot raise: Replace two closure structures gate structures are 12 feet height by 30 feet width including two 300 LF of 100-foot-wide 6-inch scour pad at each closure structure. This plan includes raising 12,000 LF of levee 1 foot and adding floodwalls at two pump stations, 500 LF total (7 feet tall) along with reinforcing pump station walls at four existing pump stations.

- I-Wall Near Valero
  - No fail: Construction of 5,000 LF of 15-foot-wide 6-inch scour pad to provide additional structural integrity and erosion protection to reduce the likelihood of failure.
  - 1-foot raise: Construction of 5,000 LF of 15-foot-wide 6-inch scour pad with a 1-foot rise will provide additional system capacity, increase structural integrity of the I-wall and provide erosion protection to reduce the likelihood of system overtopping. Additionally, 3,000 LF of levee will need to be raised 1 foot.
  - 2-foot raise: This option will require significant reconstruction of the HFPP in the evaluated area including 5,000 LF of flood wall (15 feet tall), 10 closure structures 15 feet height and 20 foot width, 3,000 LF of levee raised 2 feet along with the work

Figure 7-10. Optimization Alternatives - Port Arthur and Vicinity CSRM Project Area

- specified in the I-wall near Tank Farm (2-foot raise) and 8-10 foot I-Wall (2-foot raise) required work.

- *I-Wall Near Tank Farm*
  - No fail: Construction of 1,800 LF of 15-foot-wide 6-inch scour pad to provide additional structural integrity and erosion protection to reduce the likely hood of a brittle failure if the systems' capacity is exceeded.
  - 1-foot raise: Construction of 1,800 LF of 15-foot-wide 6-inch scour pad and batter piling and wailer system with 1-foot rise will provide additional system capacity, increase structural integrity of the I-wall and provide erosion protection to reduce the likely hood of a brittle failure if the system's capacity is exceeded. Additionally, 7,000 LF of levee will need to be raised 1 foot.
  - 2-foot raise: Construction of 2,000 LF of floodwall (15 feet tall) along with 9,000 LF of levee raised 2 feet. There would be construction of a floodwall at 1 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 feet tall floodwall. There would be rebuilding four existing pump stations at 1,100 cubic feet per second (cfs).

Economic Evaluation
The economic evaluation of the alternatives for the Port Arthur and Vicinity CSRM damage reaches are presented in Table 7-13. Environmental impacts and associated mitigation costs were not needed in the comparison.

7.2.3 Freeport and Vicinity CSRM

The following section describes the proposed Freeport and Vicinity CSRM Optimization Alternatives. The plans include modifications to the existing HFPP at Freeport. Figure 7-11 shows the location of the Optimization Alternatives listed below.

- *Dow Barge Canal Protection*

The Dow Barge Canal levees are approximately eight 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. The study team utilized 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 gallons per minute (gpm). The structure length will be approximately 500 feet long, two sector gates totaling approximately 80 feet width for vessel traffic. Additional tidal circulation will be provided by two sluice gates approximately 15 feet wide each. The final configuration of this structure will match the proposed level of protection for the system.

Table 7-13. Economic Performance of Port Arthur and Vicinity CSRM

(FY 2015 Price Level/3.375% interest rate)

	8ft-10ft I-Wall			Closure Structure			I-Wall Near Valero			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	**92.13**	**45.23**	**6.89**	**16.69**	**7.23**	**3.63**	**135.79**	**130.24**	**4.00**	**106.44**	**104.11**	**3.28**

Note: Tables may not add up exactly due to rounding.

Figure 7-11. Location of Optimization Alternatives in the Freeport and Vicinity CSRM Project Area

- *Oyster Creek Levee*

Oyster Creek Levee was constructed at varying elevations to account for the changes in flood elevation as noted in the hydraulic modeling. Updated hydraulic modeling showed a height deficiency over 3,500 LF.

- No fail: The Oyster Creek levee will be raised 2 feet over 3,500 LF in order to correct the noted height deficiency. The construction procedure will include stripping topsoil, removal of a 12 feet wide asphalt road, placement of fill, replacement of a 12 feet wide road and turfing.
- 1-Foot Raise: Construction will include 3,500 LF of 3 feet 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.
- 2-Foot Raise: Construction will include 3,500 LF of a 4-foot levee raise and 1,000 LF of floodwall reconstruction along with raising Highway 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 gravity structures would be required.

- *East Storm Levee*

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 and turfing.

- No Fail: Construction of 13,115 LF of High Performance Turf Reinforcing Mat (HPTRM)
- 1-foot raise: Construction includes 13,115 LF of levee raised 1 foot with HPTRM
- 2-foot raise: Construction includes 19,115 LF of levee raised 2 foot with HPTRM, and a floodwall at one pump station 800 LF total (5 feet tall). Reinforcing pump station walls and raising Highway 332 at the levee crossing would be required.

- *South Storm Levee*

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. Over the last 40 years, USACE constructed dredge disposal areas for the deep draft navigation channel to 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-foot: Construction would include earth placement on top of the existing earth embankment for a 1-foot raise.
- 2-foot: Construction would include earth placement on top of the existing earth embankment for a 2-foot raise.

- *Freeport Dock Floodwall*

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 CFR 65.10, the local sponsor noted that the wall/panels were structurally deficient. This deficiency was confirmed during the Freeport SQRA.

- Partial Fail: Construction includes replacing the drop in panels and anchor system.
- 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.
- 1-Foot Raise: Construction would require complete reconstruction of the dock and flood wall assembly.

- *Old River Levee 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.

- No Fail: Construction of 14,500 LF of HPTRM and 4,000 LF of 15-foot-wide 6-inch scour pad to provide erosion protection to reduce the likelihood of failure.
- 1-Foot Raise: Construction of 4,000 LF of 15-foot-wide 6-inch scour pad along with 3,000 LF of levee raised 1 foot and 14,500 LF of HPTRM to "level up" the low spots and provide erosion protection to reduce the likely hood of a brittle failure if the system's capacity is exceeded.
- 2-Foot Raise: Due to extremely low Factors of Safety (FOS) for global stability raising the levee over existing heights by adding additional earth fill is not an option; therefore, under this scenario, the existing embankment would be removed and 12,000 LF of 10 feet 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.

- *Tide Gate I-Wall*

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 design elevation. The very soft foundation materials that were present in the old river channel would not support the additional weight of the embankment section. The proposed construction will be to reconstruct the I-wall as a pile founded T-wall. The overall length of the T-wall is approximately 362 feet.

- No Fail: Construction of 362 LF of floodwall 10 feet tall.
- 1-Foot Raise: Construction of 700 LF of floodwall (11 feet tall) along with 2,000 LF of levee raised 1 foot.
- 2-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 a 2-foot raise.

Economic Evaluation
The economic evaluation of the alternatives for the Freeport Arthur and Vicinity CSRM damage reaches are presented in Table 7-14.

7.2.4 Sabine and Brazoria Nonstructural Buyouts

Surveys of aerial imagery for the three counties were performed to look for the potential for nonstructural 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 Port Arthur and Freeport CSRM project areas. 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; however, these structures are commercial and buying out these structures is very unlikely to be the economic viable. Figure 11 of Appendix C 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 a lot 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 nonstructural buyout. The analysis showed the nonstructural buyouts had negative net benefits and any potential buyouts were screened from the analysis. The economic evaluation results are included in Table 13 of the Economic Appendix.

7.3 COMPARISON OF ALTERNATIVE PLANS

This section provides a summary of the results of the Final Array of Alternatives evaluation and a comparison of plans. The screening criteria are applied to select a TSP. Table 7-15 presents the final array plans and a summary of the contributions to the planning objectives. Plans were evaluated first to identify an NED plan.

Objectives 1, 4 and 6 are described first since they were the objectives related to NED. The following is a summary and comparison of the plans for these objectives. For Objective 1, the net benefits were calculated for each Optimization Alternative. The plan the reasonably maximizes net benefits is the NED plan. Objective 4 is embedded within the NED and RED accounts. Specifically for NED, the values of the critical infrastructure were included in the economic analysis, and measured when the economic evaluation of the Optimization Alternatives was performed and an NED plan was identified.

Table 7-14. Economic Performance of Freeport and Vicinity

(FY 2015 Price Level/3.375% interest rate)

	Dow Barge Canal	Oyster Creek Levee			East Storm Levee			Freeport Dock		
	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	**21.01**	**28.53**	**11.86**	**1.21**	**6.13**	**3.92**	**1.10**	**2.86**	**17.74**	**0.40**

Economic Performance of Freeport and Vicinity CSRM (cont'd)
(FY 2015 Price Level/3.375% interest rate)

	Old River at Dow				South Storm Levee		Tide Gate		
	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	**3.92**	**4.42**	**0.46**		**0.49**	**0.44**	**21.35**	**11.37**	**1.35**

Note: Tables may not add up exactly due to rounding.

Table 7-15. Comparison of Final Array of Alternative by Planning Objectives

	NED			OSE		RED
	Objective 1		Objective 6	Objective 2		Objective 4 and 5
	Net Benefits	Screening Status	Sea Level Rise	Population at Risk		Critical Infrastructure Impacts
Orange-Jefferson CSRM						
Orange 1			Surplus/Deficit Range (Approx. Feet NAVD)	PAR FWOP/Expected Impact		Number of Facilities by County
11-foot Raise	($1,769,000)	Screened Out		17,014	Expected Positive Impact	Reduces likelihood of secondary impacts on: • 20 schools • 14 law enforcement • 2 hospitals/6 nursing homes • 11 fire stations • 20 chemical manufacturing • 5 electric generation • 0 petroleum refining
12-foot Raise	($2,380,000)	Screened Out				
13-foot Raise	($2,996,000)	Screened Out				
14-foot Raise	($3,617,000)	Screened Out				
Orange 2						
11-foot Raise	($1,757,000)	Screened Out		13,952	Expected Positive Impact	
12-foot Raise	($2,112,000)	Screened Out				
13-foot Raise	($2,467,000)	Screened Out				
14-foot Raise	($2,822,000)	Screened Out				
Orange 3						
11-foot Raise	$9,851,000	$9,851,000	-1.3 – 4.8 feet deficit	60,044	Expected Positive Impact	
12-foot Raise	$10,232,000	$10,232,000	-0.5 – 3.8 feet deficit			
13-foot Raise	$9,804,000	Screened Out	0.5 surplus - 2.8 feet deficit			
14-foot Raise	$8,810,000	Screened Out				
Beaumont A						
11-foot Raise	$2,743,000	Screened Out	-1.3 – 4.8 feet deficit	2,078	Expected Positive Impact	Reduces likelihood of secondary impacts on: • 42 schools • 19 law enforcement • 13 hospitals/7 nursing homes • 26 fire stations • 54 chemical manufacturing • 1 electric generation • 0 petroleum refining • 1 airport
12-foot Raise	$2,992,000	$2,992,000	-0.5 – 3.8 feet deficit			
13-foot Raise	$3,037,000	$3,037,000	0.5 surplus - 2.8 feet deficit			
14-foot Raise	$2,942,000	Screened Out				
Beaumont B						
11-foot Raise	($58,000)	Screened Out		2,078	Expected Positive Impact	
12-foot Raise	($82,000)	Screened Out				
13-foot Raise	($106,000)	Screened Out				
14-foot Raise	($131,000)	Screened Out				
Beaumont C						
11-foot Raise	($442,000)	Screened Out		2,078	Expected Positive Impact	
12-foot Raise	($449,000)	Screened Out				
13-foot Raise	($574,000)	Screened Out				
Jefferson Main						
11-foot Raise	$22,461,000	$22,461,000	-1.3 – 4.8 feet deficit	116,762	Expected Positive Impact	
12-foot Raise	$22,580,000	$22,580,000	-0.5 – 3.8 feet deficit			
13-foot Raise	$22,496,000	Screened Out	0.5 surplus - 2.8 feet deficit			
14-foot Raise	$22,123,000	Screened Out				
Port Arthur and Vicinity CSRM*						
8-10ft I-Wall						
No Fail	$13,305,000	Screened Out		116,762	Expected Positive Impact	Reduces likelihood of secondary impacts on: • 42 schools • 19 law enforcement • 13 hospitals/7 nursing homes • 26 fire stations • 54 chemical manufacturing • 1 electric generation • 0 petroleum refining
1-foot Raise	$17,292,000	$17,292,000				
2-foot Raise	$17,215,000	Screened Out				
Closure Structure						
No Fail	$2,622,000	Screened Out				
1-foot Raise	$2,908,000	$2,908,000				
2-foot Raise	$2,628,000	Screened Out				
I-Wall Near Valero						
No Fail	$45,153,000	Screened Out				
1-foot Raise	$50,662,000	$50,662,000				
2-foot Raise	$41,076,000	Screened Out				
I-Wall Near Tank Farm						

	NED			OSE		RED
	Objective 1		Objective 6	Objective 2		Objective 4 and 5
	Net Benefits	Screening Status	Sea Level Rise	Population at Risk		Critical Infrastructure Impacts
No Fail	$12,758,000	Screened Out				• 1 airport
1-foot Raise	$20,932,000	$20,932,000				
2-foot Raise	$18,843,000	Screened Out				
Freeport and Vicinity CSRM*						
Dow Barge Canal						
No Fail	$113,914,000	$113,914,000				
Oyster Creek Levee						
No Fail	$2,010,000	Screened Out				
1-foot Raise	$2,314,000	$2,314,000				
2-foot Raise	$490,000	Screened Out				
East Storm Levee						
No Fail	$769,000	Screened Out				
1-foot Raise	$835,000	$835,000				
2-foot Raise	$120,000	Screened Out				
Freeport Dock						
Partial Fail	$123,000	Screened Out				
No Fail	$2,093,000	$2,093,000				
1-foot Raise	($3,944,000)	Screened Out				
Old River at Dow Thumb						
No Fail	$969,000	Screened Out				
1-foot Raise	$1,241,000	$1,241,000				
2-foot Raise	($2,196,000)	Screened Out				
South Storm Levee						
1-foot Raise	($74,000)	Screened Out				
2-foot Raise	($164,000)	Screened Out				
Tide Gates						
No Fail	$1,526,000	Screened Out				
1-foot Raise	$1,721,000	$1,721,000				
2-foot Raise	$549,000	Screened Out				
Sabine Nonstructural Buyout	Need Result	Screened Out				
Brazoria Nonstructural Buyout	Need Result	Screened Out				

	16,559	Expected Positive Impact	Reduces likelihood of secondary impacts on: • 6 schools • 3 law enforcement • 0 hospitals/0 nursing homes • 2 fire stations • 24 chemical manufacturing • 0 electric generation • 0 petroleum refining

*The comparison shows the economic analysis performs well with the RSLC scenario for the 50-year period for Port Arthur and Vicinity and the Freeport and Vicinity CSRM; therefore, the surplus is not reported in this table

In the Orange-Jefferson CSRM project area, Optimization Alternatives within the Orange 1, Orange 2, Beaumont B and Beaumont C Alternative Reaches did not have positive net benefits; therefore, the new levees considered at the various heights for those reaches were screened from further consideration. In the Port Arthur and Vicinity CSRM project area, all alternative reaches had positive net benefits. In the Freeport and Vicinity CSRM project area, all Alternative Reaches had positive net benefits except the South Storm Levee. The raises considered for that reach was screened from further consideration. The nonstructural buyouts for the Sabine and Brazoria Regions were not economically viable and screened from further consideration. The plans that reasonably maximized NED from each project area are highlighted green in Table 7-15 and listed below:

The NED plan for the Orange-Jefferson CSRM is:

- Orange 3 New Levee (11-foot)
- Jefferson Main New Levee (11-foot)
- Beaumont A New Levee (12-foot)

The NED plan for the Port Arthur Vicinity CSRM is:

- 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)

The NED plan for the Freeport and Vicinity CSRM is:

- DOW Barge Canal Gate Structure
- Oyster Creek Levee Raise (1-foot)
- East Storm Levee Raise (1-foot)
- Freeport Dock Floodwall Raise (1-foot)
- Old River Levee Raise at Dow Thumb (1-foot)
- Tide Gate I-Wall Raise (1-foot)

Regarding Objective 6, the EADs presented in this report use storm surge levels without considering sea level rise scenarios for the 20-, 50- and 100-year sea level change scenarios; however, a performance of the NED plans against RSLC is provided. Table 7-16 shows the performance of the NED plans against the 50-year RSLC estimated for the project areas. This table was developed by averaging levee heights specified by engineering criteria for the 50-year RSLC and comparing them to the elevation of the index points used in the HEC-FDA model for the NED Plans. The column highlighted yellow is the height of the NED plans in the economic analysis. The comparison shows the NED Plans perform well with the RSLC scenario for the 50-year period, except for areas in the “Sabine Region.” The rows highlighted in light blue show the Orange-Jefferson CSRM (NED plan) is deficient in height at the 50-year project life.

Table 7-16. Average Recommended Relative Sea Level Change (RSLC), Feet NAVD

Location	Without RSLC	Low RSLC	Int.* RSLC	High RSLC	Height in Economic analysis**	Surplus/ Deficit (Without)	Surplus/ Deficit (Low)	Surplus /Deficit (Int.)	Surplus/ Deficit (High)
Dow Barge Canal	15.85	16.58	17.15	18.93	26.00	10.15	9.43	8.85	7.08
Sabine Floodwall	12.50	13.43	13.98	15.77	11.00	-1.50	-2.43	-2.98	-4.77
Sabine Levee	12.33	13.24	13.83	15.59	11.00	-1.33	-2.24	-2.83	-4.59
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
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

*Note Int. – Intermediate
** Note heights listed are different under the recommended plan, due to final refinements under feasibility design

Table 7-15 summarizes the range in RSLC deficits for the Orange-Jefferson CSRM project area. As the height of the plan decreases, the range in the deficit increases among the Optimization Alternatives. The locations listed in Table 7-15 correspond to locations included in the H&H analysis.

The expectation for each project area would be all plans would positively impact life-safety risk and reduce the likelihood of secondary impacts to critical infrastructure to meet Objectives 2 and 4. This is shown in Table 7-15 as an expected positive impact. Additional qualitative discussion of Objectives 2 and 4 is provided in the next section. Objective 3 was removed from consideration in this planning study from an ER implementation standpoint. Opportunities to meet these objectives could be pursued under different study authorizations. The ER objective is achieved in this study through avoiding, minimizing, and mitigating impacts on existing habitats.

7.4 IDENTIFYING A TENTATIVELY SELECTIVE PLAN (TSP)

The decision criteria for selecting a TSP at this point in the study was based on building a plan for each project area that reasonably maximized net benefits (Objective 1 for the study) from the Final Array of Alternatives. The current TSP is the NED plan for each project area and only considers economics as the decision criteria. The TSP includes the following features:

Orange-Jefferson CSRM

- Orange 3 New Levee (11-foot)
- Beaumont A New Levee (12-foot)
- Jefferson Main New Levee (11-foot)

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)

Freeport and Vicinity CSRM

- Dow Barge Canal Gate Structure
- Oyster Creek Levee Raise (1-foot)
- East Storm Levee Raise (1-foot)
- Freeport Dock Floodwall Raise (1-foot)
- Old River Levee Raise at Dow Thumb (1-foot)
- Tide Gate I-Wall Raise (1-foot

7.5 SELECTION OF THE RECOMMENDED PLAN

Note: This section describes the selection process that led to the identification of the TSP. The information contained herein was presented in the Sept 11, 2015 DIFR-EIS that was released for public review. Changes to the TSP have occurred since the public review are briefly described at the end of this section. The changes to the TSP resulted in the Recommended Plan presented in the last section and in the Main Report.

USACE guidance requires selection of the TSP as the Recommended Plan unless there are other Federal, state, local, or international concerns that make another alternative viable to recommend at full cost sharing. In addition, there is an opportunity for the local sponsor to request implementation of a locally preferred plan (LPP) in which they would fully fund the cost above the NED plan if it were higher, or the plan would be reduced in cost if they preferred a smaller plan. Any plan other than the NED Plan would require a waiver from the Assistant Secretary of the Army for Civil Works. It is unlikely there will be a locally preferred plan for this study. However, it may make sense to recommend a plan that provides a higher level of performance because it fulfills other, non-economic objectives of the study, including considerations of life-safety, critical infrastructure, and RSLC.

This draft report will undergo public, policy, Agency Technical Review (ATR), Independent External Peer Review (IEPR), and the Study Team will address all comments from these reviews. Based particularly on input from public and agency reviews concerning public safety and infrastructure concerns, it may be appropriate for USACE to consider recommending a more robust plan for the Orange-Jefferson CSRM after the Agency Decision Milestone (ADM) is conducted. The ADM is the decision point where a Senior Leader Panel confirms the TSP and makes the decision on the Recommended Plan to carry forward for detailed feasibility-level design based on policy, public, ATR and IEPR reviews of the draft report.

The decision to select a plan other than the TSP is not based on quantitative economic analysis alone, but rather takes into consideration other factors that could justify higher project cost and more robust construction than could be otherwise justified. The following discussion identifies other compelling factors that might support a plan larger than the TSP for the Orange-Jefferson

CSRM for consideration by the Senior Leader Panel. If approved, a TSP providing greater protection for the Orange-Jefferson CSRM would be further refined in the next study phase.

For example, Table 7-17 is a summary of comparable Optimization of Alternatives in terms of net benefits, percent change in net benefits, annual costs, and total project cost differences within the Orange-Jefferson CSRM project area. An increase in one foot above the Optimization Alternatives would cost about $72 million more but would only provide about $545,000 more in net annual benefits. Based on economics alone, even though the 11-foot levee is incrementally justified, it doesn't make sense to recommend a plan that costs that much more for such minimal benefits.

However, based on the qualitative evaluation performed, each alternative reach is expected to have a positive impact on life-safety, because reductions in economic damages are generally considered highly correlated to reductions in risk in terms of life-safety. For the Orange-Jefferson CSRM project area, the population at risk is estimated as follows:

- Orange 3 Alternative Reach – 60,044 residents
- Beaumont A Alternative Reach – 2,078 residents
- Jefferson Main Alternative Reach – 116,762 residents
-

Table 7-17. Cost Analyses Comparison for Optimization Alternatives in the Orange-Jefferson Project Area

Objective 1						
	Net Benefits	**Net Benefits % Change**	**Annual Cost**	**Annual Cost % Change**	**Total Project Cost**	**Incremental Change in Total Project Cost**
Orange-Jefferson CSRM						
Orange 3						
11-foot Raise	$9,851,000	N/A	$14,895,000	N/A	$246,811,000	N/A
12-foot Raise	$10,232,000	3.9%	$16,711,000	12.2%	$288,284,000	$41,473,000
Beaumont A						
12-foot Raise	$2,992,000	N/A	$3,075,000	N/A	$70,202,000	N/A
13-foot Raise	$3,037,000	1.5%	$3,405,000	10.7%	$77,743,000	$7,541,000
Jefferson Main						
11-foot Raise	$22,461,000	N/A	$3,250,000	N/A	$64,726,000	N/A
12-foot Raise	$22,580,000	0.5%	$4,212,000	29.6%	$87,674,000	$22,948,000

The risk assessment for the Orange-Jefferson CSRM is largely qualitative. Defining the population at risk, above, and the depth of flooding is evaluated in a risk assessment. Other considerations include populations in high risk areas with special needs, such as elderly populations over 65, and care and shelter facilities including hospitals, nursing homes and schools. Figures 7-12 and 7-13 depict the locations of hospitals, nursing homes and schools in the areas of Orange and Jefferson Counties that would be protected by the TSP. Flooding depths for the Orange 3, Beaumont A, and Jefferson Main Alternative Reaches are approximately 6-8 feet (estimated depths of flooding at the 1% ACE from the economic analysis). Disabled residents are a high risk population that would be particularly vulnerable in 6 to 8 feet of flooding if there were not sufficient lead time for evacuations or if evacuation procedures are not implemented

appropriately. Approximately 19% of the 178,884 people at risk in the Orange-Jefferson CSRM project area, or 33,000 people, would be considered disabled (2015 U.S. Census). Of the approximately 500,000 people in New Orleans during Hurricane Katrina, 100,000 were too elderly, disabled, or lacked transportation and resources to evacuate, with disastrous results (2015 datacenterresearch.org) and it is assumed that the Orange-Jefferson CSRM project area could experience similar outcomes. In addition, given the critical infrastructure and refining capacity also located in the project area, a compelling argument can be made to provide a higher level of storm surge risk reduction by building a foot higher than the current TSP.

In addition to increased life-safety benefits, there are other non-traditional secondary or ancillary economic benefits not included in the NED Plan that should be considered, including preventing disruptions in business such as loss of revenue, wages, and sales tax, and their multiplier effects. The cost of emergency response and clean up would also be avoided. Most importantly, increased protection would also avoid disruption to significant industrial and manufacturing facilities located in the project area, notably, the Motiva and Exxon Mobil refineries that have the capacity to refine 945,000 barrels of crude oil per day and can produce 6.7 billion gallons of gasoline annually. In 2014 the U.S. Energy Information Administration reports that the U.S. consumed 136.78 billion gallons of gasoline. These two refineries alone can produce about 5%

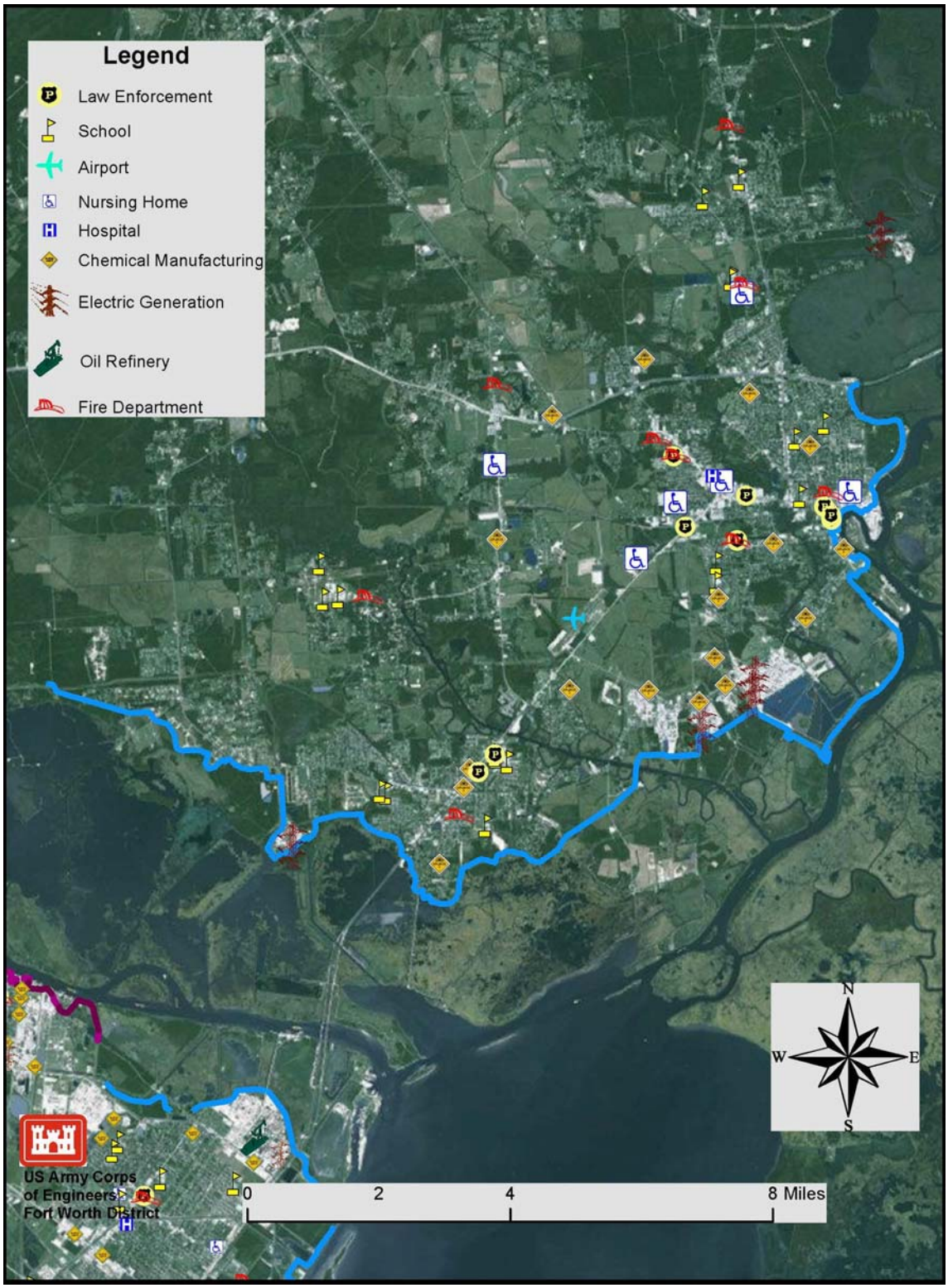

Figure 7-12. Orange County Critical Infrastructure

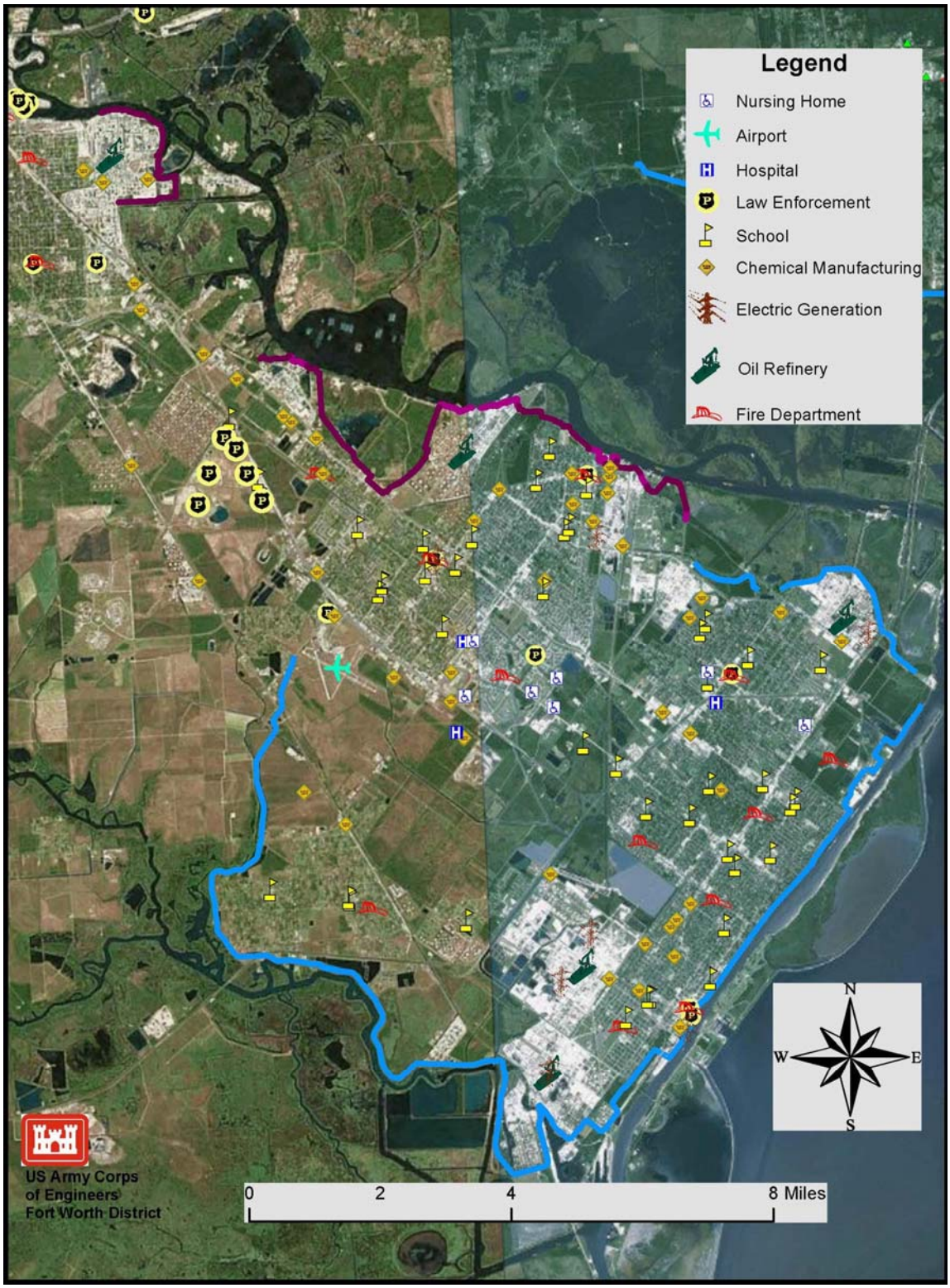

Figure 7-13. Jefferson County Critical Infrastructure

of that demand. If they were running at full production with gas prices at $2.50/gallon and were to go out of production for even a month, this could be up to a $1.4 billion hit to the national economy and would be even more significant to the regional and local economies. Spending $72 million to provide an additional foot of performance and lower the probability of being impacted would seem to be a small investment to protect such significant infrastructure and would be worth the investment.

In addition, the current TSP could result in larger future project modifications to account for RSLC in the Orange-Jefferson CSRM project area. Efficiencies would be gained by spending an additional $72 million now to account for projected RSLC. Table 7-18 displays the ranges for RSLC for each of the alternative reaches. The deficit is already a concern for feasibility-level design and would need to be taken into further consideration in the study to ensure the recommended plan would meet USACE design criteria for RSLC. With this in mind, the 12-foot levees would perform better than the NED Plan when considering RSLC scenarios and would be worth the additional Federal investment. If the NED plan remains the final recommendation from the Senior Leader Panel at the ADM, then it may still be appropriate for the Corps to consider cost sharing in the design and construction of any recommended floodwall or I-wall to accommodate future construction for RSLC adaptation. This expense would be minimal compared to the significant expense of project replacement in the future.

Table 7-18. Ranges for RSLC for the Orange-Jefferson CSRM Project Area

Orange 3	**Range of RSLR Projected**
11-foot Raise	-1.3 – 4.8 feet deficit
12-foot Raise	-0.5 – 3.8 feet deficit
13-foot Raise	0.5 surplus - 2.8 feet deficit
Beaumont A	
11-foot Raise	-1.3 – 4.8 feet deficit
12-foot Raise	-0.5 – 3.8 feet deficit
13-foot Raise	0.5 surplus - 2.8 feet deficit
Jefferson Main	
11-foot Raise	-1.3 – 4.8 feet deficit
12-foot Raise	-0.5 – 3.8 feet deficit
13-foot Raise	0.5 surplus - 2.8 feet deficit

7.5.1 Selection of the Recommended Plan Summary

Based on the planning objectives and USACE policy, the TSP is likely to be considered the Recommended Plan as listed in Section 7.1.8 and described in detail in Section 6 of the main report. This does not preclude a decision to refine or alter the TSP at the ADM based on responses from public, policy and technical reviews of the DIFR-EIS, specifically for the Orange-Jefferson CSRM. Compelling factors exist to support a decision to select a plan at least one foot higher than the NED Plan based on economics (the higher plans provides more net benefits), life safety (the lower the probability of flood event damaging property generally results in lower risk to loss of life), critical infrastructure (major oil refineries that could produce significant impacts to local,

regional, and the national economy), and RSLC (a resilient project would be cheaper to build it now rather than retro-fit it later). A final decision will be made at the ADM following the reviews and higher-level coordination within USACE to select a plan for feasibility-level design and recommendation for implementation. The decision made, ie., NED versus a foot higher, will be documented in the FIFR-EIS. A supplemental DIFR-EIS would not likely be produced unless there are substantial design changes that significantly alter environmental impacts. Coordination with the natural resource agencies will continue throughout the study process as required by the Fish and Wildlife Coordination Act.

7.5.2 Cost Summary of the Recommended Plan

The cost estimate included here is intended to provide an estimate of total costs of the TSP. An MCACES cost estimate will be provided for the plan selected for feasibility-level design. The TSP cost is included in Table 7-19 through 7-20. Figures 7-14 through 7-16 provide a graphic representation of the TSP.

Table 7-19. Economic Summary of the 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 7-20. Economic Summary of the 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
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**

Table 7-21. Economic Summary of the 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**

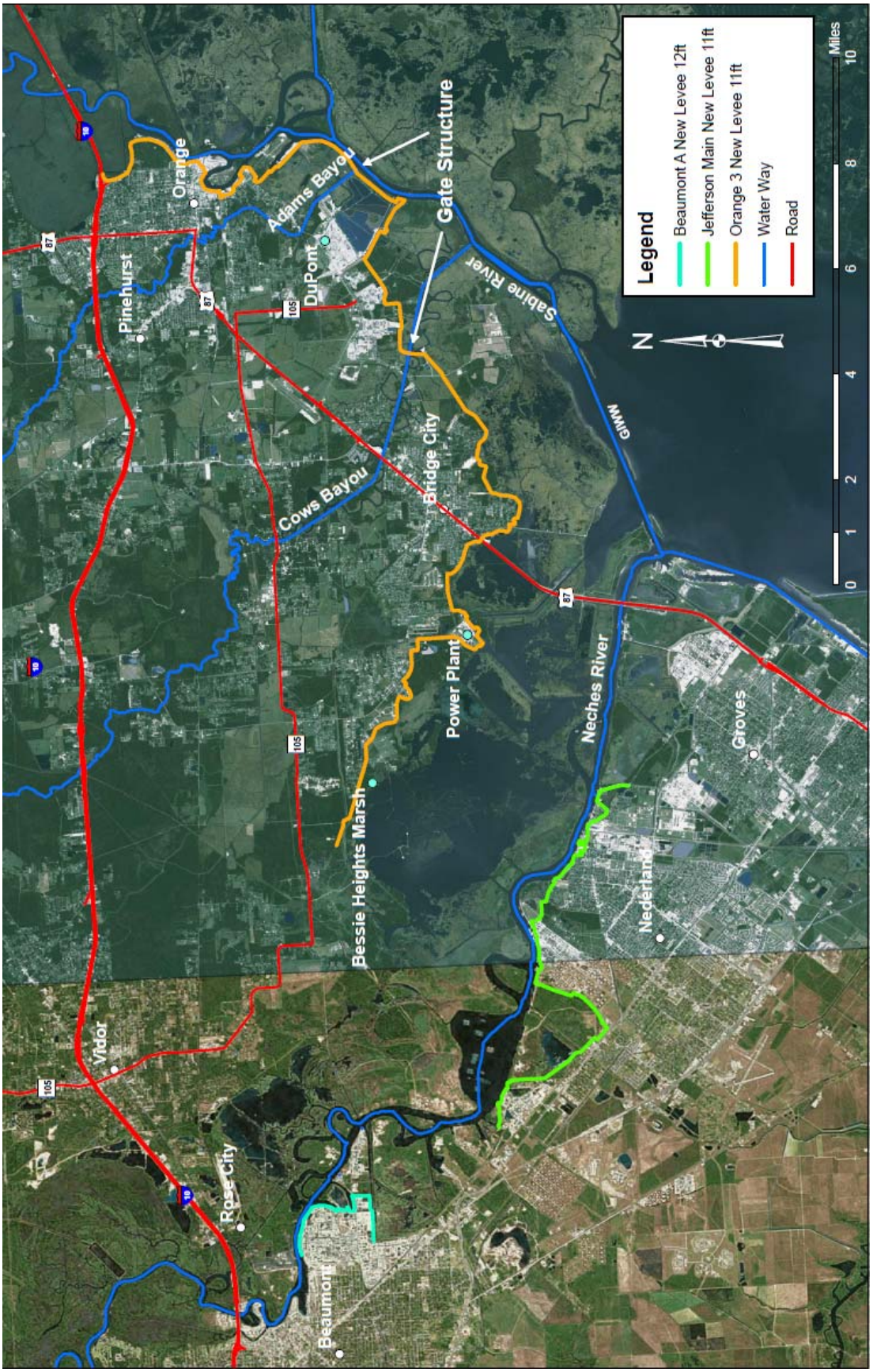

Figure 7-14. Orange-Jefferson CSRM Plan

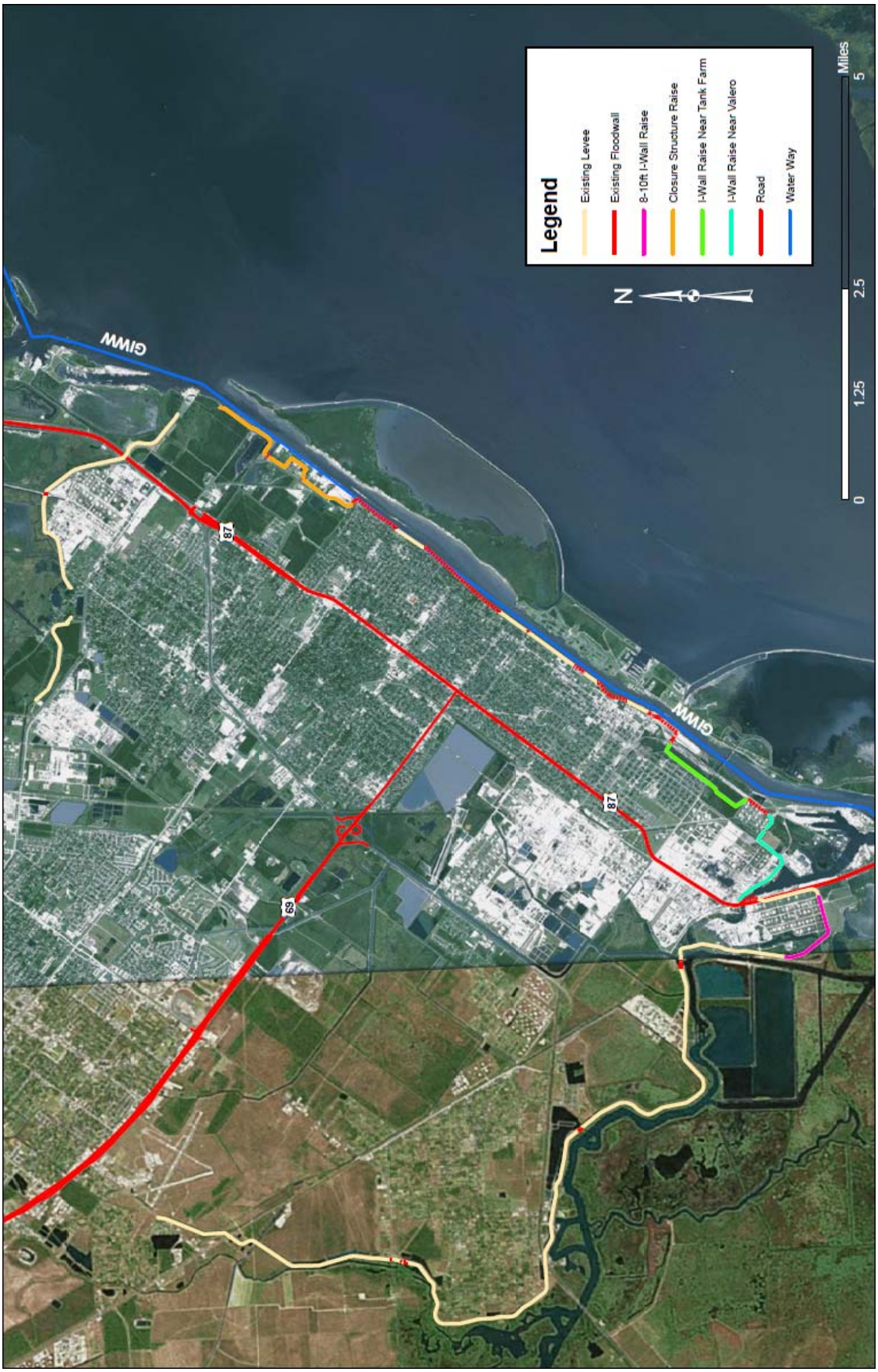

Figure 7-15. Port Arthur and Vicinity CSRM Plan

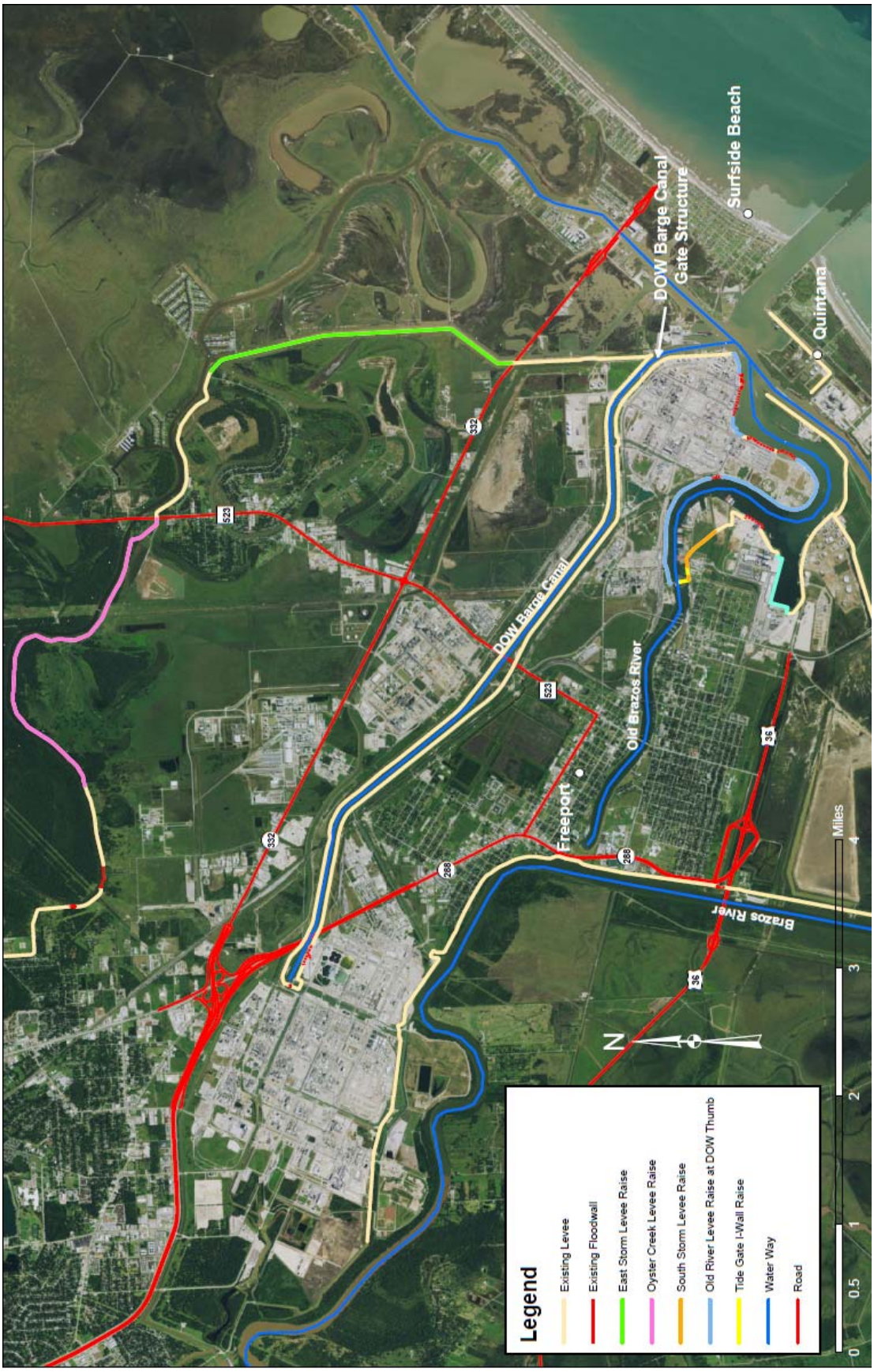

Figure 7-16. Freeport and Vicinity CSRM Plan

7.5.3 Separable Elements

A separable element is any part of a project which has separately assigned benefits and costs, and which can be implemented as a separate action (at a later date or as a separate project). Orange-Jefferson, Port Arthur, and Freeport CSRM Plans function individually and are separable. Each piece of Port Arthur and Freeport are not separable elements but need to be constructed together in order to function as a system. For Orange-Jefferson CSRM Plans on the other hand, the Alternative Reaches could potentially be separated out.

7.5.4 Changes to TSP and Selection of the Recommended Plan Summary

As described in the DIFR-EIS the alternatives in each project area were evaluated in detail, then compared against each other to identify which plan contributes most to the objectives. This process continued throughout the detailed feasibility analysis. As described in section 7.1.19., after the release of the DIFR-EIS, and after policy, public, ATR, and IEPR reviews a Senior Leader Panel Agency Decision Milestone (ADM) was held to confirm the TSP and initiate detailed feasibility-level design. Table 7.22 presents an overview of the TSP and changes from the DIFR-EIS. During technical reviews and based on new information from the feasibility level design phase of the study, additional work and other assessments were completed for several of the features presented in the DIFR-EIS as the TSP. Additional details on features such as, required pump stations, required road crossings and required OMRR&R increased the overall construction and OMRR&R cost for all plans. The sections below explain the changes that have occurred since the release of the DIFR-EIS.

Table 7-22: Overview of changes since release of DIFR-EIS

Project Area	Elements presented in Sept 11, 2015 DIFR-EIS	Elements in Final Recommendation
Orange-Jefferson CSRM	Orange 3 New Levee (11-foot)	**Included in Final Recommended Plan**
	Beaumont A New Levee (12-foot)	Removed due to limited net benefits, and recently constructed risk reduction improvements.
	Jefferson Main New Levee (11-foot)	Removed due to limited net benefits
Port Arthur and Vicinity CSRM	8-10 ft I-Wall Raise (1-foot)	**Included in Final Recommended Plan**
	Closure Structure Raise (1-foot)	**Included in Final Recommended Plan**
	I-Wall Raise Near Valero (1-foot)	**Included in Final Recommended Plan**
	I-Wall Raise Near Tank Farm (1-foot)	**Included in Final Recommended Plan**
	-------	**Final Recommended Plan included an additional 1,830 LF of new levee added to Existing Port Arthur and Vicinity HFPP to address flanking of surges**
Freeport and Vicinity CSRM	Dow Barge Canal Gate Structure	**Included in Final Recommended Plan**
	Oyster Creek Levee Raise (1-foot)	**Included in Final Recommended Plan**
	East Storm Levee Raise (1-foot)	**Included in Final Recommended Plan**
	Freeport Dock Floodwall Raise (1-foot)	**Included in Final Recommended Plan**

	Old River Levee Raise at Dow Thumb (1-foot)	**Included in Final Recommended Plan**
	Tide Gate I-Wall Raise (1-foot)	**Included in Final Recommended Plan**
Brazoria and Sabine Nonstructural	-------	Buyouts were considered ancillary to the implementation of new levees/floodwalls in Orange and Jefferson Counties and to the enhancement of features in the Port Arthur and Freeport CSRM project areas. Buyout opportunities in Brazoria were virtually non-existent and very limited in both Orange and Jefferson Counties. A quantitative analysis was conducted to determine the viability of any proposed nonstructural buyout. The analysis showed the nonstructural buyouts had negative net benefits and any potential buyouts were screened from the analysis.

7.5.5 Removal of Beaumont A New Levee (12-foot) and Jefferson Main New Levee (11-foot) from Recommended Plan

After the ADM, the Beaumont A New Levee (12-foot) and Jefferson Main New Levee (11-foot) were removed from consideration under the Recommended Plan. Beaumont A New Levee (12-foot was removed due to recent the local industrial actions to reduce the area's risk from storm surges. In the last few years the local industries have developed a levee and floodwall system at the same location as the TSP (Figure 7-14 and Figure 7-15). The structural integrity of the existing system is not fully known; however, an assessment of the systems height appears to place it above the heights considered in the Recommended Plan. Additional detailed economic evaluation of Beaumont A was not performed following the ADM; however, it was estimated that the current residual economic damages and life-safety risk are now limited. Risk from storm surge flooding is mainly concentrated to the industrial areas which is now being mitigated for with the newly constructed system. Based on the considerations above the Beaumont A New Levee (12-foot) was removed from the final Recommended Plan.

Figure 7-17. Local industrial CSRM Improvements near Beaumont A

The Jefferson Main New Levee was removed from the final Recommended Plan based on a lack of local sponsorship and due to the limited perceived benefits. During the concurrent review period, local entities suggested that the economic performance of Jefferson Main should be reevaluated because there was not a perceived need for this component of the TSP. There was limited life-safety risk due to the industrial makeup of the area. Based on results of these evaluation, the sponsor decided to not to pursue this component of the final Recommended Plan.

7.5.6 Reevaluation of Orange 3 as a component of the Recommended NED Plan

Due to the increases in construction cost and OMRR&R there were concerns on whether Orange 3 required a reevaluation against other alternatives to confirm it was still the NED component of the plan. The selected plan does obtain positive net benefits, but during final technical reviews there were question on whether other measures or alignments such as the Gate and No-Gate Alternatives discussed in section 5.3.2 would have achieved higher net benefits if carried forward through feasibility design. The sections below explains why the Orange 3 plan is still the plan that reasonably maximizes net benefits.

7.5.6.1 Revaluation of Orange 3 vs Gate

As described in section 6.2.11 an analysis for an alternatives to cross the Neches River was developed to investigate cost saving with the Gate and No-Gate Alternatives. At the time of the DIFR-EIS the cost of the Gate Alternative was approximately $865 million more expensive than the No-Gate Alternative. Although there were significant cost increases from the TSP to the

Recommended Plan the estimated first cost differences presented under the DIFR-EIS would not have changed plan selection by making the "gate" alternative a cheaper alternative. Cost increases would have also been applied to the gate alternative. The "gate" alternative includes additional factors, shown in table 7-23, limited its viability.

Table 7-23: Planning Review of "gate" alternative

Areas of Focus	Planning Evaluation
Cost	West of Bridge City the final Recommendation included 33,700 lf of levees and 9,500 lf of floodwalls (43,200 lf Total) and although the "gate" is approximately half that length, the cost per linear foot for a floodwall crossing a river system is significantly higher vs a levee system built near upland areas due to soil stability in the area.
	The two largest pump stations Adams and Cow Bayou would still be included in the Orange 3 system with or without the gate option. The overall structure cost account will just increase with another structure across the Neches River.
	A gate across the Neches River would significantly increase the annual OMRR&R.
Benefits	There would be limited benefits to be gained on the east and west side of the Neches River above the point of the gate closure. As described in section 7.1.23, the current residual economic damages and life-safety risk are now limited. Risk from storm surge flooding is mainly concentrated to the industrial areas which is now being mitigated for with the newly constructed system.
Environmental Impacts	The floodwall and gate crossing the Neches River would impact additional wetlands. Also, there would be concerns with indirect impacts. None of these cost were included in the original evaluation.

7.5.6.2 Reevaluation of Orange 3 vs Ring Levees or Nonstructural Measures

As described in section 7.1.22 additional details on features such as, required pump stations, required road crossings and required OMRR&R increased the overall construction and OMRR&R cost for the Recommended Plan. One of the largest cost changes for Orange 3 was the addition of the two largest pump stations in the system at Adams and Cow Bayou. Due to the large increases in cost with these features additional investigation into removing these features were conducting. Based on the FWOP conditions it was determined that the only two viable alternatives investigating were smaller ring levee systems avoiding the gates and pump stations on Adams and Cow Bayou or complete acquisitions of structures at risk.

Nonstructural Measures, such as acquisitions of structures to achieve the same level of benefits as the Recommended Plan were deemed to be infeasible and would be detrimental to community cohesion in the area. Over 9,000 residential and nonresidential structures are in the 100 yr floodplain (Figure 6-3 and Figure 7-18) and would have to be relocated out of the floodplain.

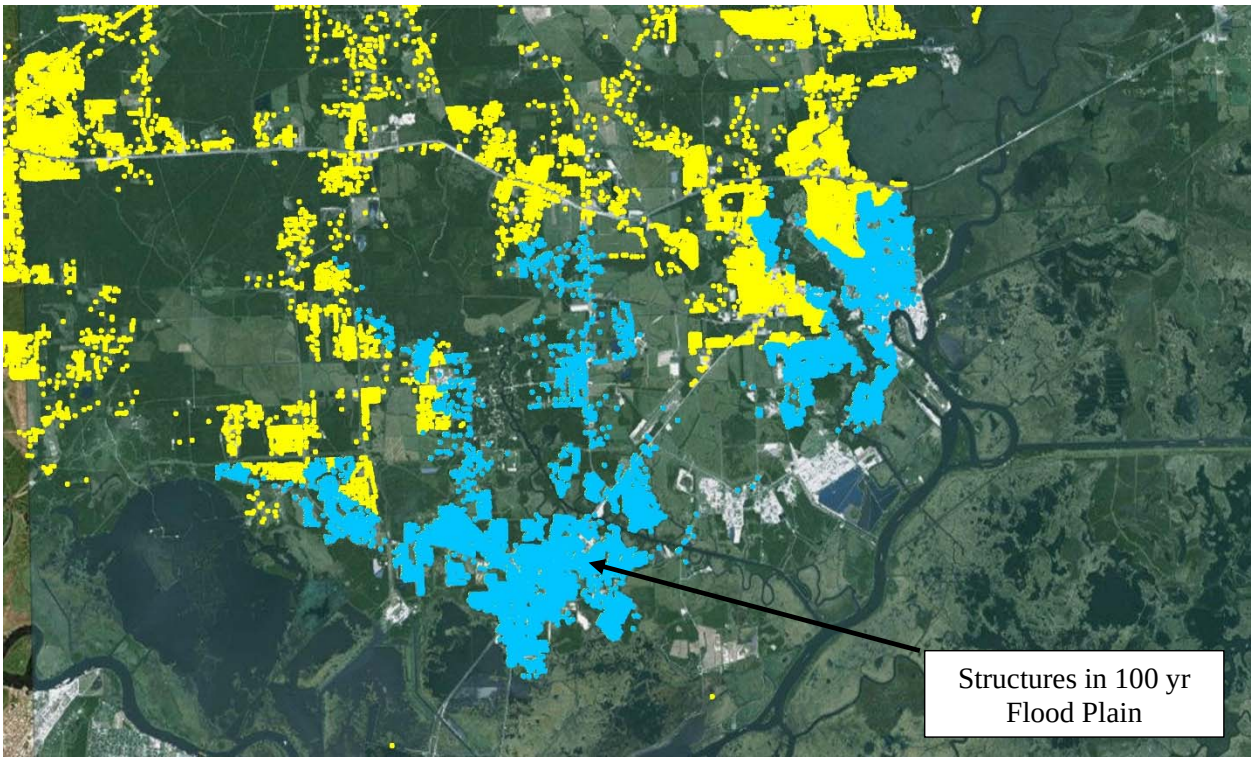

Figure 7-18. Orange 3 Structures in 100 yr Flood Plain

(Note: As shown structures in geographic view. Structures' first floor maybe above the 100 yr Flood Plain)

Structures would have to be relocated outside of the existing communities and rough order magnitude (ROM) cost estimates that this cost, $3.2 B would be well over the existing cost for Orange 3, $1.5B. Relocating outside of the floodplain would also have NED tradeoffs. Although NED damages would be avoided, residents and local municipalities would occur increased NED cost, since many of the vital commercial activities would still take place within the floodplain. Many of the residents in the area depend on the local waterways for commerce. There would be added travel times to reach these commerce centers adding to increased NED cost.

A review of measures using ring levees enclosing the same benefit areas as Orange 3 was also conducted to determine if there would be cost saving by removing the high cost features along Adams and Cow Bayou. The segments of the levee and pump stations removed are shown in yellow on Figure 7-19.

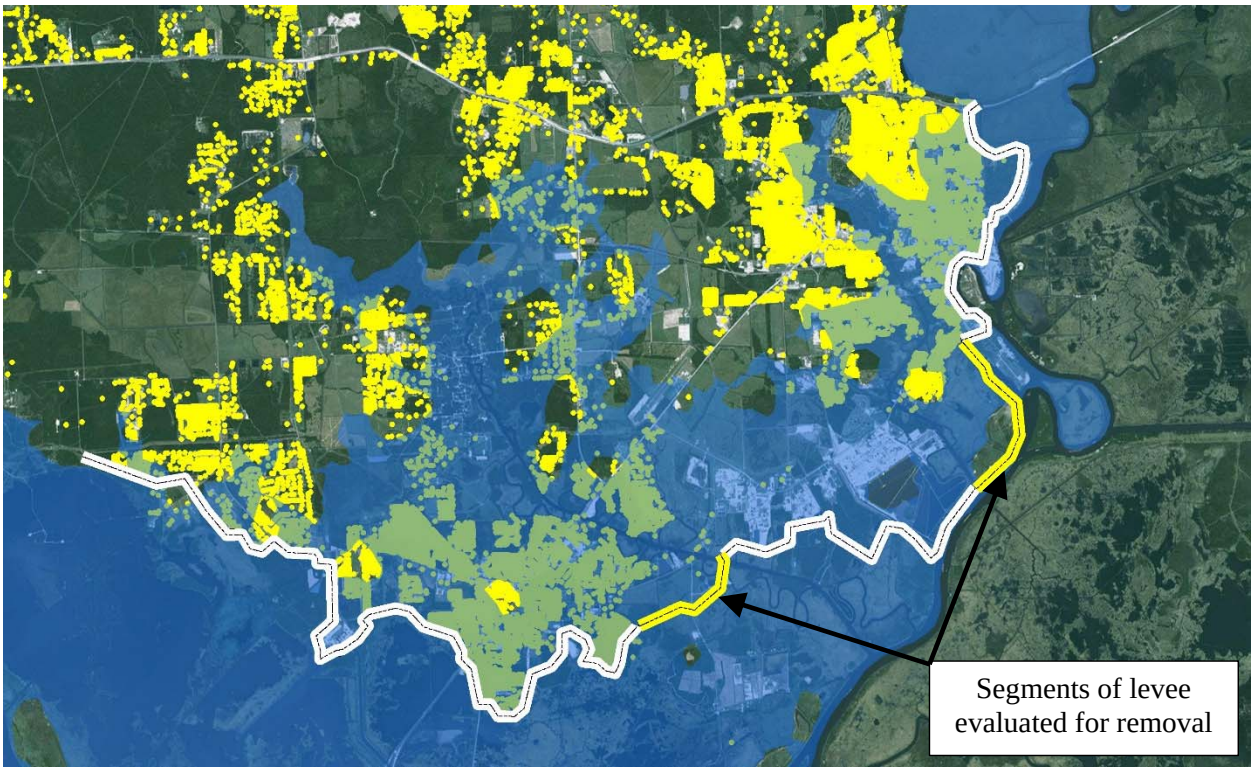

Figure 7-19. Orange 3 Evaluation of Adams and Cow Bayou

The evaluation determined that due to the extent of the flooding and very flat nature of the flood plain, ring levees would not have been a viable alternative. Although the plan would have removed two of the large pump stations, smaller ring levees would have required additional cost, further reducing the economic viability of this option. As shown on Table 7-24 smaller ring levee would have add 29 extra miles of levees and floodways to obtain the same level of risk reduction as with the Adams and Cow Bayou closures. There would also be added cost with approximately 30 extra drainage, railroad and roadway crossings. Environmental impacts, as also shown in table 7-24, would have limited this alternatives viability. All of these features would have doubled the size of the system that would have to be operated under storm event (Figure 7-20), making it an unreasonable alternative when compared to the Recommended Plan.

Table 7-24 Evaluation of Orange Ring Levees

Review Parameter	Options Reviewed			vs	Recommendation: Orange 3	Comments
	System of Ring Levees					
Cost	Ring 1 (Bridge City)	14.58 miles	Total of 55.6 Miles		Total of 27 miles	Requires ~29 extra miles of levees and floodwalls with system of ring levees option. Plan removes Adams and Cow Bayou Gate structures and pump stations, but the addition of ~29 miles of levee/floodwall, would increase the overall cost of plan when compared to the recommended plan. There could be adjacent impacts (induced flooding) to areas previously behind levee
	Ring 2 (Industrial Area)	16.32 miles				
	Ring 3 (City of Orange)	24.7 miles				
	12 Additional New Significant Roadway/Railroad Crossing				32 Closure Gates (Road/Railroad Crossings)	Most of the 32 closure gates exist near the City of Orange which wouldn't be removed with smaller ring levees. Ring Levee would cross major highways; and evacuation routes that were avoided under the single levee plan.
Environmental	Ring 1 (Bridge City)	~ 3 miles of habitat along Cow Bayou	~ 6.5 miles of habitat		Currently impacts are to less than 2 miles when crossing Cow and Adams Bayou.	A switch to ring levees would have significant impacts to the Adams and Cow Bayou habitat. The system would require significant environmental control features for the ring levees. This would also add to the overall cost.
	Ring 2 (Industrial Area)	~1 mile of habitat along Cow Bayou ~1.5 miles of habitat along Adams Bayou				
	Ring 3 (City of Orange)	~.1 miles of habitat along Adams Bayou				
Life Safety Risk	Increased Life Safety Risk to residents inside of the small ring levees. There would be minimum time to react to exceedance events due to the limited storage capacity. Also all evacuations routes would likely be flooded.	Increased Life Safety Risk to residents outside of the ring levee system. There could be induced stages outside of the ring levees and changes in historical flood patterns could catch resident off guard.			Under exceedance events the surge overtopping the system would be allowed to expand over the flat coastal flood plain. Under the current plan there are limited structures outside of the proposed levee system, reducing the risk of induced stages and life safety risk.	Smaller ring levees would go against a key Constraint: Structural plans do not increase life-safety risk.

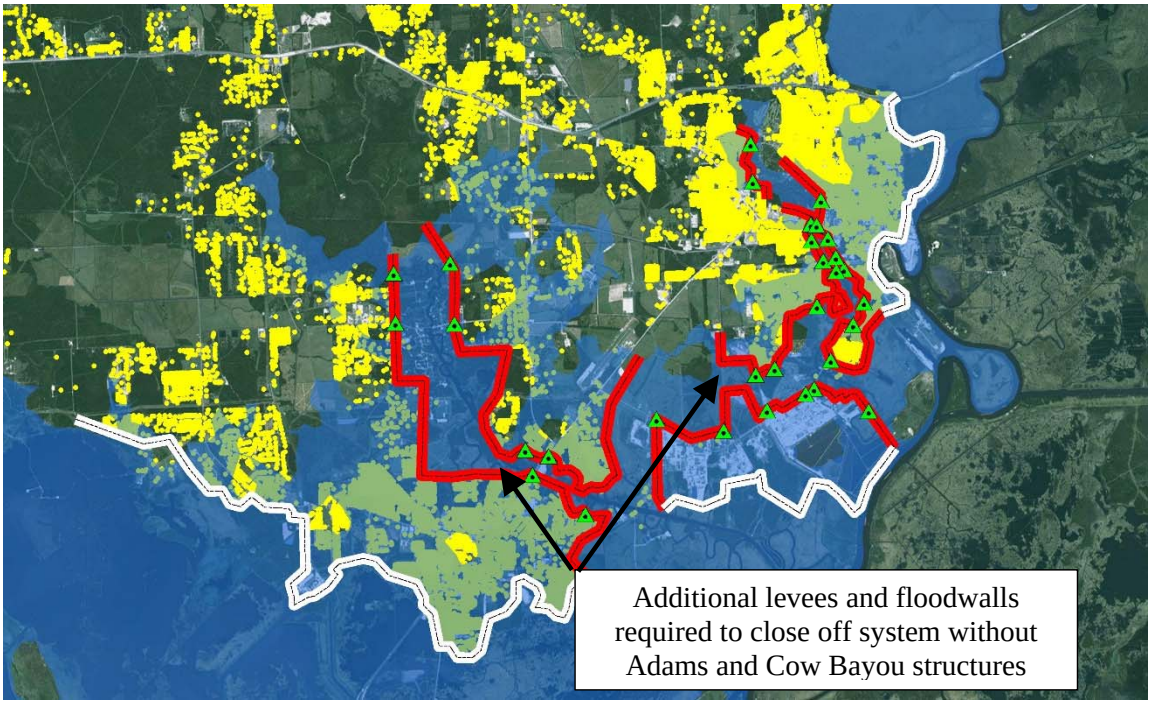

Figure 7-20. Orange 3 Evaluation of Adams and Cow Bayou Structures Removed

7.5.7 Confirmation of Orange 3 as a component of the Recommended NED Plan

Based on the information presented in Section 7.5.6, Orange 3 still would have the lowest total cost (including mitigation), the highest BC ratio, and the highest net benefits. In conclusion, Orange 3 is still the plan that maximizes NED benefits while protecting the nation's environment, pursuant to national environmental statutes, applicable executive orders, and other Federal planning requirements.