APPENDIX 5-E
CITY OF KILGORE DOWNTOWN STORM SEWER MASTER PLAN

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Innovative approaches
Practical results
Outstanding service


Downtown Storm Sewer Master Plan

Prepared for:

City of Kilgore

August 2014

Prepared by:

FREESE AND NICHOLS, INC.
2711 North Haskell Avenue, Suite 3300
Dallas, Texas 75204
214-217-2200

KLG13364

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TEXAS REGISTERED ENGINEERING FIRM F-2144

KLG13364

TABLE OF CONTENTS

List of Figures

List of Tables

List of Appendices

BACKGROUND

Freese and Nichols, Inc. (FNI) was contracted by the City of Kilgore (City) to study the storm sewer system located in the downtown area. The project area for this storm sewer study is roughly bordered by Commerce Street to the west, Kilgore Street to the north, Highway 101 to the south, and U.S. Highway 259 to the east. The downtown storm sewer system consists mainly of pipe systems and a few open channels. There are five (5) main trunklines (North Main, North Subsystem A, North Subsystem B, South Main and South Subsystem) with several laterals. There are two open channels located in Kilgore City Park, one open channel between residential properties southwest of North Street, and the main outfall channel is located east of U.S. Highway 259 and north of Kay Street. See Figure 1 for a location map.

The U.S. Environmental Protection Agency's Storm Water Management Model version 5.0.018 (EPA-SWMM) was used for the hydrologic and hydraulic analysis of the downtown area. This software was selected for its capabilities in analyzing pipe flow, channel flow, and street flow simultaneously. Data collected from the City and field survey using a handheld GPS system allowed FNI to accurately model existing conditions for all systems.

Data Collection

Two main sources of information were used to develop the storm sewer pipe systems. The sources are listed below with brief descriptions. Figure 2 shows a summary of the source data for the study area.

<u>FNI Field Survey Team</u>

FNI sent a survey team to Kilgore to collect information on all accessible storm sewer inlets, manholes, channels, headwalls and outfalls within the downtown study area. A Trimble survey-grade GPS was used to obtain ground elevations for all survey points. Invert elevations and pipe sizes were obtained using a measuring tape down hole. Channel geometry was measured in the field. FNI staff documented any observed maintenance issues such as clogged inlets or pipes and noted any inaccessible inlets or manholes that would need City assistance to access. A summary of the observed maintenance issues is shown in Figure 3.

<u>City of Kilgore</u>

The City provided FNI with as-builts for the existing storm sewer system along Main Street between Kilgore Street and Rusk Street as shown in Figure 2. KSA Engineers completed these as-builts in February of 2010. These as-builts were used in conjunction with the survey obtained from FNI to confirm proper delineation of the pipe network.

The City sent maintenance crews out to the manholes that were marked by FNI's field survey team as inaccessible to collect data that was sent back to FNI. The City provided 2-foot contours which were used for drainage area delineations.

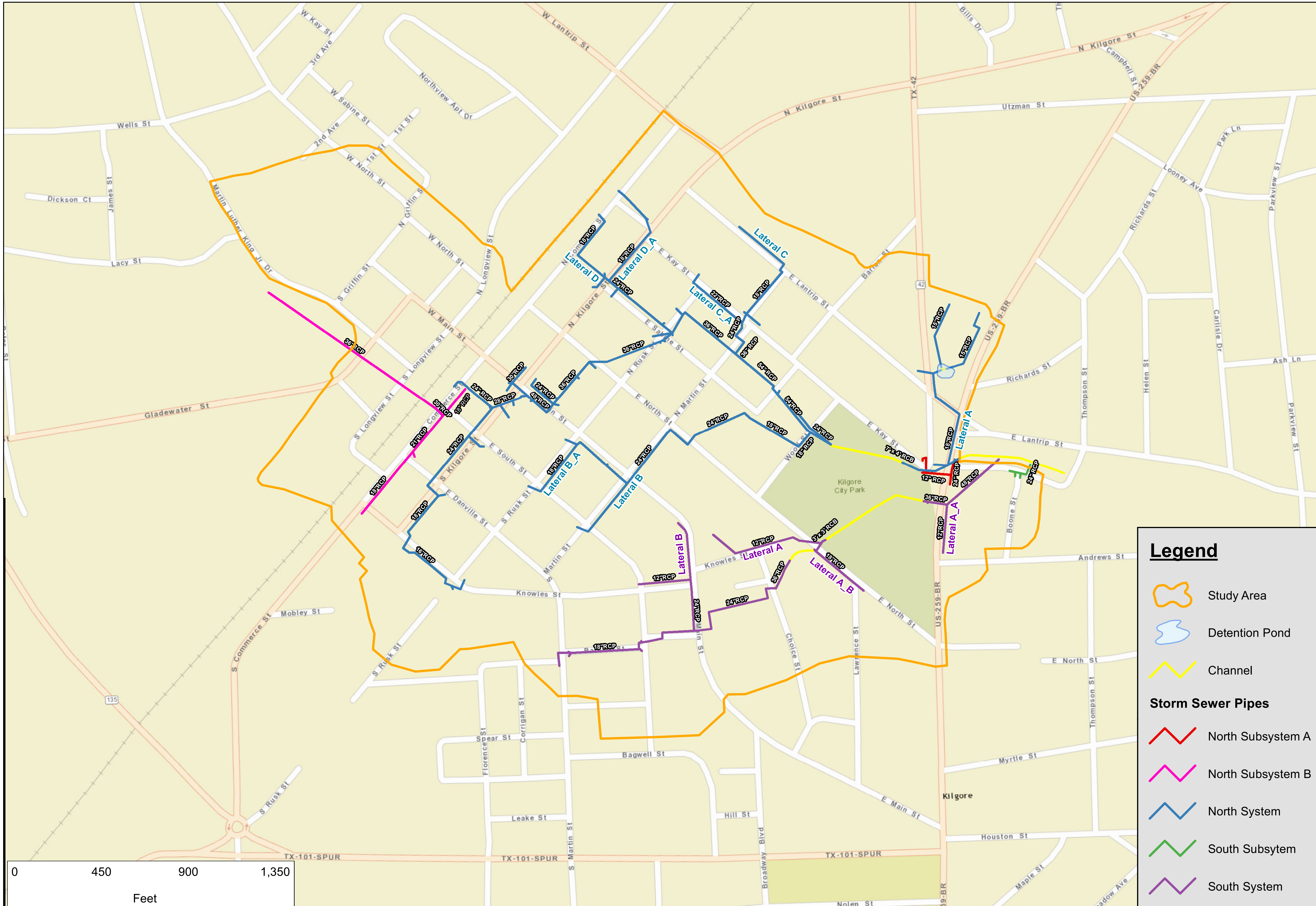
METHODOLOGY

Hydrology

The hydrologic analysis for each system was performed using EPA-SWMM. Drainage areas were delineated using 2-foot topography from the City of Kilgore for groupings of inlets or for single inlets, as deemed appropriate. This method was chosen to simplify the EPA-SWMM model. The SCS Curve Number method was used for determining runoff. Time of concentration and lag time calculations were performed for all drainage areas based on 2-foot contours and GIS aerials. Rainfall data was obtained from the *City of Kilgore Engineering Design Manual* for the 2-, 5-, 10-, 25-, and 100-year storm frequencies. Curve numbers were determined by using the City of Kilgore Future Land Use map and USDA soil data. Soil classification for this area is all B soils. There were no large variances between future and existing land use within the study area. Due to the minor difference in land use, only future land use was used to determine the composite curve number values for the subcatchments.

Hydraulics

The hydraulic analysis for each system was performed using EPA-SWMM. A hydraulic model was developed in EPA-SWMM to represent storm water runoff throughout all systems. Cross sections for streets and channels were estimated from field visit data and 2-foot contours to account for right-of-way exceedance and flow outside the channel banks. Flow routing throughout each drainage area was represented in EPA-SWMM using junctions, conduits, weirs, orifices, storage units and outfalls. Junctions were placed throughout each model at subcatchment outlets and at critical points within the drainage area where hydraulic information was needed. All pipes in this system were assumed to be reinforced concrete with a roughness coefficient of 0.013 unless otherwise indicated. Entrance loss coefficients ranged between 0.50 and 1.25 while an exit loss coefficient of 1.0 was used for all pipe segments. Curb inlets were modeled as weirs with a length equivalent to the sum of the inlet openings where more than one inlet was present. Grate inlets were modeled as orifices. The hydraulic model was constructed so that each area of downtown could be analyzed in detail to see where possible flooding issues may occur.



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DATE:	July, 2014
SCALE:	5,400
DESIGNED:	LMB
DRAFTED:	ETB
FILE:	1_Overall_Map.mxd

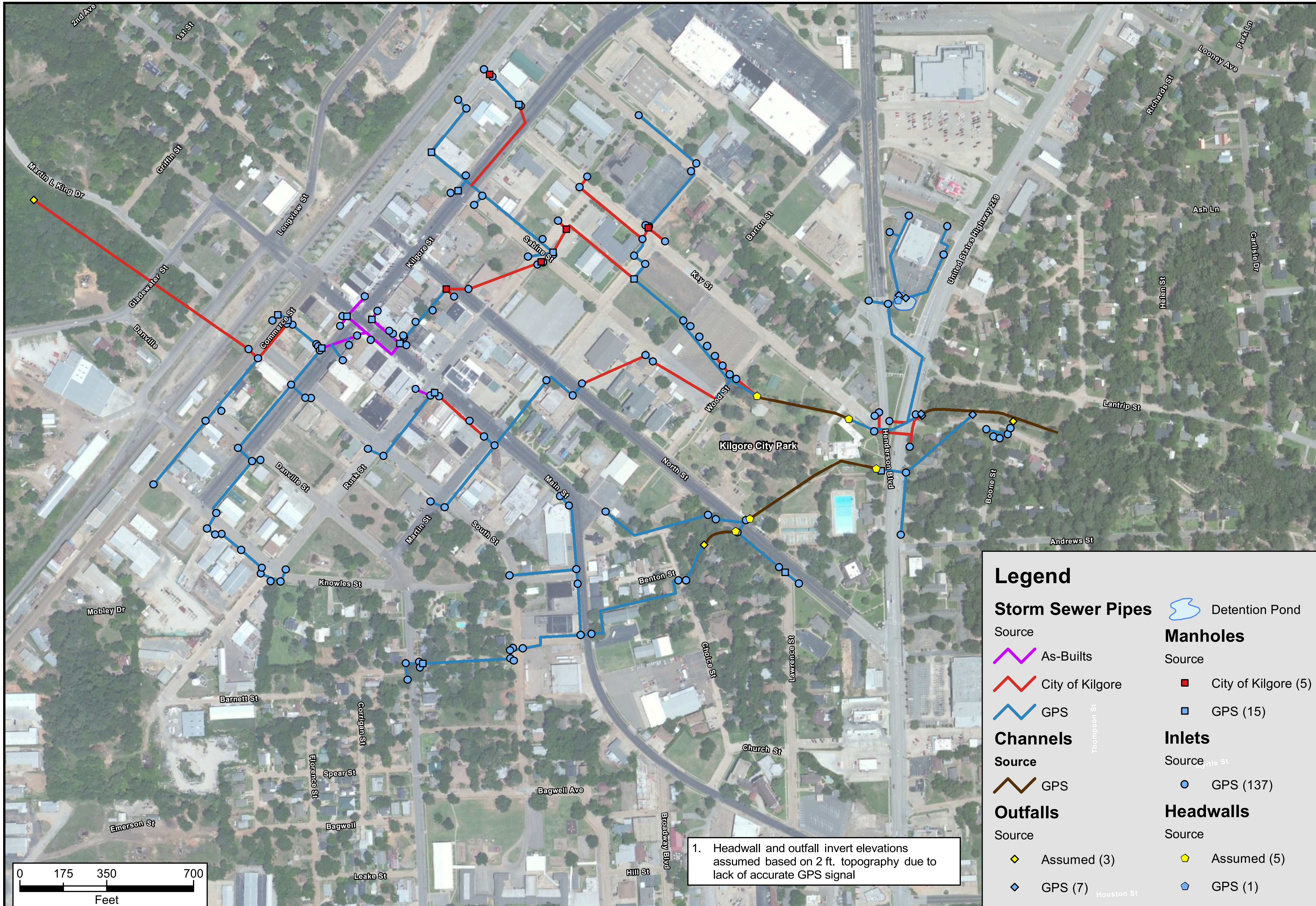
City of Kilgore

Location Map

Freese and Nichols
4055 International Plaza Suite 200
Fort Worth, Texas 76109-4895
817-735-7300

FIGURE

1



F&N JOB NO. KLG13364

DATE: July, 2014

SCALE: 4,200

DESIGNED: LMB

DRAFTED: ETB

FILE: 2_Source Info Map

City of Kilgore

Source Information Map

N S E W

Freese and Nichols

4055 International Plaza Suite 200
Fort Worth, Texas 76109-4895
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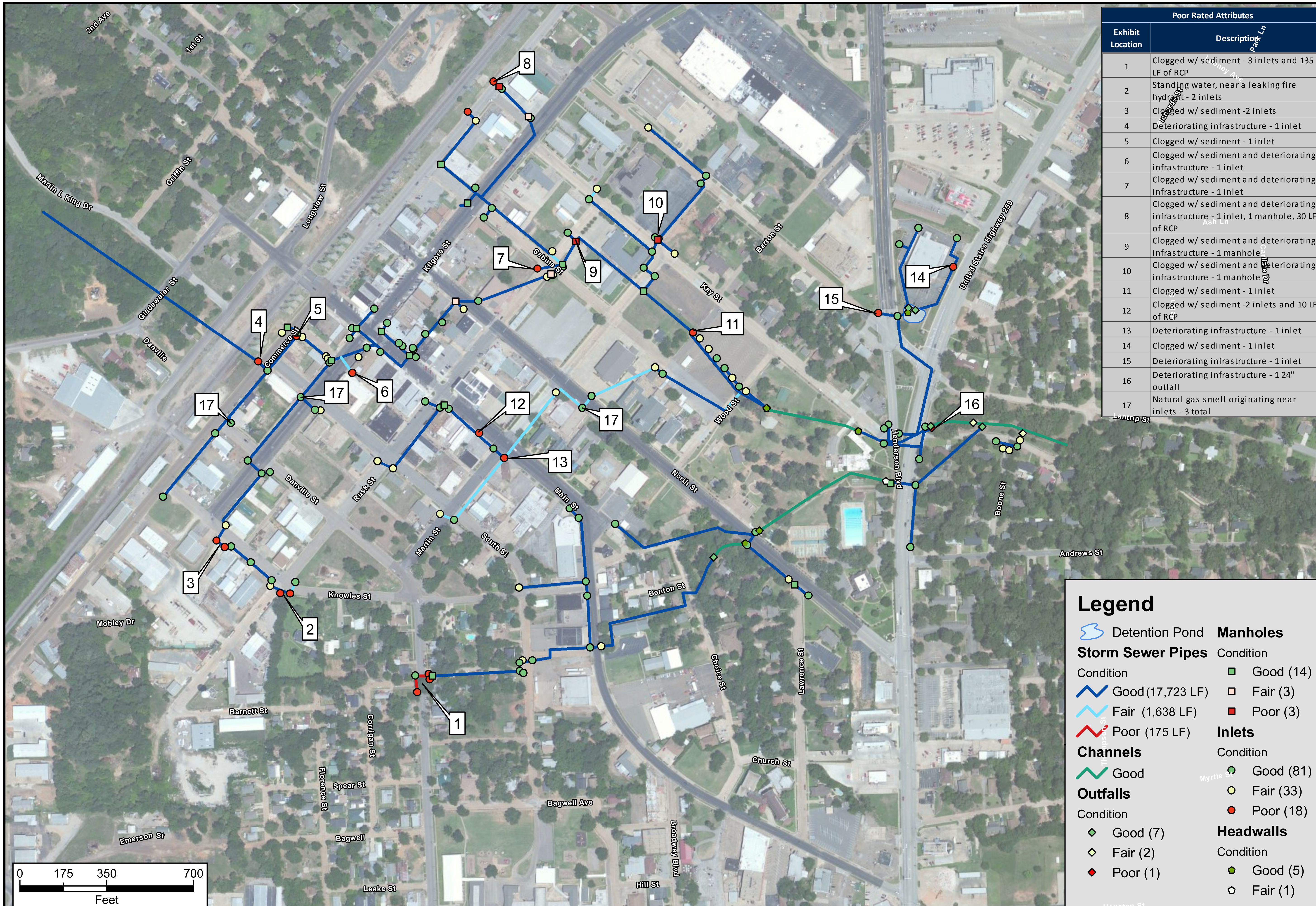
FIGURE

2



Poor Rated Attributes	
Exhibit Location	Description
1	Clogged w/ sediment - 3 inlets and 135 LF of RCP
2	Standing water, near a leaking fire hydrant - 2 inlets
3	Clogged w/ sediment -2 inlets
4	Deteriorating infrastructure - 1 inlet
5	Clogged w/ sediment - 1 inlet
6	Clogged w/ sediment and deteriorating infrastructure - 1 inlet
7	Clogged w/ sediment and deteriorating infrastructure - 1 inlet
8	Clogged w/ sediment and deteriorating infrastructure - 1 inlet, 1 manhole, 30 LF of RCP
9	Clogged w/ sediment and deteriorating infrastructure - 1 manhole
10	Clogged w/ sediment and deteriorating infrastructure - 1 manhole
11	Clogged w/ sediment - 1 inlet
12	Clogged w/ sediment -2 inlets and 10 LF of RCP
13	Deteriorating infrastructure - 1 inlet
14	Clogged w/ sediment - 1 inlet
15	Deteriorating infrastructure - 1 inlet
16	Deteriorating infrastructure - 1 24" outfall
17	Natural gas smell originating near inlets - 3 total

Legend

Detention Pond

Storm Sewer Pipes

Condition

- Good (17,723 LF)
- Fair (1,638 LF)
- Poor (175 LF)

Channels

- Good

Outfalls

Condition

- Good (7)
- Fair (2)
- Poor (1)

Manholes

Condition

- Good (14)
- Fair (3)
- Poor (3)

Inlets

Condition

- Good (81)
- Fair (33)
- Poor (18)

Headwalls

Condition

- Good (5)
- Fair (1)

F&N JOB NO. KLG13364
DATE: July, 2014
SCALE: 4,200
DESIGNED: LMB
DRAFTED: ETB
FILE: 3_Maintenance Assessment Map.mxd

City of Kilgore

Maintenance Assessment Map

N
W
E
S

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FIGURE

3

NORTH SYSTEM

The main North System trunkline begins at the intersection of Knowles Street and S. Rusk Street as a 16” reinforced concrete pipe (RCP) winds through downtown heading northeast as a 36” RCP and continues southeast towards Kilgore City Park as a 54” RCP, where it outfalls into the northern channel in Kilgore City Park east of Wood Street. Runoff is conveyed through the open channel until it enters a 7’ x 4’ reinforced concrete box (RCB) under U.S. Highway 259 that discharges into an open channel east of U.S. Highway 259. Improvements to the storm sewer system along E. Main Street consisted of a 48” RCP that ties in to an existing 36” RCP according to the 2010 as-builts from KSA Engineering.

Two subsystems and several laterals are located within this system, which are shown in Figure 1. The watershed, including both subsystems, is 110.98 acres. The main laterals and subsystems include the following:

North Lateral A

Lateral A begins in the parking of lot of Walgreen’s between N. Henderson Boulevard and U.S. Highway 259. The parking lot collects runoff into two 15” RCPs that outfall into a detention pond south of the parking lot. The detention pond is approximately 3 feet deep and is approximately 0.37 acre-feet. Runoff is detained here then is carried under N. Henderson Boulevard in a 12” RCP. The 12” RCP increases to an 18” RCP then travels under E. Lantrip Street and U.S. Highway 259 before converging with the main 7’ x 4’ RCB west of the outfall.

North Lateral B

This lateral begins at the corner of South Street and Martin Street. The system runs northeast along Martin Street and beneath commercial property in a 24” RCP. The 24” RCP is reduced to an 18” RCP northwest of Wood Street before converging with the 54” RCP of the main trunkline upstream of the Kilgore City Park outfall.

North Lateral C

Lateral C includes an 18” RCP along Lantrip Street and a 22” RCP along Kay Street that converge into a 24” RCP at the intersection of Kay Street and N. Martin Street. The lateral increases to a 36” RCP before converging with the 54” main trunkline just south of N. Martin Street between Sabine Street and Kay Street.

North Lateral D

Lateral D consists of two separate 18” RCPs that collect runoff from N. Commerce Street that is conveyed south. The two lines converge at the intersection of Kilgore Street and Sabine Street into a 24” RCP. The lateral ties into the 36” RCP main trunkline at the intersection of Rusk Street and Sabine Street.

North Subsystem A

A smaller subsystem included in this North System is located at the northeast corner of Kilgore City Park. This pipe system collects runoff northwest of N. Henderson Boulevard between E. Kay Street and E. Lantrip Street in a 12” RCP. The system crosses N. Henderson Boulevard and outfalls into the channel east of U.S. Highway 259 as a 24” RCP.

North Subsystem B

Another subsystem included in the North System is located along Commerce Street. This system collects runoff starting at the corner of S. Commerce Street and Knowles Street in an 18” RCP and continues northeast along S. Commerce Street as a 21” RCP. An inlet from the north ties in at the intersection of Commerce Street and South Street with an 18” lateral. After the two laterals join the runoff is conveyed to the northwest with a 30” RCP that increases to a 36” RCP on the north side of Commerce Street. The 36” RCP continues northwest under the railroad and outfalls into a channel west of Martin Luther King Jr Drive. The outfall of this system was verified by City staff through dye testing.

Hydrology

The existing hydrologic analysis of the North System was performed by dividing the 110.98 acre drainage area into 67 subcatchments ranging in size from 0.04 to 8.76 acres. See Figure 4.

Runoff in this drainage area generally flows northeast and southwest towards the sag on Wood Street between Sabine Street and Kay Street before outfalling to the channel in Kilgore City Park. It is conveyed through the channel to the 7’ x 4’ RCB that intercepts the channel flow at the northeast end of the park and conveys it under U.S. Highway 259. Photo 1 shows the outfall to the east of U.S. Highway 259. A 24” RCP collects runoff from the corner of E. Kay Street and N. Henderson Boulevard and outfalls east of the 7’ x 4’ RCB. This outfall is independent of the box culvert and therefore had to be analyzed as a separate system, North Subsystem A, and is seen in Photo 2.

Photo 1 – 7'x4' RCB outfall underneath U.S. Highway 259 discharging to a concrete-lined channel

Photo 2 – 24" RCP outfall of North Subsystem A

EPA-SWMM was used to model hydrology for this system. Data was entered through the corresponding nodes, conduits and subcatchments to obtain peak flows shown in Table 1. The table is highlighted based on the color of the associated drainage areas in Figure 4.

Table 1- Drainage Area Attributes for North System

Drainage Area Name	Area (ac)	CN value	T_C (min)	Peak $Flow_{100yr}$ (cfs)
North System				
B-01	2.38	94	10.00	10.53
B-02	4.08	95	10.00	16.93
B-03	1.13	94	10.00	7.85
B-04	0.54	94	10.00	4.53
B-05	0.60	94	10.00	4.61
B-06	4.46	79	10.05	20.64
B-07	2.11	94	10.00	12.65
B-08	1.32	94	10.00	9.90
B-09	1.95	92	10.00	9.90
B-10	1.82	95	10.00	10.01
B-11	2.49	95	10.00	11.06
B-12	0.61	94	10.00	3.72
B-13	1.90	95	10.00	12.92
B-14	1.25	95	10.00	6.33
B-15	0.24	97	10.00	1.44
B-16	2.08	95	19.41	10.18
B-17	1.04	94	10.00	6.90
B-18	3.18	95	10.00	13.73
B-19	1.64	94	13.24	10.59
B-20	1.93	95	10.00	10.17
B-21	0.20	96	10.00	1.44
B-22	1.74	94	10.00	10.26
B-23	3.28	95	13.46	14.95
B-24	1.86	95	10.00	10.76
B-25	2.89	95	13.62	13.24
B-26	2.21	95	13.22	11.29
B-27	0.70	96	10.00	3.36
B-28	1.27	94	10.00	7.62
B-29	0.82	96	10.00	4.66
B-30	1.44	96	10.00	5.89
B-31	3.45	95	10.00	13.37
B-32	2.15	94	12.27	9.12
B-33	0.86	96	10.98	4.93
B-34	2.91	94	12.79	12.77
B-35	1.92	94	19.65	10.30
B-36	1.80	95	10.00	7.64
B-37	0.39	97	10.00	2.22
B-38	1.46	95	10.00	7.13

Table 1- Drainage Area Attributes for North System

Drainage Area Name	Area (ac)	CN value	T_C (min)	Peak Flow$_{100yr}$ (cfs)
North System				
B-39	0.20	94	10.00	1.79
B-40	0.18	94	10.00	1.10
B-41	0.04	96	10.00	0.32
B-42	0.32	96	10.00	2.05
B-43	0.23	96	10.00	1.25
B-44	0.63	96	10.00	3.28
B-45	0.41	97	10.00	2.10
B-46	0.91	96	10.00	6.45
B-47	1.80	96	10.00	7.91
B-48	1.55	95	10.00	6.93
B-49	0.80	94	16.68	4.65
B-50	0.69	95	10.00	3.64
B-51	1.82	95	12.58	8.16
B-52	0.63	96	10.00	3.97
B-53	2.50	95	10.80	12.79
B-54	0.58	97	10.00	2.85
B-55	3.06	95	13.67	13.23
B-56	1.26	95	10.00	5.67
B-57	2.19	91	10.00	11.40
B-58	0.49	92	10.00	3.15
B-59	3.65	86	18.50	19.37
B-60	3.55	84	12.79	17.36
North Substyem A				
D-01	1.01	86	13.53	5.59
D-02	8.76	95	25.25	29.96
North Substyem B				
E-01	1.13	92	10.00	7.72
E-02	0.45	96	10.00	2.22
E-03	1.08	95	10.00	5.19
E-04	2.76	94	23.62	10.25
E-05	0.19	96	10.00	1.36

Existing Conditions Hydraulic Results

Analysis of the existing conditions model was performed to locate potential flooding areas. There are ten (10) main sag locations within the North System. One (1) open channel as well as one (1) detention pond was analyzed in the model. Table 2 lists the sag and channel locations with their flooding depths and bypass flow for the various storm events. These ponding areas and approximate overflow paths are shown in Figure 5 with the pipe network color coded to indicate the capacity throughout the system.

Table 2 - North System Inundation Depths & Bypassed Flow

Figure 5 Location	Sag Location	100 yr Storm Event		25 yr Storm Event		10 yr Storm Event		5 yr Storm Event		2 yr Storm Event	
		Ponding (ft)	Bypass (cfs)	Ponding (ft)	Bypass (cfs)	Ponding (ft)	Bypass (cfs)	Ponding (ft)	Bypass (cfs)	Ponding (ft)	Bypass (cfs)
1	N. Commerce St.	1.22	6.29	1.11	1.70	1.00	0.00	0.64	0.00	0.44	0.00
2	N. Martin St.	0.82	18.08	0.71	7.73	0.63	3.39	0.59	1.53	0.54	0.34
3	S. Commerce St.	0.59	17.90	0.50	12.38	0.42	7.11	0.39	8.27	0.29	5.63
4	Kilgore St.	1.91	89.91	1.81	59.16	1.74	38.34	1.71	32.59	1.61	15.84
5	E. Main St. & Kilgore St.	1.12	106.66	0.91	73.06	0.76	52.58	0.69	43.13	0.51	25.63
6	E. Main St.	1.30	114.76	1.08	71.92	0.92	48.69	0.86	40.46	0.65	18.87
7	E. North St.	3.04	74.22	2.79	12.02	2.26	0.00	1.69	0.00	0.76	0.00
8	N. Rusk St. & E. Sabine St.	0.93	103.38	0.63	30.90	0.51	16.82	0.44	11.20	0.34	5.96
9	Wood St.	1.17	94.03	0.87	19.79	0.77	8.31	0.69	3.05	0.58	0.29
10	Channel-3 (Northern channel in Kilgore City Park)	5.57*	73.94	5.35*	9.47	4.64*	0.00	4.10*	0.00	3.39*	0.00
11	U.S. Highway 259 - North	0.78	100.13	0.63	28.41	0.61	15.72	0.60	12.48	0.58	8.08

*Channel-3 has a depth of 5 feet from the bottom of the channel to the top of the headwall. Any depth over 5 feet overtops the headwall and exceeds the channel banks.

Sag locations on S. Commerce Street and N. Commerce Street are in the upstream end of the pipe system and most likely flood due to insufficient pipe capacity throughout the system, resulting in high hydraulic grade lines. Ponding at the sag locations at N. Martin Street and the intersection of N. Rusk Street and E. Sabine Street are most likely due to insufficient inlet and pipe capacity.

Ponding in the downtown sag locations (E. Main Street, Kilgore Street, E. North Street) are due to both pipe and inlet capacity, with a significant amount of bypass flow coming from the upstream system. Decrease in pipe size diameter and an insufficient number of inlets from E. Main Street to E. North Street cause inundation in the E. Main Street sag location.

The inundation at the sag location on Wood Street is due to the large amount of bypass flow from the upstream system. The majority of runoff in the North System is conveyed to this sag location before overtopping the curb into Kilgore City Park. The overtopping of the open channel through Kilgore City Park is a result of a high tailwater by an insufficient downstream pipe system.

SOUTH SYSTEM

The main South System trunkline begins at the intersection of S. Martin and Barnett Streets in an 18" RCP that conveys runoff east and increases to a 24" RCP at the Main Street intersection and Lateral B tie-in. The pipe system continues east, increasing to a 36" RCP at Choice Street and then outfalls into the small open channel on private property between Choice Street and E. North Street. The open channel runs northeast approximately 150 feet until it reaches the 3' x 3' RCB E. North Street crossing that outfalls into Kilgore City Park. Runoff is conveyed through the southern open channel in Kilgore City Park until it enters a 36" RCP under U.S. Highway 259 that discharges as a 48" RCP east of U.S. Highway 259 approximately 220 feet downstream of the North System.

Several laterals and a subsystem are located within this system, which is shown in Figure 1. The watershed, including the subsystem is 53.23 acres. The main laterals and subsystem include the following:

South Lateral A
This lateral begins near a parking lot off E. Main Street north of E. North Street as a 12" RCP and runs under commercial property along Knowles Street before converging with the 3' x 3' RCB main trunkline upstream of the Kilgore City Park outfall.

South Lateral B
Lateral B includes a 24" RCP along E. Main Street and a 12" RCP along Knowles Street that converge at that intersection and ties in to the 24" RCP main trunkline at the intersection of Barnett Street and E. Main Street.

South Subsystem A
A separate subsystem included in this South System collects runoff in the neighborhood east of U.S. Highway 259. The runoff is collected by a series of inlets located at the intersection of E. Kay Street and Boone Street into a 24" RCP before outfalling approximately 165 feet downstream of the main South System outfall into a channel. This system was not originally in

the study area but field crews collected data on the inlets and outfalls and an analysis was performed.

Hydrology

The existing hydrologic analysis of the North System was performed by dividing the 53.23 acre drainage area into 16 subcatchments ranging in size from 0.68 to 6.83 acres. See Figure 4.

Runoff in this drainage area generally flows east towards Kilgore City Park, enters the 36” RCP under U.S. Highway 259, and then continues northeast through the 48” RCP under E. Kay Street until outfalling into the open channel north of Kay Street. This outfall is shown in Photo 3. South Subsystem A, with a 24” RCP outfall (shown in Photo 4), collects runoff through five (5) inlets before outfalling approximately 165 feet downstream of the 48” RCP. This outfall is independent of the South System and therefore had to be analyzed as a separate system.

Photo 3 – South System 48” RCP outfall to concrete lined channel north of E. Kay Street

Photo 4 – South Subsystem A 24" RCP outfall downstream of 48" pipe

EPA-SWMM was used to model hydrology for this system. Data was entered through the corresponding nodes, conduits and subcatchments to obtain peak flows shown in Table 3. The table is highlighted based on the color of the associated drainage areas in Figure 4.

Table 3- Drainage Area Attributes for South System

Drainage Area Name	Area (ac)	CN value	T_C (min)	Peak Flow$_{100yr}$ (cfs)
South System				
A-01	2.61	83	13.74	12.68
A-02	4.46	87	10.00	19.89
A-03	3.54	79	10.48	21.89
A-04	5.62	93	21.96	25.98
A-05	3.30	94	10.00	19.83
A-06	2.92	94	10.00	15.45
A-07	0.68	95	10.00	3.90
A-08	1.19	94	10.12	7.79
A-09	6.83	94	13.93	30.43
A-10	5.14	94	10.00	26.54
A-11	2.36	95	10.00	10.65
A-12	1.09	95	11.60	5.33
A-13	1.15	94	10.00	6.68
A-14	6.14	91	10.00	30.63
A-15	2.52	85	13.40	12.16
Total	**49.56**	--	--	**249.83**
South Subsystem A				
C-01	3.67	82	10.00	19.02
Total	**3.67**	--	--	**19.02**

Existing Conditions Hydraulic Results

Analysis of the existing conditions model was performed to locate potential flooding areas. Six (6) main sag locations are within the South System. Two (2) open channels were also analyzed in the model. Table 4 lists the sag and channel locations with their flooding depths and bypass flow for the various storm events. These ponding areas and approximate overflow paths are shown in Figure 5 with the pipe network color coded to indicate the capacity throughout the system.

Table 4 - South System Inundation Depths & Bypassed Flow

Figure 5 Location	Sag Location	100 yr Storm Event		25 yr Storm Event		10 yr Storm Event		5 yr Storm Event		2 yr Storm Event	
		Ponding (ft)	Bypass (cfs)	Ponding (ft)	Bypass (cfs)	Ponding (ft)	Bypass (cfs)	Ponding (ft)	Bypass (cfs)	Ponding (ft)	Bypass (cfs)
12	Barnett St. & E. Main St.	0.81	61.06	0.77	39.85	0.74	28.45	0.72	21.12	0.68	11.27
13	Choice St.	0.79	73.33	0.72	45.54	0.67	28.85	0.63	18.46	0.56	5.25
14	Channel-2 (Channel on private property)	4.65*	87.86	4.58*	55.99	4.55*	38.79	4.53*	23.47	4.51*	7.11
15	E. North St.	0.57	121.72	0.55	74.86	0.54	48.18	0.53	30.58	0.51	7.55
16	Channel-1 (Southern channel in Kilgore City Park)	4.55**	153.76	4.30**	106.62	4.01**	76.26	3.90**	54.39	3.73**	24.65
17	U.S. Highway 259 - South	1.90	100.94	1.64	38.71	1.36	5.59	1.05	0.24	0.65	0.00

*Channel-2 has a depth of 4.40 feet from the bottom of the channel to the top of the headwall. Any depth over 4.40 feet overtops the headwall and exceeds the channel banks.

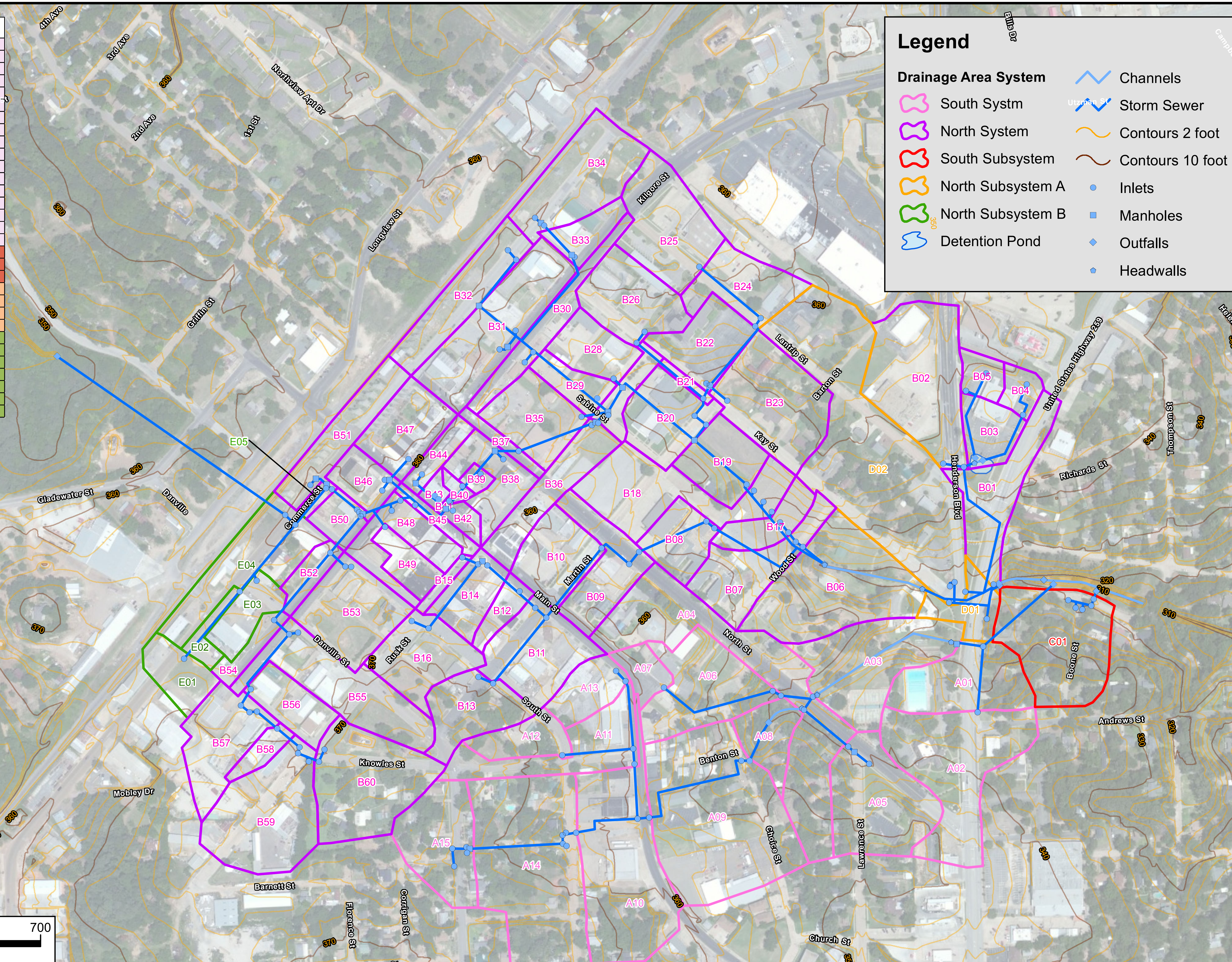
**Channel-1 has a depth of 3.5 feet from the bottom of the channel to the top of the headwall. Any depth over 3.5 feet overtops the headwall and exceeds the channel banks.

The ponding at Barnett Street and E. Main Street is the most upstream sag location in the South System. Ponding likely occurs here due to bypass from the north on Main Street and insufficient pipe sizes downstream of this location. The sag location at Choice Street ponds because it collects overflow from the Barnett Street and E. Main Street sag and there is insufficient pipe capacity downstream.

The runoff in the channel on private property upstream of Kilgore City Park overtops the channel banks due to an insufficient road crossing at North Street. The sag location here collects runoff from the main trunkline as well as runoff from North System Lateral B (N. Martin Street) which is conveyed southeast along E. North Street. The 3' x 3' RCB under E. North Street is undersized which contributes to flooding at this sag. This insufficient pipe size causes a tailwater effect on the upstream open channel.

The runoff in the open channel through Kilgore City Park overtops the channel banks due to an insufficient road crossing at U.S. Highway 259. U.S. Highway 259 is a major sag location in this system and therefore collects runoff from the main South System trunkline and Lateral A_A. After ponding, the runoff overflows north on U.S. Highway 259 towards E. Kay Street and outfalls in the open channel east of U.S. Highway 259.

Drainage Area Name	Area (ac)	Drainage Area Name	Area (ac)
North System		South System	
B-01	2.38	A-01	2.61
B-02	4.08	A-02	4.46
B-03	1.13	A-03	3.54
B-04	0.54	A-04	5.62
B-05	0.60	A-05	3.30
B-06	4.46	A-06	2.92
B-07	2.11	A-07	0.68
B-08	1.32	A-08	1.19
B-09	1.95	A-09	6.83
B-10	1.82	A-10	5.14
B-11	2.49	A-11	2.36
B-12	0.61	A-12	1.09
B-13	1.90	A-13	[illegible]
B-14	1.25	A-14	[illegible]
B-15	0.24	A-15	2.52
B-16	2.08	**Total**	49.56
B-17	1.04	**South Subsytem**	
B-18	3.18	C-01	3.67
B-19	1.64	**Total**	**3.67**
B-20	1.93	**North Subsytem A**	
B-21	0.20	D-01	1.01
B-22	1.74	D-02	8.76
B-23	3.28	**Total**	**9.77**
B-24	1.86	**North Subsytem B**	
B-25	2.89	E-01	1.13
B-26	2.21	E-02	0.45
B-27	0.70	E-03	1.08
B-28	1.27	E-04	2.76
B-29	0.82	E-05	0.19
B-30	1.44	**Total**	**5.60**
B-31	3.45		
B-32	2.15		
B-33	0.86		
B-34	2.91		
B-35	1.92		
B-36	1.80		
B-37	0.39		
B-38	1.46		
B-39	0.20		
B-40	0.18		
B-41	0.04		
B-42	0.32		
B-43	0.23		
B-44	0.63		
B-45	0.41		
B-46	0.91		
B-47	1.80		
B-48	1.55		
B-49	0.80		
B-50	0.69		
B-51	1.82		
B-52	0.63		
B-53	2.50		
B-54	0.58		
B-55	3.06		
B-56	1.26		
B-57	2.19		
B-58	0.49		
B-59	3.65		
B-60	3.55		
Total	**95.62**		



F&N JOB NO. KLG13364
DATE: July, 2014
SCALE: 4,200
DESIGNED: LMB
DRAFTED: ETB
FILE: Drainage_Area_Map.mxd

City of Kilgore

Drainage Area Map

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FIGURE
4

City of Kilgore

Existing Conditions Map

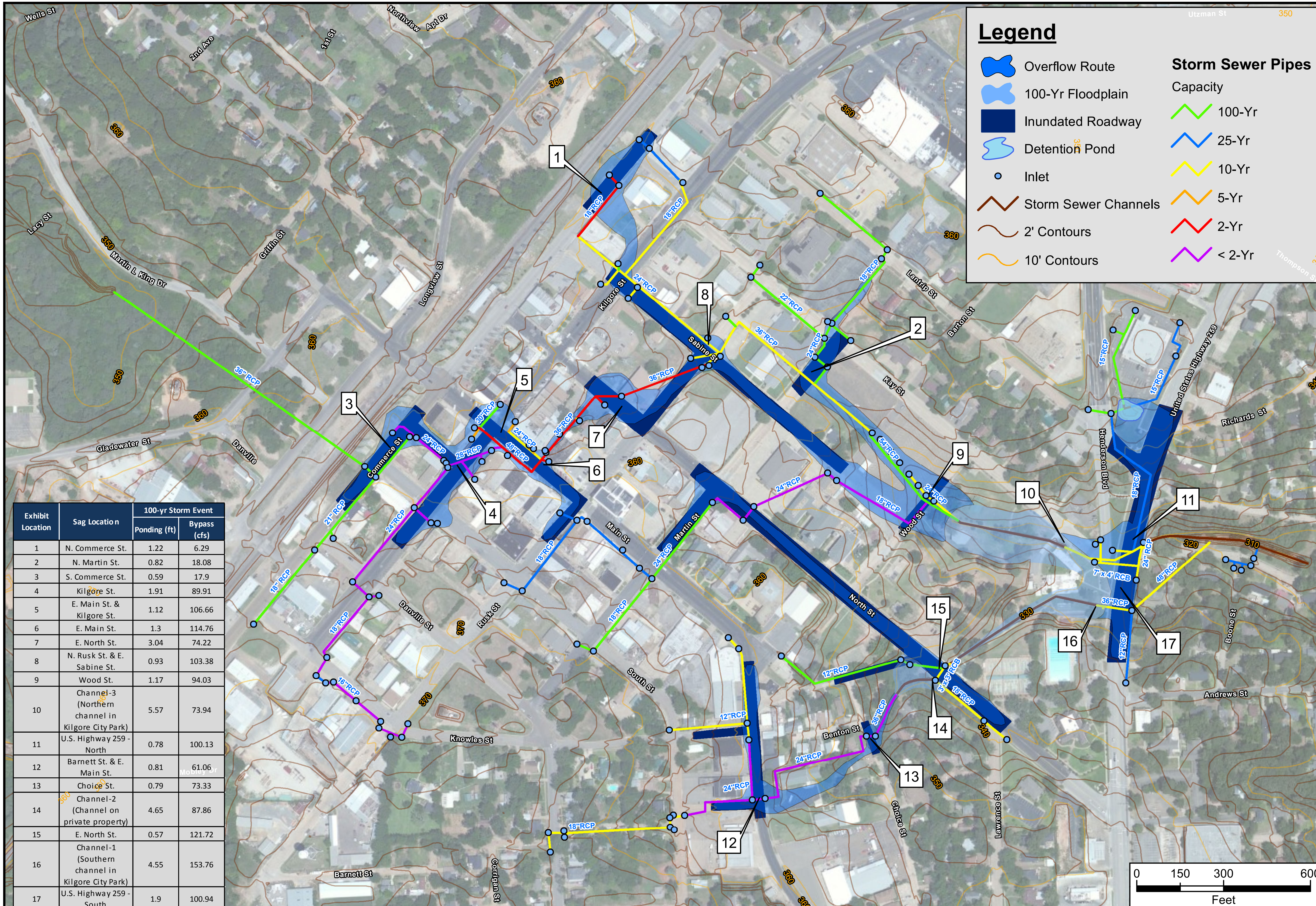

Exhibit Location	Sag Location	100-yr Storm Event	
		Ponding (ft)	Bypass (cfs)
1	N. Commerce St.	1.22	6.29
2	N. Martin St.	0.82	18.08
3	S. Commerce St.	0.59	17.9
4	Kilgore St.	1.91	89.91
5	E. Main St. & Kilgore St.	1.12	106.66
6	E. Main St.	1.3	114.76
7	E. North St.	3.04	74.22
8	N. Rusk St. & E. Sabine St.	0.93	103.38
9	Wood St.	1.17	94.03
10	Channel-3 (Northern channel in Kilgore City Park)	5.57	73.94
11	U.S. Highway 259 - North	0.78	100.13
12	Barnett St. & E. Main St.	0.81	61.06
13	Choice St.	0.79	73.33
14	Channel-2 (Channel on private property)	4.65	87.86
15	E. North St.	0.57	121.72
16	Channel-1 (Southern channel in Kilgore City Park)	4.55	153.76
17	U.S. Highway 259 - South	1.9	100.94

F&N JOB NO. KLG13364
DATE: July, 2014
SCALE: 3,600
DESIGNED: LMB
DRAFTED: ETB
FILE: Existing_Conditionst_Map.mxd

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FIGURE
5

PROPOSED IMPROVEMENTS

Hydrologic Results

There were no large variances between future and existing land use within the study area. Due to the minor difference in land use, only future land use was used to determine the composite curve number values for the subcatchments for both existing conditions and proposed alternatives.

Hydraulic Results

Areas with high ponding depths and bypass flow were identified under existing conditions. FNI met with City staff to discuss the system deficiencies and options for proposed improvements to increase the capacity of the storm sewer system. A major source of flooding is the bypass flow from the upstream end of the North System which includes approximately 107 cfs of bypass flow at the Main Street and Kilgore Street intersection. There were two main options for reducing the bypass flow through this downtown location;

- increase the number of inlets and pipe capacity through downtown to the outfall south of Wood Street OR
- re-route the existing pipe system upstream of Kilgore Street and Main Street to convey runoff to the northwest under the railroad along Martin L King Drive.

After conceptual modeling and cost estimating was performed it was decided by City staff that the option to increase the pipe capacity through downtown would not be economically feasible. The option to re-route the pipe system to the northwest under the railroad was evaluated in more detail.

Along with the re-routing of the North System, four (4) additional proposed improvement projects are recommended to alleviate roadway flooding and ponding throughout the system. Details on all five (5) projects are presented below.

Figure 6 shows the proposed improvements with probable cost estimates for each improvement. Appendix A provides a breakdown of the engineer’s opinion of probable construction cost (OPCC) for all proposed improvements. The total estimated cost for all proposed improvements is approximately $2 million. This includes contingency, mobilization, and overhead and profit (OH&P).

Re-route North System and optional improvements

The ponding along Main Street between Kilgore Street and Rusk Street is largely due to the large amount of runoff from the upstream end of the system. This runoff is conveyed by the North System which is inadequately sized. The North Subsystem A is located to the north of this area and has sufficient capacity to convey additional flow. The proposed re-route would begin just east of the Kilgore Street and South Street where the existing 24" RCP of the North System would be disconnected and re-routed to the northwest by adjusting invert elevations of the existing system. Once the invert elevations have been adjusted to convey runoff to the North Subsystem A outfall the pipe system from the disconnection point to the outfall west of Martin Luther King Jr Drive should be increased to 2-36" RCPs for 100-yr capacity. This allows the existing 36" RCP to remain utilized. Diverting the existing flow of the North System from Knowles Street to the outfall will improve ponding and bypass flow at sag locations. Implementing just the re-route option will decrease inundation depths and bypass flow throughout the North System. Tables 5 and 6 below show inundation depths and bypass flow at sag locations implementing just the re-route improvements compared to existing conditions.

Table 5 - Inundation Depths & Bypassed Flow for Re-route Improvements Only

		3. S. Commerce St.		4. Kilgore St.		5. E. Main St. & Kilgore St.		6. E. Main St.	
Event	Conditions	Ponding (ft)	Bypass (cfs)	Ponding (ft)	Bypass (cfs)	Ponding (ft)	Bypass (cfs)	Ponding (ft)	Bypass (cfs)
100-Yr	Existing	0.59	17.90	1.91	89.91	1.12	106.66	1.30	114.76
	Proposed	0.27	12.48	1.38	1.75	0.34	8.64	0.51	8.76
25-Yr	Existing	0.50	12.38	1.81	59.16	0.91	73.06	1.08	71.92
	Proposed	0.24	8.77	0.79	0.00	0.22	2.32	0.19	0.22
10-Yr	Existing	0.42	7.11	1.74	38.84	0.76	52.58	0.92	48.69
	Proposed	0.23	6.78	0.59	0.00	0.20	1.72	0.13	0.04
5-Yr	Existing	0.39	8.27	1.71	32.59	0.69	43.13	0.86	40.46
	Proposed	0.21	5.63	0.52	0.00	0.19	1.36	0.09	0.00
2-Yr	Existing	0.29	5.63	1.61	15.84	0.51	25.63	0.65	18.87
	Proposed	0.19	4.39	0.40	0.00	0.17	1.01	0.08	0.00

Table 6 - Inundation Depths & Bypassed Flow for Re-route Improvements Only

		7. E. North St.		8. N. Rusk St. & E. Sabine St.		9. Wood St.		11. U.S. Highway 259 North	
Event	Conditions	Ponding (ft)	Bypass (cfs)	Ponding (ft)	Bypass (cfs)	Ponding (ft)	Bypass (cfs)	Ponding (ft)	Bypass (cfs)
100-Yr	Existing	3.04	74.22	0.93	103.38	1.17	94.03	0.78	100.13
	Proposed	0.74	0.00	0.56	21.89	0.97	36.41	0.75	78.50
25-Yr	Existing	2.79	12.02	0.63	30.90	0.87	19.79	0.63	28.41
	Proposed	0.52	0.00	0.44	11.86	0.78	9.55	0.64	24.62
10-Yr	Existing	2.26	0.00	0.51	16.82	0.77	8.31	0.61	15.72
	Proposed	0.47	0.00	0.40	8.95	0.71	4.01	0.61	15.72
5-Yr	Existing	1.69	0.00	0.44	11.20	0.69	3.05	0.60	12.48
	Proposed	0.43	0.00	0.37	7.49	0.65	1.87	0.60	12.49
2-Yr	Existing	0.76	0.00	0.34	5.96	0.58	0.29	0.58	8.08
	Proposed	0.38	0.00	0.34	5.86	0.58	0.28	0.58	8.10

Completing these proposed improvements will also address maintenance items 4 and 5 which include replacing an inlet with deteriorating infrastructure and clearing a clogged inlet of sediment. Increasing the outfall pipe of North Subsystem A will include the crossing under the existing railroad. This will require tunneling and additional coordination with the railroad.

Even with the re-routing of the upstream system there continues to be ponding and bypass at the N. Rusk Street and E. Sabine Street sag location although reduced from existing conditions. To provide 100-yr capacity it is recommended that the existing 36" RCP from the intersection of Rusk Street and Sabine Street be increased to a 54" RCP. To avoid construction between the private properties along the existing pipe path it is recommended that the pipe be re-routed to continue to the intersection of Rusk Street and Kay Street and then would replace the existing 22" RCP with adjusted invert elevations to the tie-in with the existing 4" RCP on the south side of Martin Street. The existing 36" RCP from Rusk Street to Martin Street will then be abandoned.

Both improvements have an estimated construction cost of $652,100. See the complete cost estimate in Appendix A for additional information.

Increase U.S. Highway 259 crossings (both North and South Systems)

U.S. Highway 259 is a heavily trafficked road that would benefit from having 100-yr road crossing capacity. Increasing the north and south road crossings will also reduce the potential overtopping of the channels in Kilgore City Park. The proposed improvements include the following:

South Road Crossing: Increase the existing 36" RCP to 2-48" RCPs and re-route the system east of the U.S. Highway 259 crossing to avoid private property.

North Road Crossing: Increase culvert size from 7' x 4' RCB to 8' x 5' to the west side of U.S. Highway 259 and then increase to a 10' x 6' RCB until the outfall east of U.S. Highway 259. Increase size of 16" lateral to 36" and connect to 8' x 5' RCB. In order to accommodate these improvements, the upstream and downstream invert elevations of the road crossing will need to be lowered. The upstream elevation will need to decrease by approximately one (1) foot. The downstream elevation will need to decrease approximately two (2) feet. The channel to the east of U.S. 259 will need to be re-graded due to the decrease in flowline elevation for approximately 240 feet. The existing slope of the channel is approximately 0.026 ft/ft and the proposed slope of the channel after re-grading will be approximately 0.018 ft/ft.

Table 7 below shows the impacts the improvements to the crossings have on the North and South Systems.

Table 7 - Inundation Depths & Bypassed Flow for U.S. Highway 259 Crossings

		10. Channel 3 (Northern channel in Kilgore City Park)		11. U.S. Highway 259 North		16. Channel 1 (Southern channel in Kilgore City Park)		17. U.S. Highway 259 South	
Event	**Conditions**	**Ponding (ft)**	**Bypass (cfs)**	**Ponding (ft)**	**Bypass (cfs)**	**Ponding (ft)**	**Bypass (cfs)**	**Ponding (ft)**	**Bypass (cfs)**
100-Yr	Existing	5.57	73.94	0.78	100.13	4.55	153.76	1.90	100.94
	Proposed	3.90	0.00	0.48	0.00	3.57	0.00	0.58	0.00
25-Yr	Existing	5.35	9.47	0.63	28.41	4.30	106.62	1.64	38.71
	Proposed	3.23	0.00	0.34	0.00	2.75	0.00	0.46	0.00
10-Yr	Existing	4.64	0.00	0.61	15.72	4.01	76.26	1.36	5.59
	Proposed	2.81	0.00	0.29	0.00	2.40	0.00	0.39	0.00
5-Yr	Existing	4.10	0.00	0.60	12.48	3.90	54.39	1.05	0.24
	Proposed	2.51	0.00	0.27	0.00	2.19	0.00	0.35	0.00
2-Yr	Existing	3.39	0.00	0.58	8.08	3.73	24.65	0.65	0.00
	Proposed	2.17	0.00	0.24	0.00	1.93	0.00	0.29	0.00

Completing these proposed improvements will also address maintenance item 16 by replacing the deteriorating headwall of the north channel outfall.

Both improvements have an estimated construction cost of $618,600. See the complete cost estimate in Appendix A for additional information.

At the request of the City, all the proposed improvements were modeled minus the U.S. Highway 259 crossing improvements. Without improvements to the crossings at U.S. Highway 259, there is a slight decrease in the overtopping of U.S. Highway 259; however, there is still significant overtopping that could be hazardous during large storm events. Table 8 compares the bypass flow over U.S. Highway 259 with and without improvements to the U.S. Highway 259 road crossings.

Table 8 - Bypass Flow over Highway 259 with and without road crossing improvements for the 100-Yr Storm Event

Highway 259 Crossing	Existing Bypassed Flow (cfs)	Bypassed Flow without Highway 259 Improvements (cfs)	Bypassed Flow Including Highway 259 Improvements (cfs)
North Crossing	100.13	83.33	0.00
South Crossing	100.94	86.03	0.00

Re-route and increase pipe size from North Street to Wood Street

There is a significant amount of bypass flow, approximately 37 cfs during a 100-yr storm event, which travels from the North System to the South System down North Street to the North Street road crossing. This is due to the inadequate pipe size of North System Lateral B. To eliminate this bypass flow it is proposed that the North System Lateral B pipe from just south of the Martin Street and North Street intersection to the tie-in with the main line at Wood Street be re-routed along North Street and Wood Street to avoid construction on private property and increased to a 30” RCP down North Street and a 36” RCP down Wood Street. With these improvements, bypass flow to the North Street road crossing is reduced to 17 cfs. Table 9 shows the impacts of the improvements on Wood Street and E. North Street, including the improvements to the North Street crossing discussed after this section.

Table 9 - Inundation Depths & Bypassed Flow for Wood St. & E. North St.

		9. Wood St.		15. E. North St.	
Event	Conditions	Ponding (ft)	Bypass (cfs)	Ponding (ft)	Bypass (cfs)
100-Yr	Existing	1.17	94.03	0.57	121.72
	Proposed	0.98	38.49	0.48	0.00
25-Yr	Existing	0.87	19.79	0.55	74.86
	Proposed	0.81	12.81	0.42	0.00
10-Yr	Existing	0.77	8.31	0.54	48.18
	Proposed	0.73	5.40	0.38	0.00
5-Yr	Existing	0.69	3.05	0.53	30.58
	Proposed	0.67	2.25	0.34	0.00
2-Yr	Existing	0.58	0.29	0.51	7.55
	Proposed	0.58	0.28	0.30	0.00

Completing these proposed improvements will also replace approximately 340 feet of pipe that was designated as fair condition.

Improvements have an estimated construction cost of $197,100. See the complete cost estimate in Appendix A for additional information.

Increase the crossing at North Street

The road crossing under North Street that conveys runoff from the channel located on private property to the southern channel of Kilgore City Park is inadequately sized and causes the channel on private property to pond and the road crossing to be overtopped. It is proposed that this crossing be increased from an existing 3'x3' RCB to a 7'x4' RCB to reduce overtopping during the 100-yr storm event. It is also recommended that the 18" RCP lateral to the east of the crossing be increased to a 24" RCP to capture bypass from the east. Table 10 shows the impacts the improvements to the crossings have on E. North Street, including the previously mentioned improvements to the North System Lateral B.

Table 10 - Inundation Depths & Bypassed Flow for E. North St. Crossing

		14. Channel 2 (Channel on private property)		15. E. North St.	
Event	Conditions	Ponding (ft)	Bypass (cfs)	Ponding (ft)	Bypass (cfs)
100-Yr	Existing	4.65	87.86	0.57	121.72
	Proposed	4.48	0.00	0.48	0.00
25-Yr	Existing	4.58	55.99	0.55	74.86
	Proposed	3.14	0.00	0.42	0.00
10-Yr	Existing	4.55	38.79	0.54	48.18
	Proposed	2.57	0.00	0.38	0.00
5-Yr	Existing	4.53	23.47	0.53	30.58
	Proposed	2.25	0.00	0.34	0.00
2-Yr	Existing	4.51	7.11	0.51	7.55
	Proposed	1.87	0.00	0.30	0.00

Completing these proposed improvements will also replace an inlet on the existing 18" lateral that was identified as being in fair condition during the maintenance assessment.

Improvements have an estimated construction cost of $173,100. See the complete cost estimate in Appendix A for additional information.

Increase pipe from Main Street to Channel-2 Outfall

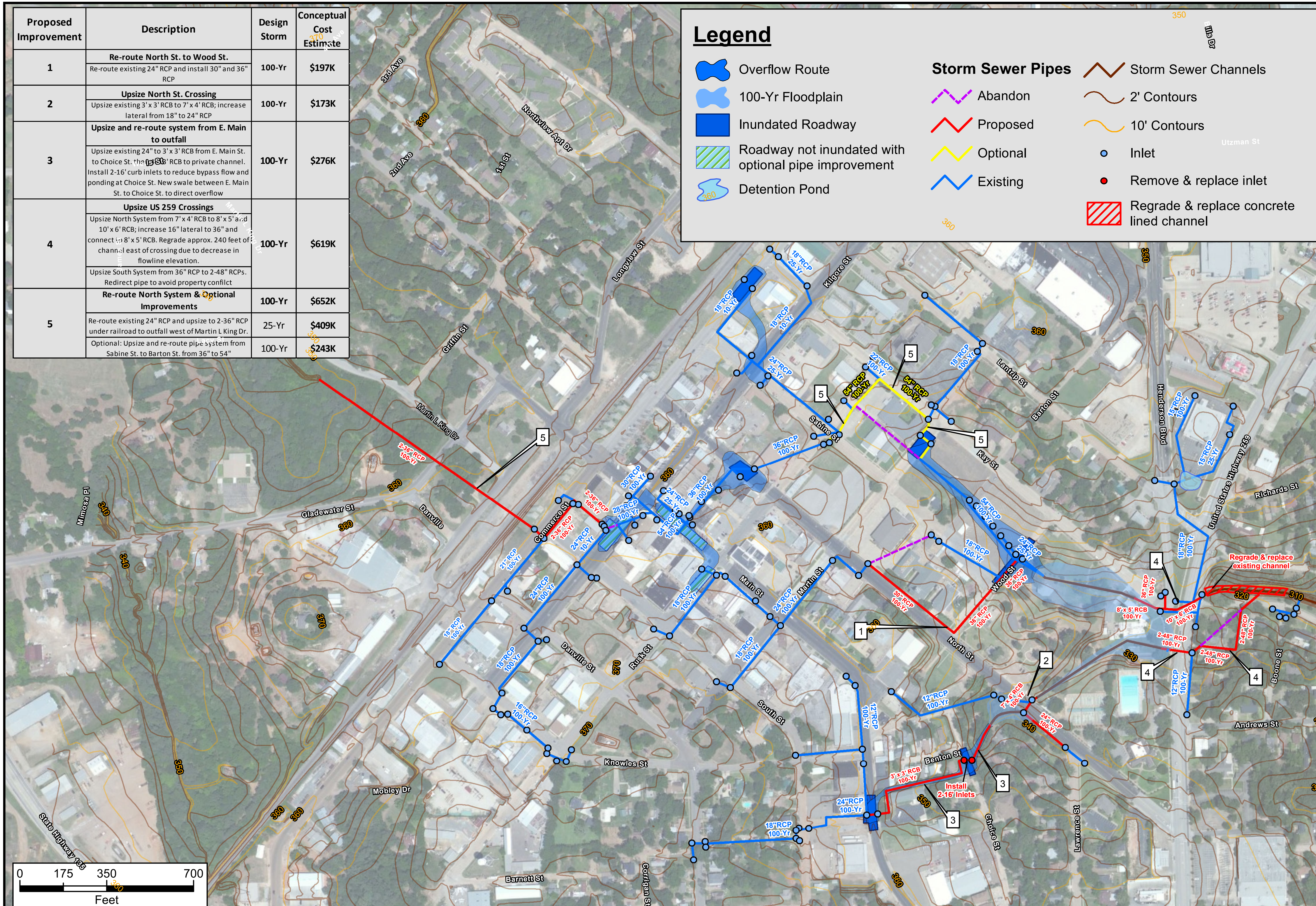
On the main line of the South System there is ponding and bypass flow running through private properties between Main Street and Choice Street due to inadequate pipe capacity. It is recommended that the existing 24" RCP beginning at the west side of E. Main Street to the west side of Choice Street be increased to a 3' x 3' RCB. The existing 36" RCP under Choice Street and on private property northeast of Choice Street should be increased to a 4' x 3' RCB. The existing two (2) – 8' curb inlets located at the sag on Choice Street should be increased to two (2) – 16' curb inlets to reduce bypass flow and ponding. It is also recommended that a swale or flume be installed on the private property Main Street to Choice Street to direct overflow during large storm events. Table 11 shows the impacts the improvements to this area have on the Barnett Street and E. Main Street sag and the Choice Street sag.

Table 11 - Inundation Depths & Bypassed Flow for Barnett St. & E. Main St.

		12. Barnett St. & E. Main St.		13. Choice St.	
Event	Conditions	Ponding (ft)	Bypass (cfs)	Ponding (ft)	Bypass (cfs)
100-Yr	Existing	0.81	61.06	0.79	73.33
	Proposed	0.95	54.68	0.62	19.29
25-Yr	Existing	0.77	39.85	0.72	45.54
	Proposed	0.86	35.40	0.55	4.92
10-Yr	Existing	0.74	28.45	0.67	28.85
	Proposed	0.79	24.48	0.49	0.00
5-Yr	Existing	0.72	21.12	0.63	18.46
	Proposed	0.74	17.92	0.42	0.00
2-Yr	Existing	0.68	11.27	0.56	5.25
	Proposed	0.67	10.00	0.37	0.00

Improvements have an estimated construction cost of $275,600. See the complete cost estimate in Appendix A for additional information.

Proposed Improvement	Description	Design Storm	Conceptual Cost Estimate
1	**Re-route North St. to Wood St.** Re-route existing 24" RCP and install 30" and 36" RCP	100-Yr	$197K
2	**Upsize North St. Crossing** Upsize existing 3' x 3' RCB to 7' x 4' RCB; increase lateral from 18" to 24" RCP	100-Yr	$173K
3	**Upsize and re-route system from E. Main to outfall** Upsize existing 24" to 3' x 3' RCB from E. Main St. to Choice St. then 4' x 3' RCB to private channel. Install 2-16' curb inlets to reduce bypass flow and ponding at Choice St. New swale between E. Main St. to Choice St. to direct overflow	100-Yr	$276K
4	**Upsize US 259 Crossings** Upsize North System from 7' x 4' RCB to 8' x 5' and 10' x 6' RCB; increase 16" lateral to 36" and connect to 8' x 5' RCB. Regrade approx. 240 feet of channel east of crossing due to decrease in flowline elevation. Upsize South System from 36" RCP to 2-48" RCPs. Redirect pipe to avoid property conifict	100-Yr	$619K
5	**Re-route North System & Optional Improvements**	100-Yr	$652K
	Re-route existing 24" RCP and upsize to 2-36" RCP under railroad to outfall west of Martin L King Dr.	25-Yr	$409K
	Optional: Upsize and re-route pipe system from Sabine St. to Barton St. from 36" to 54"	100-Yr	$243K



City of Kilgore

Proposed Conditions Map

F&N JOB NO. KLG13364
DATE: August, 2014
SCALE: 4,200
DESIGNED: LMB
DRAFTED: ETB
FILE: Both_Systems.mxd

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FIGURE
6

CIP RANKING

The storm sewer capital improvement projects (CIPs) are prioritized according to a ranking system. The ranking system was used to assess the relative severity of the drainage problems identified in the downtown area of the City of Kilgore. The CIP ranking will assist the City in distinguishing between projects of various priorities and determining which projects will receive attention from the City's annual drainage budget. The system is also intended to be a "living" document with which future projects can be added and prioritized.

Criteria Weighting

FNI determined weights for five different ranking criteria:

- Life Safety and Road Flooding
- Property Damage
- Frequency of Flooding
- Project Cost
- Maintenance Cost and Drainage Complaints

A pair-wise comparison table was developed by FNI that was used to rank each of the five criteria against each other. A score of 3 means that the criterion being evaluated is more important than the one in which it is being compared to, a score of 2 means each of the criterion have equal importance, and a score of 1 means that the criterion is considered less important than the other. For example, life safety is considered more important than structure flooding. Therefore life safety received a score of 3 when compared to structure flooding, and adversely structure flooding received a score of 1. The sum of scores for each category is considered its "weight", with weights ranging from a minimum of four (4) to a maximum of twelve (12).

The scores given to each criterion were summed to assign a final weight to each category. The pair-wise ranking table populated with the scores and weights are shown in Table 12.

Table 12 - Pair-wise Stormwater Evaluation Criteria Ranking Results for the City of Kilgore

	1	2	3	4	5		
Criteria	Life Safety / Road Flooding	Property Damage	Frequency of Flooding	Project Cost	Maintenance Cost/Drainage Complaints	**Sum**	**Rank**
Life Safety / Road Flooding		3.00	3.00	3.00	3.00	12	**1**
Property Damage	1.00		3.00	3.00	3.00	10	**2**
Frequency of Flooding	1.00	1.00		3.00	3.00	8	**3**
Project Cost	1.00	1.00	1.00		3.00	6	**4**
Maintenance Cost (Work Orders)	1.00	1.00	1.00	1.00		4	**5**

Criteria Descriptions

After weights were given to the general criteria described above, FNI developed descriptions for each category that would allow future projects to be scored with as much consistency as possible. It was determined that each criterion would have a 5-point scoring range, ranging from a minimum score of zero (0) and a maximum score of five (5). FNI developed quantifiable ranges for each criterion. The following list provides descriptions of the ranking process and the scoring ranges developed for each criterion.

1. Life Safety/Road Flooding: This criterion awards points for the life safety component of the project. Because most flood related fatalities involve motorists driving into floodwaters, this criteria is scored based on the depth of flow in or over the road during a 100-year storm event.

Severe (> 30”)	5
Very High (24-30”)	4
High (18-24”)	3
Moderate (12-18”)	2
Low (6-12”)	1
None (<6”)	0

2. Property Damage: This criterion awards points based on the potential for property damage due to flooding. Ranking is scored based on the number of structures that are likely to flood during a 100-year storm event.

Severe (>20)	5
Very High (16 to 20)	4
High (11 to 15)	3
Moderate (6 to 10)	2
Low (1 to 5)	1
None	0

3. Frequency of Flooding: This criterion awards points based on the storm event in which significant flooding begins to occur. Ranking should consider both structure flooding and street flooding based on ROW exceedance.

2 - year	5
5 - year	4
10 - year	3
25 - year	2
50 - year	1
100 - year	0

4. Project Cost: This criteria awards points for smaller projects which may be implemented with lesser impact on City budgets. The ranking is scored based on the estimated cost of the project.

Less than $100,000	5
Between $100,000 and $250,000	4
Between $250,000 and $500,000	3
Between $500,000 and $1,000,000	2
Between $1,000,000 and $2,000,000	1
More than $2,000,000	0

5. Reduction in Maintenance: This criteria awards points for the potential reduction of long term maintenance costs associated with the project. The ranking is scored based on the reduction of field identified maintenance needs that were identified in “fair” or “poor” condition associated with the project.

Very High (Multiple poor rated items)	5
High (1 poor rated item and additional fair rated items)	4
Moderate (1 poor rated item)	3
Low (1 or more fair rated item)	2
Very Low (1 fair rated item)	1
None (0)	0

The ranking scores were multiplied with their corresponding weighting, and summed together. This provided a point value where the project area with the highest point total was considered the highest priority. A table showing the scoring and ranking of the 5 projects is presented in Table 13. This scoring process was programmed into a Microsoft Access database that allows the user to input detailed information about each project. Using this database, FNI ranked the proposed projects.

The Access database produced a report for the overall ranked list of projects, Table 13, as well as a one page report of each project which is located in Appendix B. The overall ranking list shown in Table 13 provides the City with a method of properly selecting which projects receive priority. This ranking process is not intended to provide a prioritized list in which the City must complete in order without exception. However, it is a tool that can be used to help the City staff in annual budgeting and project implementation for their storm water infrastructure. The database should be considered a “live document” that can be altered as needed in the future as new projects arise or as the City’s needs change. It should be noted that some aspects of the Capital Improvement Plan may need to be revisited annually. The ranking criteria for each project may have changed over the course of a year, and the City may want to update their criteria weights. These changes can be made within the current database, and the process is described in the next section.

Using the criteria and scoring method described above, projects were scored and ranked for the City of Kilgore CIP. The final rankings for these projects are shown in Table 13 below.

Table 13 – CIP Ranking for Proposed Storm Sewer Improvements for Downtown

	Criteria Weighting	12	10	8	6	4	
Rank	Project Name	Life Safety/Road Flooding	Property Damage	Frequency of Flooding	Project Cost	Reduction in Maintenance	Sum of Product
1	DOWNTOWN SYSTEM IMPROVEMENTS	3	2	4	2	5	120
2	US259 CROSSINGS	3	2	3	2	3	104
3	RE-ROUTE NORTH STREET TO WOOD STREET	1	1	5	4	2	94
4	MAIN STREET TO CHOICE STREET	1	1	4	3	1	76
5	NORTH STREET CROSSING	1	1	3	4	0	70

Database

It was determined that a Microsoft Access database would be the most efficient and easily updated deliverable for the project screening phase of the project. FNI created a data input form customized for the City of Kilgore. The data input form has fields for the following input:

- **Project ID** – Number given to identify the area. (ex. DT_01)
- **Project Name** – Name of the project area.
- **Date Identified** – Year that the initial request or complaint was filed.
- **Date Completed** – Month and year that the project was completed
- **CIP Rank** – Ranking of the CIP project.
- **CIP Year** – Recommended project implementation period.
- **Project Description** – Summary of the drainage issue and the existing conditions.
- **Proposed Improvements** – A preliminary recommendation for improvements.
- **Cost Range** – Approximate range of construction cost based on an opinion of probable construction cost. This is intended to be a conceptual estimate for budgeting purposes only.
- **Project Type** – Type of project based on the proposed improvements. (i.e.: pipe system, lined channel, natural channel, etc.)
- **Score for all 5 Ranking Criteria** – Scores as shown in Table 13 and determined as shown under the Ranking section.
- **Photo 1 Description** – Short description of photo 1, if included.
- **Photo 2 Description** – Short description of photo 2, if included.

All input is displayed in a one-page report that Access generates for each project area. The goal of these reports is to provide a general overview of all possible drainage CIP projects within the City. Attached to each one-page report is a location map of the project area showing drainage area delineations and calling out any pertinent information from the problem description.

One-page reports and location maps for the project areas are provided in Appendix B.

Appendix A – Opinion of Probable Construction Costs

Table A1 – Opinion of Probable Construction Cost for Downtown System Improvements

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
Re-route Downtown and Optional Improvements					
General					
	Traffic Control	2	MO	$ 5,000.00	$10,000
	Site Preparation	0.4	AC	$ 25,000.00	$10,000
	Erosion Control and SWPPP Implementation	1	LS	$ 4,000.00	$4,000
	Railroad Coordination	1	LS	$ 10,000.00	$10,000
Storm Drain					
	Trench Safety	1,440	LF	$ 2.00	$2,880
	Install 36" RCP	1,840	LF	$ 95.00	$174,800
	Install headwall	1	LS	$ 7,000.00	$7,000
Paving					
	Concrete Pavement Saw, Remove and Dispose	520	SY	$ 6.00	$3,120
	Concrete Pavement	520	SY	$ 33.00	$17,160
	6" Stabilized Subgrade Install	520	SY	$ 2.50	$1,300
	Concrete Curb remove and replace	330	LF	$ 4.00	$1,320
	Sod	2,800	SF	$ 4.00	$11,200
Water and Sewer					
	Miscellaneous Utility Adjustments	1	LS	$ 20,000.00	$20,000
				SUBTOTAL	**$272,780**
Additional Downtown Improvements					
General					
	Traffic Control	2	MO	$ 5,000.00	$10,000
	Site Preparation	0.1	AC	$ 25,000.00	$2,500
	Erosion Control and SWPPP Implementation	1	LS	$ 4,000.00	$4,000
Storm Drain					
	Trench Safety	525	LF	$ 2.00	$1,050
	Remove Existing 36" RCP	525	LF	$ 15.00	$7,875
	Install 54" RCP	525	LF	$ 150.00	$78,750
Paving					
	Concrete Pavement Saw, Remove and Dispose	465	SY	$ 6.00	$2,790
	Concrete Pavement	465	SY	$ 33.00	$15,345
	6" Stabilized Subgrade Install	465	SY	$ 2.50	$1,163
	Concrete Curb remove and replace	432	LF	$ 4.00	$1,728
Water and Sewer				$ -	$0
	Miscellaneous Utility Adjustments	1	LS	$ 20,000.00	$20,000
				SUBTOTAL	**$145,201**
		SUBTOTAL:			$418,000
		OH & P		15%	$62,700
					$480,700
		MOBILIZATION		5%	$20,900
					$501,600
		CONTINGENCY		30%	$150,500
PROJECT TOTAL					**$652,100**

Table A2 – Opinion of Probable Construction Cost for Re-route of North St. to Wood St.

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
North Street to Wood Street					
General					
	Traffic Control	1	MO	$ 5,000.00	$5,000
	Site Preperation	0.1	AC	$ 25,000.00	$2,500
	Erosion Control and SWPPP Implementation	1	LS	$ 4,000.00	$4,000
Storm Drain					
	Trench Safety	840	LF	$ 2.00	$1,680
	Remove Existing 18" RCP	97	LF	$ 15.00	$1,455
	Install 30" RCP	440	LF	$ 76.00	$33,440
	Install 36" RCP	400	LF	$ 83.00	$33,200
Paving				$ -	$0
	Concrete Pavement Saw, Remove and Dispose	560	SY	$ 6.00	$3,360
	Concrete Pavement	560	SY	$ 33.00	$18,480
	6" Stabilized Subgrade Install	560	SY	$ 2.50	$1,400
	Concrete Curb remove and replace	415	LF	$ 4.00	$1,660
Water and Sewer				$ -	$0
	Miscellanious Utility Adjustments	1	LS	$ 20,000.00	$20,000
				$ -	$0
				$ -	$0
				$ -	$0
		SUBTOTAL:			$126,200
		OH & P		15%	$19,000
					$145,200
		MOBILIZATION		5%	$6,400
					$151,600
		CONTINGENCY		30%	$45,500
PROJECT TOTAL					**$197,100**

Table A3 – Opinion of Probable Construction Cost for U.S. Highway 259 Crossings

Increase US 259 Crossings					
General					
	Traffic Control	2	MO	$ 5,000.00	$10,000
	Site Preparation	0.5	AC	$ 25,000.00	$12,500
	Erosion Control and SWPPP Implementation	1	LS	$ 4,000.00	$4,000
Storm Drain					
	Trench Safety	900	LF	$ 2.00	$1,800
	Remove Existing 7'x4' RCB	315	LF	$ 18.00	$5,670
	Install 8'x5' RCB	178	LF	$ 400.00	$71,200
	Install 10'x6' RCB	123	LF	$ 660.00	$81,180
	Remove and replace headwall	2	EA	$ 7,000.00	$14,000
	Remove 16" RCP	80	LF	$ 15.00	$1,200
	Install 36" RCP	80	LF	$ 83.00	$6,640
	Remove Existing 36" RCP	122	LF	$ 15.00	$1,830
	Install 48" RCP	600	LF	$ 138.00	$82,800
	Remove and replace headwall	2	EA	$ 7,000.00	$14,000
	Remove concrete in channel and regrade	240	LF	$ 10.00	$2,400
	Replace concrete lined channel	510	SY	$ 35.00	$17,850
Paving					
	Concrete Pavement Saw, Remove and Dispose	1,000	SY	$ 6.00	$6,000
	Concrete Pavement	1,000	SY	$ 33.00	$33,000
	6" Stabilized Subgrade Install	1,000	SY	$ 2.50	$2,500
	Concrete Curb remove and replace	60	LF	$ 4.00	$240
	Sidewalk remove and replace	115	LF	$ 15.00	$1,725
	Sod	1,450	SF	$ 4.00	$5,800
Water and Sewer					
	Miscellaneous Utility Adjustments	1	LS	$ 20,000.00	$20,000
				$ -	$0
				$ -	$0
				$ -	$0
		SUBTOTAL:			$396,400
					$455,900
					$475,800
PROJECT TOTAL					**$618,600**

Table A4 – Opinion of Probable Construction Cost for Main St. to Outfall Improvements

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
Increase Pipe from Main Street to Channel Outfall					
General					
	Site Preparation	0.3	AC	$ 25,000.00	$7,500
	Erosion Control and SWPPP Implementation	1	LS	$ 4,000.00	$4,000
Storm Drain					
	Trench Safety	760	LF	$ 2.00	$1,520
	Remove Existing 24" and 36" RCP	760	LF	$ 15.00	$11,400
	Remove existing inlet	2	LS	$ 500.00	$1,000
	Install 16 foot curb inlet	2	LS	$ 4,800.00	$9,600
	Install 3'x3' RCB	570	LF	$ 120.00	$68,400
	Install 4'x3' RCB	190	LF	$ 150.00	$28,500
	remove and replace headwall	1	LS	$ 7,000.00	$7,000
Paving					
	Concrete Flume Pavement	130	SY	$ 33.00	$4,290
	Concrete Pavement Saw, Remove and Dispose	75	SY	$ 6.00	$450
	Concrete Pavement	75	SY	$ 33.00	$2,475
	6" Stabilized Subgrade Install	75	SY	$ 2.50	$188
	Sod	2,550	SF	$ 4.00	$10,200
Water and Sewer					
	Miscellaneous Utility Adjustments	1	LS	$ 20,000.00	$20,000
				$ -	$0
				$ -	$0
				$ -	$0
				$ -	$0
		SUBTOTAL:			$176,600
		OH & P		15%	$26,500
					$203,100
		MOBILIZATION		5%	$8,900
					$212,000
		CONTINGENCY		30%	$63,600
PROJECT TOTAL					**$275,600**

Table A5 – Opinion of Probable Construction Cost for North St. Crossing Improvements

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
North Street Crossing					
General					
	Traffic Control	2	MO	$ 5,000.00	$10,000
	Site Preperation	0.1	AC	$ 25,000.00	$2,500
	Erosion Control and SWPPP Implementation	1	LS	$ 4,000.00	$4,000
Storm Drain					
	Trench Safety	330	LF	$ 2.00	$660
	Remove Existing 3'x3' RCB	80	LF	$ 18.00	$1,440
	Install 7'x4' RCB	80	LF	$ 361.00	$28,880
	Remove Existing 18" RCP	250	LF	$ 15.00	$3,750
	Install 24" RCP	250	LF	$ 40.00	$10,000
	Remove and replace headwall	2	EA	$ 7,000.00	$14,000
Paving				$ -	$0
	Concrete Pavement Saw, Remove and Dispose	150	SY	$ 6.00	$900
	Concrete Pavement	150	SY	$ 33.00	$4,950
	6" Stabilized Subgrade Install	150	SY	$ 2.50	$375
	Concrete Curb remove and replace	30	LF	$ 4.00	$120
	Sidewalk remove and replace	280	LF	$ 15.00	$4,200
	Sod	1,250	SF	$ 4.00	$5,000
Water and Sewer				$ -	$0
	Miscellanious Utility Adjustments	1	LS	$ 20,000.00	$20,000
				$ -	$0
				$ -	$0
				$ -	$0
		SUBTOTAL:			$110,800
		OH & P		15%	$16,700
					$127,500
		MOBILIZATION		5%	$5,600
					$133,100
		CONTINGENCY		30%	$40,000
PROJECT TOTAL					**$173,100**

Appendix B – Microsoft Access One Page Project Summaries

Downtown Storm Sewer CIP
Project: RE-ROUTE NORTH DOWNTOWN SYSTEM

Project Information

Project ID:	DT-1	**Project Cost Range:**	$500,000 to $1,000,000
Project Name:	RE-ROUTE NORTH DOWNTOWN SYSTEM	**CIP Rank:**	1
Project Type:	Pipe System Improvements	**CIPYear:**	
Date Identified:	2014	**Date Completed:**	

Problem Description:

The North System in the downtown area is significantly undersized and results in a large amount of bypass ponding at sag locations on Kilgore Street, Main Street, and North Street. Improvements to the storm drain system were performed in 2010 by KSA Engineers but were limited to Main Street and connected to the existing undersized system at the alley between Kilgore Street and Rusk Street.

Proposed Improvements:

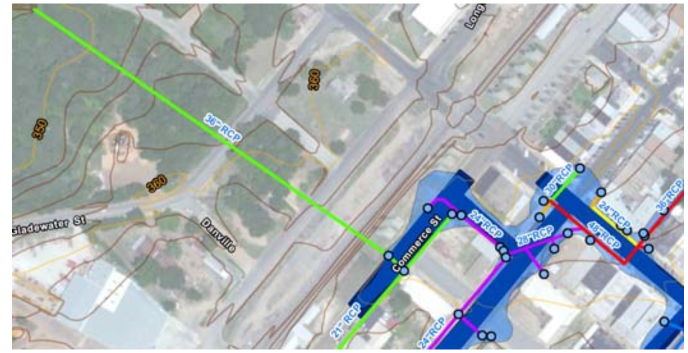
Re-route existing 24" RCP between Main Street and South Street to the north of Kilgore Street to connect to North Subsystem B and increase size to 2-36" RCPs. Increase North Subsystem B outfall pipe from a 36" RCP to 2-36" RCPs under the existing railroad to the outfall west of Martin L King Drive.

To provide additional system capacity, increase and re-route the storm sewer starting at the intersection of Sabine Street and Rusk Street. Increase the existing pipe from a 36" RCP to a 54" RCP. To avoid construction on private property, re-route the existing pipe to continue north east on Sabine Street until it ties-in to the 22" RCP along Kay Street. At this tie-in location the invert elevations will need to be lowered and the pipe size increased to a 54" RCP until it ties-in to the existing 54" RCP on Martin Street.

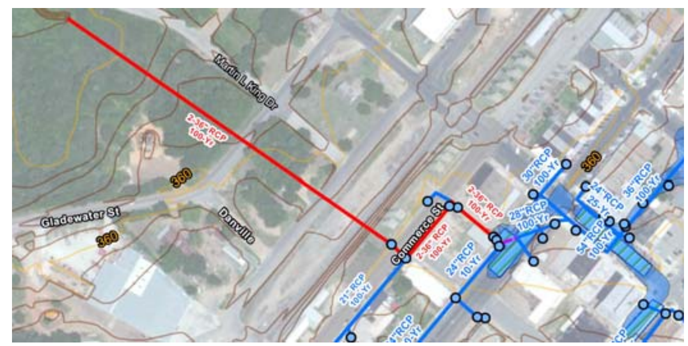
CIP Ranking Criteria

Life Safety / Road Flooding:	3
Property Damage:	2
Frequency of Flooding:	4
Prjoject Cost:	2
Maintenance:	5
Total Weighted Point Score:	120

Project Photos



Existing flooding in the downtown area.



Proposed improvements in the downtown area.

Project Information

Project ID: DT-2
Project Name: INCREASE HIGHWAY 259 ROAD CROSSINGS
Project Type: Pipe System Improvements
Date Identified: 2014
Project Cost Range: $100,000 to $250,000
CIP Rank: 2
CIPYear:
Date Completed:

Problem Description:

There are two channels located in the Kilgore City Park that convey flow to two separate culverts that run under Highway 259 and outfall into the channel east of Highway 259 and north of Kay Street. Both culverts are substantially undersized for the 100-yr storm event resulting in the road overtopping.

Proposed Improvements:

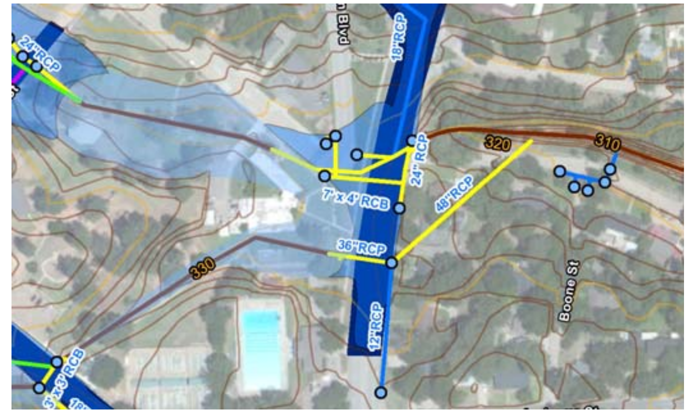
South Road Crossing: Increase size of 36" RCP to 2-48" RCPs. Redirect existing 48" RCP east of Highway 259 to avoid property conflict and increase size to 2-48" RCPs.

North Road Crossing: Increase culvert size from 7’ x 4’ RCB to 8’ x 5’ to the west side of Highway 259 and then increase to a 10’ x 6’ RCB until the outfall east of Highway 259. Increase size of 16” lateral to 36” and connect to 8’ x 5’ RCB. In order to accommodate these improvements, the upstream and downstream invert elevations of the road crossing will need to be lowered. The upstream elevation will need to decrease by approximately one (1) foot. The downstream elevation will need to decrease approximately two (2) feet. The channel to the east of U.S. 259 will need to be re-graded due to the decrease in flowline elevation for approximately 240 feet. The existing slope of the channel is approximately 0.026 ft/ft and the proposed slope of the channel after re-grading will be approximately 0.018 ft/ft.

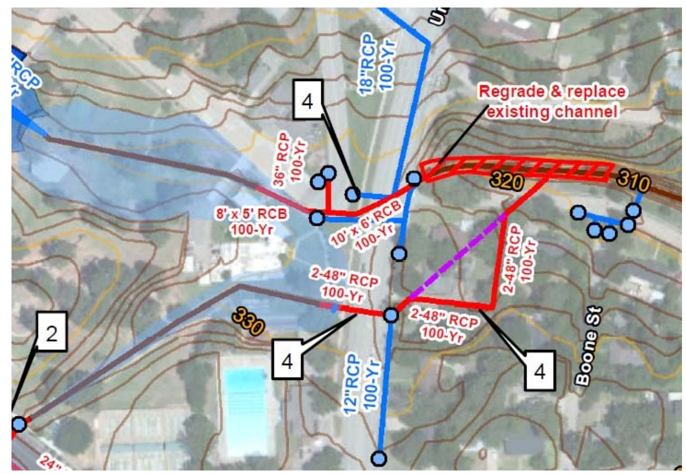
CIP Ranking Criteria

Life Safety / Road Flooding:	3
Property Damage:	2
Frequency of Flooding:	3
Prjoject Cost:	2
Maintenance:	3
Total Weighted Point Score:	104

Project Photos



Existing flooding at the Highway 259 crossings



Proposed improvements of the Highway 259 crossings

Downtown Storm Sewer CIP
Project: RE-ROUTE PIPE FROM NORTH ST TO WOOD ST

Project Information

Project ID:	DT-3	**Project Cost Range:**	$500,000 to $1,000,000
Project Name:	RE-ROUTE PIPE FROM NORTH ST TO WOOD ST	**CIP Rank:**	3
Project Type:	Pipe System Improvements	**CIPYear:**	
Date Identified:	2014	**Date Completed:**	

Problem Description:

The pipe system that runs along Martin Street, crosses North Street, and outfalls south of Wood Street was determined to be undersized. The result of the insufficient pipe is a large amount of bypass flow that continues south on North Street and enters the South System at the North Street road crossing which increases existing road overtopping.

Proposed Improvements:

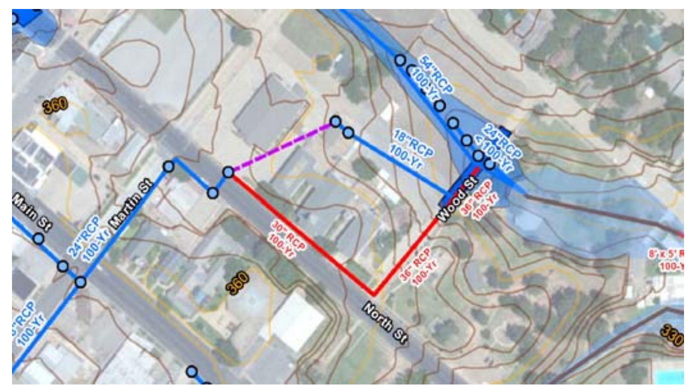
To eliminate the bypass between the two systems and reduce road inundation the storm sewer system needs to be enlarged from the intersection of Martin Street and North Street to the tie-in location at Wood Street. The current pipe system travels through several commercial properties. To reduce the requirements of easements or tunneling, it is recommended that a new pipe path down North Street and Wood Street be utilized for the increased system. This includes a 30" RCP that will start at the north inlet on North Street and convey runoff southeast to the intersection of North Street and Wood Street. At the intersection the pipe should be increased to a 36" RCP and will convey runoff northeast until tying in to the 54" RCP that outfalls into Kilgore City Park.

CIP Ranking Criteria

Life Safety / Road Flooding:	1
Property Damage:	1
Frequency of Flooding:	5
Prjoject Cost:	4
Maintenance:	2
Total Weighted Point Score:	94

Project Photos

Existing bypass of the North Street system



Proposed improvements of the North Street to Wood Street pipe system

Downtown Storm Sewer CIP

Project: INCREASE NORTH STREET ROAD CROSSING

Project Information

Project ID:	DT-4	**Project Cost Range:**	$100,000 to $250,000
Project Name:	INCREASE NORTH STREET ROAD CROSSING	**CIP Rank:**	5
Project Type:	Pipe System Improvements	**CIPYear:**	
Date Identified:	2014	**Date Completed:**	

Problem Description:

There is a North Street road crossing approximately 700 feet northwest of Highway 259. The crossing consists of a 3'x3' RCB that conveys runoff from a residential channel to the southern channel of Kilgore City Park. There are two laterals that tie-in to the box culvert. Existing condition modeling determined that the road crossing was under sized and is being overtopped with the potential to cause flooding problems upstream.

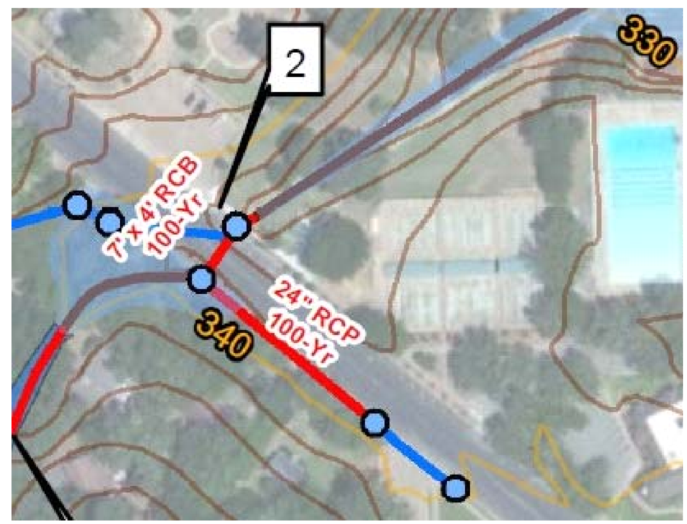
Proposed Improvements:

It is recommended that the culvert crossing be increased to convey the 100-yr storm event. This would require the crossing be increased from a 3'x3' RCB to a 7'x4' RCB. The southern lateral that ties in to the culvert should also be increased from an 18" RCP to a 24" RCP to prevent excessive spread in the street.

It should be noted that the recommended proposed improvement is contingent on the DT-3 Re-route Pipe from North Street to Wood Street project which reduces the runoff from the northern pipe system from entering the southern pipe system.

Project Photos

Existing flooding at the North Street Road Crossing



Proposed Improvements at the North Street Road Crossing

CIP Ranking Criteria

Life Safety / Road Flooding:	1
Property Damage:	1
Frequency of Flooding:	3
Prjoject Cost:	4
Maintenance:	0
Total Weighted Point Score:	70

Project: INCREASE PIPE SIZE FROM MAIN ST TO CHANNEL-2 OUTFALL

Project Information

Project ID: DT-5

Project Cost Range: $250,000 to $500,000

Project Name: INCREASE PIPE SIZE FROM MAIN ST TO CHANNEL-2 OUTFALL

CIP Rank: 4

Project Type: Pipe System Improvements

CIPYear:

Date Identified: 2014

Date Completed:

Problem Description:

There is a sag location on Main Street just south of Benton Street. There are two inlets at the sag location. Existing condition modeling shows that the pipe system that conveys the runoff east under commercial property is inadequate and the ponding at the sag location is likely to overtop the curb and travel through the commercial properties until reaching the sag location on Choice Street which also overtops and conveys bypass to the open channel on residential property.

Proposed Improvements:

It is recommended that the pipe between the Main Street sag and the Choice Street sag be increased from a 24" RCP to a 3'x3' RCB and then a 4'x3' RCB from the Choice Street sag to the Channel-2 outfall on residential property. The two 8' inlets at the Choice Street sag should be increased to two 16' inlets. This additional capacity will reduce the ponding in both sag locations.

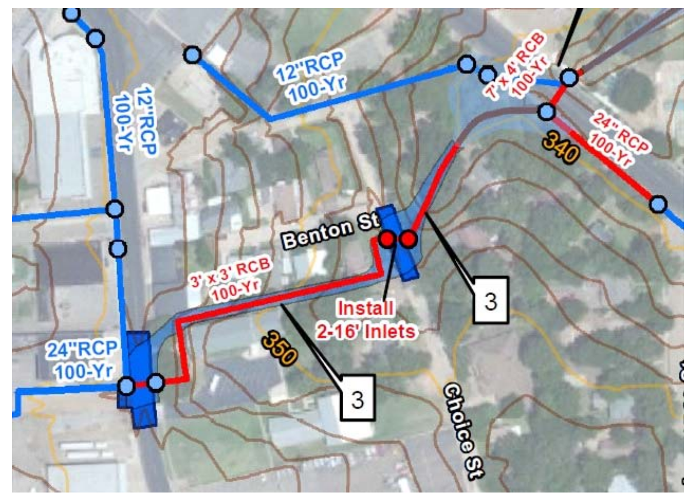
It is also recommended that a flume be constructed between the commercial properties from Main Street to Choice Street to direct any overflow that may occur during large storm events.

CIP Ranking Criteria

Life Safety / Road Flooding:	1
Property Damage:	1
Frequency of Flooding:	4
Prjoject Cost:	3
Maintenance:	1
Total Weighted Point Score:	76

Project Photos

Existing flooding at Main Street and Choice Street sag locations



Proposed improvements at Main Street to Channel-2 outfall

APPENDIX 5-F
SABINE PASS TO GALVESTON FINAL FEASIBILITY AND MEMORANDUM OF RECORD

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CESWG-Z 26 APRIL 2021

MEMORANDUM FOR RECORD

SUBJECT: HYDRAULIC DESIGN CRITERIA FOR THE INTERIOR AREA OF THE SABINE PASS TO GALVESTON BAY ORANGE CSRM LEVEE

References

- *i.* Public Law 115-270. Section 1401 (3)3., Water Resources Development Act of 2018
- *ii.* *USACE. Chief's Report-Sabine Pass to Galveston Bay, Texas, Coastal Storm Risk Managementand Ecosystem Restoration Study* 2017
- *iii.* USACE, *Sabine Pass to Galveston Bay, Texas Coastal Storm Risk Management and Ecosystem Restoration Final Integrated Feasibility Report – Environmental Impact Statement*, May 2017
- *iv.* TxDOT, *New Rainfall Coefficients -- Including tools for estimation of intensity and hyetographs inTexas,* 2015
- *v.* TxDOT, *Hydraulic Design Manual* 2019
- *vi.* Orange County Drainage District, *Drainage Criteria Manual* October 6, 2020
- *vii.* U.S. Geological Survey, *Water-Resources Investigations Report 96–4307 USGS Regional Equations for Estimation of Peak-Streamflow Frequency for Natural Basins in Texas,* 1996
- *viii.* Galveston Coastal Services, *Interior Drainage – Progress Summary andObservations* – 05 FEB 2021
- *ix.* USACE *Hydrologic Analysis for Interior Areas EM 1110-2-1413,* 2018
- *x.* USACE *CECW-PA MEMORADUM SUBJECT: Policy Guidance Letter No. 37, CostSharing of Interior Drainage Facilities,* No Date
- *xi.* USACE and UCF, *Assessing the Potential for Compound Flooding in Parts the Sabine And Brazoria River Basins: Joint probability analysis of high river discharge and storm surge.* No Date

1. The purpose of this memo is to establish the design criteria for the interior drainage area of theOrange CRSM levee for the Sabine Pass to Galveston Bay Project and how results of the performance of the design criteria will be determined and implemented.

2. The Sabine Pass to Galveston Bay Project was authorized in Section 1401 of the Water Resources Development Act of 2018 (P.L. 115-270) (Ref. i). The authorization states that the Sabine to Galveston Project will be carried out substantially in accordance with the plans and subject to the conditions described in the Chief's Report (Ref ii). The Chief's Report details the Orange CSRM plan which will build seven pump stations, 56 drainage structures, and 32 closuregates located at road and railway crossings to mitigate interior flooding during surge events. Twonavigable sector gates with adjacent vertical lift floodgates for normal channel flows would be constructed in Adams and Cow Bayous to reduce surge penetration.

3. The development of the interior drainage analysis in support of the study was summarized in the Sabine Pass to Galveston Bay Integrated Feasibility and Environmental Analysis Report (Ref iii). The analysis documented in the report is based on the USACE standard

covered in Ref ix which governs Hydrologic Analysis for Interior Areas. Ref ix requires that the minimum facilities design event be based on the local drainage system design event, which is published by Orange County Drainage District (Ref vi). A hydrologic analysis using the Rational Method determined the frequency-discharge values for small watersheds and regression equations were used to determine the frequency-discharge values of large watersheds. The rainfall intensity parameters used for the Rational Method were based on rainfall estimates published in 2015 by TxDOT (Ref. iv). TxDOT has since updated their Hydraulic Design Manual (Ref. v) with new parameters which are published in the current Orange County Drainage District Design Criteria Manual and Regulation (Ref. vi). For large watersheds, discharges were conservatively chosen based on the higher results of two regressions equations published by TxDOT (Ref. v) and the USGS (Ref. vii).

4. In the Feasibility Study, drainage provided by culverts through the design levee were placed in areas of known flow paths and sized to allow the 100-year discharge plus a 10% increase for climate change to pass without backwater effects. No pumps were required or anticipated for the "open gate" condition. As a result, it was assumed that there were no interior flood impacts for low exterior, or "open gate" conditions. Under a surge conditions or "closed gate conditions", it was assumed that the gravity drained flood waters equivalent to a 25-year storm behind the interior would be pumped over the levee. Pump sizes were reduced based on a Joint Probability Analysis(JPA) on the nearby Neches River due to the assumed non-coincident nature of riverine and costal surge events.

5. Due to the simplistic methods used to generate interior hydrology (Regression Equations and Rational Method) and the assumptions on culvert performance, a more detailed analysis was recommended for PED. There is concern that the interior drainage design will not perform as well as in feasibility. Reasons for reduced performance for drainage could be attributed to an increase in runoff due to application of NOAA Atlas14 precipitation values and reduced culvertperformance due to inclusion of tailwater conditions and frictional losses.

6. With any changes to the design, the hydraulic performance must meet the minimum facility requirement stated in multiple USACE guidance documents (Refs. ix, x). Minimum interior drainage facilities are defined as the measures required to provide interior drainage relief such that, during low exterior stages, the local storm drainage system will function as it did without the line-of-protection in place to accommodate the flows from the storm water system design storm. Minimum facilities may also include higher storm water design standards than accommodated by the local storm water system if these higher standards are mandated by validly promulgated Federal, State or local regulations. The current standard to which the minimum facilities is to be based on is defined in the Orange County Drainage District Drainage Criteria Manual and Regulation (Ref. vi).

7. Orange County Drainage District Drainage Criteria Manual has developed separate criteria forwhat is referred to as "primary" and "secondary" drainage features. Primary drainage facilities include open channels, bridges, culverts, and enclosed drainage systems (i.e., open channel thathas been enclosed). Secondary drainage facilities include storm sewer systems, roadside ditchesand associated structures, and other facilities such as sheet flow swales, small culverts, local detention facilities, and other structures which typically serve relatively small drainage areas, as well as lot grading and drainage requirements.

8. Primary features adopt a 100-year level of protection for future primary drainage facilities. Channels shall be designed to convey 100-year peak flow rates with a minimum freeboard of 1 foot. These channels should also be analyzed using a 10-year design storm event to ensure the channel has adequate capacity to accept and convey a more frequent and more intense storm of shorter duration which could cause "flash flooding". For open channel studies involving FederalEmergency Management Agency (FEMA) submittals, the 10-year, 50-year, 100-year, and 500- year storm frequencies must be analyzed. Other criteria existing beyond these critical regulationsare within the Orange County Drainage Manual. Conversations with the local stakeholders clarified the residual flooding requirement to mean 0.0 ft rise in water surface elevation for areas inundated by the 50% CL 100-year 24-hour storm defined in NOAA Atlas 14.

9. The minimum requirement does not address a surge or "closed gate" condition. However, the intent of the feasibility design performance was to size pump stations to pass the 25-year interiorflood over the levee. The closed condition should evaluate a design to meet this performance goal under updated inputs (NOAA Atlas 14) and methods (computational modeling using HEC-HMS and HEC-RAS). Ultimately, the closed condition should be evaluated under a coincident inland flood event to a condition or event that necessitates a "closed gate" condition, including a predicted coastal flood event. This information is resolved by developing a JointProbability Analysis. The Joint Probability Analysis should determine the coupled surge/interior flood conditions and assign a frequency probability to them. A recent JPA analysis was conducted on the Adams and Cow Bayou by USACE and UCF (Ref. xi) following the FeasibilityStudy. The analysis provided return periods for compounding flood events. For the Cow Bayou,a relationship between the Cow Bayou discharge gage at the Mauriceville and surge levels at Sabine Pass Tidal Gage were developed. For Adams Bayou, due to a lack of gage data, a relationship was developed between precipitation the weather station at Orange and surge levels at the Sabine Pass Tidal Gage. The relationships were developed by investigated correlations in the data sets and applying best-fit distributions and copulas. The results are shown in the Figures1 and 2.

10. Measures to solve residual interior flooding may include larger capacity outlets, diversion structures, pressure conduits, excavated detention storage, ponding areas, pumping plants andnonstructural solutions. Residual flooding will be analyzed using risk informed analysis, which

includes delineation of multiple storm events from the 2 year to the 500 year.

11. To summarize, the Government, during design, will follow this procedure to finalize the interior drainageanalysis:
    a. Under open gate low exterior conditions, the interior design must meet the minimum design facility standard. Evaluation will be for eight flood frequency (i.e.., 2-, 5-, 10-, 25-, 50-, 100- and 500-year) events. The final system will be designed for the NOAA Atlas 14 100-year, 24-hour, 50% CL precipitation. The Joint Venture scope will be developed to address the local residual flooding requirement of 0.0 ft rise in water surface elevation by analyzing 2 alternatives; 1) an alternative that eliminates increased water level on the interior of the system and, 2) an alternative that minimizes, but may not eliminate, increased water level on the interior of the system.
    b. Under a closed gate condition for surge events, the interior drainage system including pump stations and minimum pump capacity will be designed for the greater of the minimum facility design, or a design sized for the NOAA Atlas 14 25-year 24 hour 50% CL precipitation event (as authorized in the feasibility study). As with the open condition, evaluation will be for eight flood frequencies (i.e.., 2-, 5-, 10-, 25-, 50-, 100- and 500-year) events. However, actual probability of occurrence will be assigned through a JPA analysis (to be included inthe task order if greater fidelity than *ref. xi* can be reasonably expected to be obtained). Residual flooding will be documented for each of the flood frequencies considering the JPA.

12. The point of contact for this memorandum is Robert Thomas at 409-766-3975 or email Robert.c.thomas@usace.army.mil.

Encl

TIMOTHY R. VAIL
COL, EN
Commanding

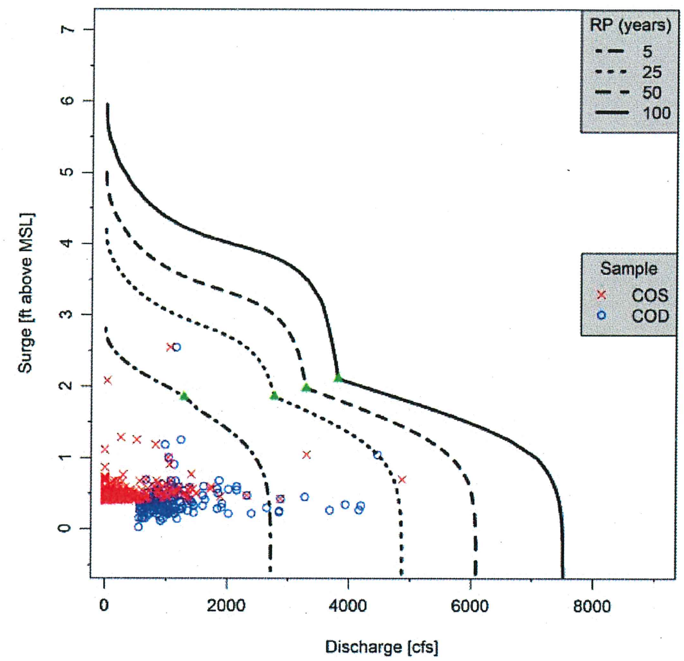

Figure 1: Cow Bayou RP for Discharge Values at the Mauriceville gage and Surge levels at the Sabine River Tidal Gare (fromFigure 21 of Ref i)

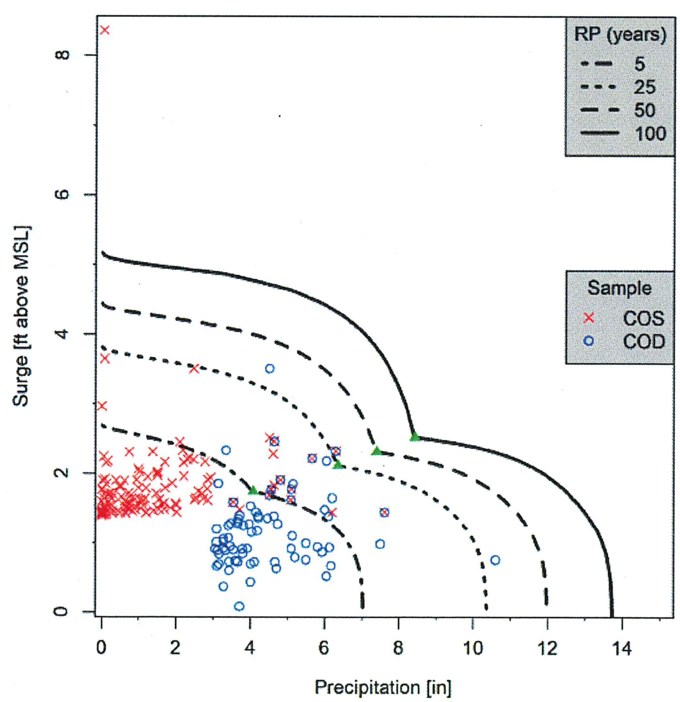

Figure 2: Compound Flood Return period for Adams Bayou with Precipitation Values at the Orange Station and Surge levels atthe Sabine River Tidal Gare (from Figure 32 of Ref i)

U.S. Army Corps
of Engineers

Galveston District
Southwestern Division

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

Final Integrated Feasibility Report – Environmental Impact Statement

May 2017

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DEPARTMENT OF THE ARMY
GALVESTON DISTRICT, CORPS OF ENGINEERS
P. O. BOX 1229
GALVESTON, TEXAS 77553-1229

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

Final Integrated Feasibility Report – Environmental Impact Statement

May 2017

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FINAL ENVIRONMENTAL IMPACT STATEMENT
FOR THE PROPOSED SABINE PASS TO GALVESTON BAY, TEXAS
COASTAL STORM RISK MANAGEMENT
AND ECOSYSTEM RESTORATION PROJECT

The U.S. Army Corps of Engineers, Galveston District (USACE), under the authority of, a resolution from the Committee on Environmental and Public Works dated June 23, 2004, entitled "Coastal Texas Protection and Restoration Study" proposes to reduce the risks of tropical storm surge impacts by constructing the new Orange 3 coastal storm risk management (CSRM) system in Orange County, and increasing the level of risk reduction and resiliency of the existing Port Arthur and Vicinity and Freeport and Vicinity Hurricane Flood Protection (HFP) systems in Jefferson and Brazoria Counties, Texas. The Orange 3 CSRM project would consist of a 26.7-mile long levee/floodwall system along the edge of the Sabine and Neches River floodplains from Orange to the vicinity of Orangefield, Texas. The Port Arthur and Freeport CSRM Projects would raise or reconstruct 11.6 miles and 18.2 miles of existing levees/floodwalls for each system respectively, replace vehicular closure structures, construct navigable surge gate structures, and increase resiliency by installing erosion protection. The Orange 3 project would result in the loss of 69.5 acres of forested wetlands and 203.0 acres of estuarine marsh, as well as functional impacts to 2,137.2 acres of estuarine marsh. These impacts would result in the loss of 43 average annual habitat units (AAHUs) for forested wetlands and 143 AAHUs for estuarine marsh. A mitigation plan is proposed that restores 453 acres of estuarine marsh and preserves 559.5 acres of forested wetlands in perpetuity, providing 263 AAHUs to fully compensate for these impacts. The total first cost of the project is estimated to be $3,248,607,000.

This Final Integrated Feasibility Report and Environmental Impact Statement (FIFR- EIS) was prepared as required by the National Environmental Policy Act to present an evaluation of potential impacts of the proposed project. The FIFR-EIS addresses the potential impacts of the proposed project on the human environment, as identified during the public interest review, including potential effects on life and safety, economic benefits, air, water and sediment quality, forested wetlands and coastal marsh, protected species, hazardous and toxic materials, historic properties, energy needs, and, in general, the welfare of the people. Public and agency comments received during the public comment period were addressed. The public and agency comments on the findings of the FIFR-EIS will be addressed in the Record of Decision.

Comments on this FIFR-EIS must be postmarked by: June 26, 2017

Comments may be submitted by email at: SabinePassToGalvestonBay@usace.army.mil
or at the following address:

U.S. Army Corps of Engineers, Galveston District
Attention: Sabine Pass to Galveston Bay, Texas, Study
P.O. Box 1229
Galveston, Texas 77553-1229

EXECUTIVE SUMMARY (*NEPA Required)

STUDY DESCRIPTION

This is a Final Integrated Feasibility Report and Environmental Impact Statement (FIFR-EIS) examining coastal storm risk management (CSRM) and ecosystem restoration (ER) problems and opportunities within six counties of the upper Texas coast (Orange, Jefferson, Chambers, Harris, Galveston, and Brazoria Counties). The study has identified and screened alternatives to address CSRM and ER problems, and is presenting a Recommended Plan. This FIFR-EIS has undergone public review, policy review, Agency Technical Review (ATR), and Independent External Peer Review (IEPR). Final public and agency comments on the findings of the FIFR-EIS will be addressed in the Record of Decision (ROD).

STUDY PURPOSE AND SCOPE

The purpose of this report is to present the final findings of the feasibility investigations and analyses conducted to determine if there is a Federal interest in potential CSRM and ER projects within the coastal areas of the six-county study area. The scope of the study was the subject of multiple vertical team meetings with Headquarters USACE (HQUSACE) in the early stages of formulation. This study is recognized as a critical effort that encompasses six counties (Orange, Jefferson, Chambers, Harris, Galveston, and Brazoria) along 120 miles of the upper Texas coast (Figure ES-1). Multiple options for study scope were considered for this extensive geographic area. It became apparent as the study team identified alternatives, that a feasibility-level evaluation of all the potential alternatives in the entire six-county study area would be difficult to accomplish and maintain compliance with the 3x3x3 Rule. This rule applies to feasibility studies and requires completion within 3 years and under $3 million, unless an exemption is approved by HQUSACE. A Feasibility-level evaluation of all of the potential alternatives in the six-county study in three years introduced risk that was too high and not acceptable for decision making. An exemption request was approved in a CECW-SWD memorandum dated February 25, 2014. The approval was granted to pursue a scope for this study that would take 3.9 years and cost $4.4 million, and address only feasibility-level evaluation of CSRM projects in two of the three regions originally identified for the study (Sabine, Galveston, and Brazoria). The exemption approved evaluation of the Sabine region, focusing on Orange and Jefferson Counties, and the Brazoria region, focusing on the Freeport area in Brazoria County. Because of cost and complexity, the decision was made to include only a comprehensive assessment of potential CSRM projects in the Galveston region (Galveston, Harris, and Chambers Counties) and potential ER projects throughout the entire six-county study area. The comprehensive assessment is a listing of future studies that have high potential for recommending CSRM and ER projects with Federal interest. For example, one of the ongoing studies, the USACE Coastal Texas CSRM and ER Feasibility Study is addressing issues in the Galveston Bay Region.

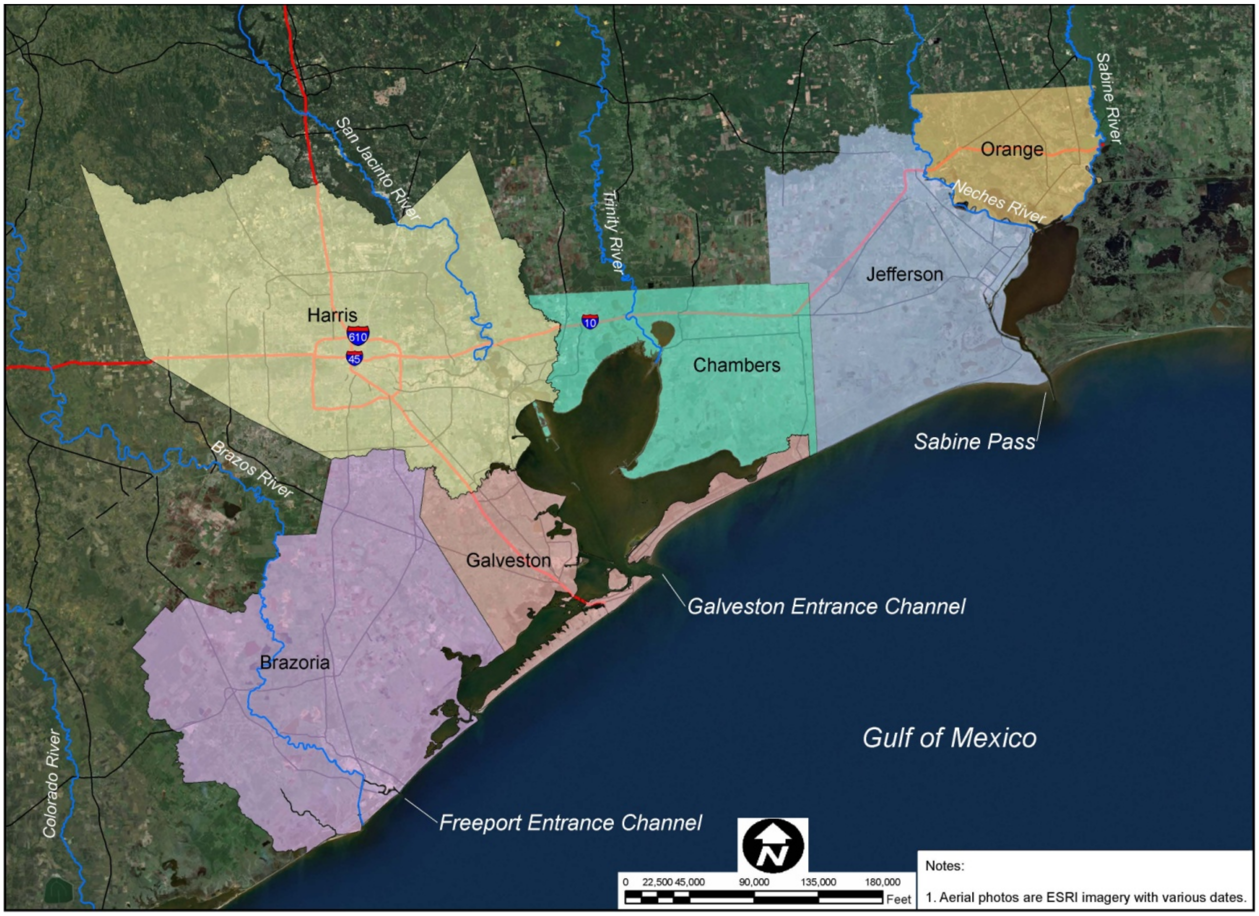

Figure ES-1: Sabine Pass to Galveston Bay Study Area

PROJECT PURPOSE AND NEED

The study area has seen several major historical surge events in the past 120 years. The most notable is the 1900 Storm, which inundated most of the island city of Galveston, Texas, and adjacent areas on the mainland. The storm was responsible for over 8,000 deaths and up to $30 million in property damage. Most recently, Hurricane Rita in 2005 resulted in storm surge of 9.24 feet in Port Arthur, Texas, and just over eight feet in Sabine Pass. Hurricane Ike in 2008 produced storm surges from 14 feet near Sabine Pass with 11 to 12 feet across Sabine Lake. Port Arthur was spared the storm surge thanks to its 14- to 17-foot seawall. However, the remaining southern half of Jefferson County was inundated, with estimated high water marks reaching 18 to 19 feet to the south and east of High Island.

Both hurricanes resulted in significant impacts on coastal shorelines, marsh, and forested wetlands. Shorelines eroded in some areas, while others were covered with several feet of sediment. Thousands of acres of coastal marsh were inundated with high salinity Gulf waters, scouring and killing marsh types that were not tolerant of the higher salinity. In addition to inundating marshes near the coast, tidal surges resulted in significantly increased salinities in large areas of swamp and freshwater marsh in the Sabine region for months after the storms.

Specific Problem and Opportunity statements were developed to address the need to reduce coastal storm risks in the study area, and these are described in the main body of this FIFR-EIS, in Chapter 4. This study identifies a Recommended Plan for implementation to address the storm surge flooding in the study area. Considering the recent damages from Hurricane Ike, the population and infrastructure of the region, and the national significance of the economic and environmental resources within the region, there is a Federal interest for implementing a project. A variety of alternatives were analyzed in the study, including the “No Action Alternative.” The “No Action Alternative” is synonymous with the terms “future without-project” or “future without-project condition”. These terms are used interchangeably throughout the FIFR-EIS and provided for a baseline comparison of all alternatives. The without-project condition describes the condition that is expected to prevail in the planning area in the future if the No Action Alternative is selected as the best thing to do. The alternatives were also measured against planning criteria developed for the study that align with USACE policies.

PLANNING OBJECTIVES

The objectives listed below were developed from problem and opportunity statements and used to guide the plan formulation for the Recommended Plan. The alternatives were measured throughout the study using the measuring criteria and in greater detail as the alternative screening progressed. The planning objectives were developed to align with the “four accounts” listed in the Economic and Environmental Principles for Water and Related Land Resources Implementation Studies. These “principles” were established pursuant to P.L. 89-80, as amended. The four accounts are established to facilitate evaluation and display of effects of alternative plans. The four accounts are: 1) National Economic Development (NED); 2) Environmental Quality (EQ); 3) Regional Economic Development (RED); and 4) Other Social Effects (OSE).

- Objective 1: Reduce economic damages to business, residents, and infrastructure for the Sabine and Brazoria regions for the 50-year period of analysis.
- Objective 2: Reduce risk to human life from storm surge impacts for the Sabine and Brazoria regions for the 50-year period of analysis.

- Objective 3: Maintain and/or restore coastal habitat that contributes to storm surge attenuation where feasible 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 regions 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 regions for the 50-year period of analysis.
- Objective 6: Identify opportunities to enhance functionality of existing hurricane protection systems including evaluation of impacts due to sea level rise for the 50-year period of analysis.

Alternative plans were formulated to reduce the risk of damages from coastal storms, minimize impacts to floodplains, and avoid environmentally significant resources. Where impacts could not be avoided, environmental impacts were quantified and a mitigation plan was formulated.

The following constraint was developed from the problem and opportunity statements and used to guide the plan formulation for this study. Reducing life-safety risk is a primary objective of the study; however, careful evaluation of alternatives is required to ensure that structural plans do not increase risk. As such, features that increase risk to human life from storm surge impacts in the Sabine and Brazoria regions for the 50-year period of analysis were not considered with the development of the Recommended Plan.

FORMULATION OF ALTERNATIVE PLANS

Nonstructural and structural measures were considered as part of the study analysis and were developed to address study objectives. The nonstructural measures considered include buyouts or relocations, as well as identification of conservation areas. Floodplain management and emergency planning were also considered. The structural measures include new coastal and inland structural barriers, reconstruction of existing and construction of new regional hurricane risk reduction systems, local surge risk reduction systems, raising roads as surge or overwash risk reduction 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.

Through the initial scoping, and performance of a SMART Planning Charette (Charette), the full Vertical Team (USACE District, Division, Headquarters, and Office of Water Project Review) with participation with the local sponsor, 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.” This resulted in a list of about 75 initial measures that served as the building blocks of alternative plans. These nonstructural and structural measures were considered as part of the study analysis and were developed to address study objectives.

The initial measures were screened to determine if they adequately addressed the problems and objectives of this study. The remaining measures were then formed into arrays of alternatives plans, which were screened in three distinct iterations (increasing in level of detail as the screening progressed) to determine the most effective alternatives including:

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

In the Initial Array of Alternatives phase, comprehensive alternative plans were formulated for each of the three regions in the six-county study area. The Initial Array of Alternatives included eleven alternatives for the Sabine Region, nine alternatives for the Galveston Region and five alternatives for the Brazoria Region, for a total of 25 alternatives considered in the Initial Array of Alternatives. The Initial Array of Alternatives were screened using three quantitative criteria (economic benefits, environmental benefits, and implementation costs) and one qualitative criterion (environmental impacts). The screening process led to the identification of the Evaluation Array of Alternative Plans, which is comprised of ten alternatives (three from Sabine Region, four from Galveston Region, and three from Brazoria Region) to be evaluated in more detail.

The Evaluation of Alternatives was used as a decision point to determine whether the data collected and utilized for this analysis are sufficient to make the determination of which alternative “Gate” or “No-Gate” in the Sabine Region to carry forward for detailed analysis. It was estimated the plans would provide roughly the same amount of benefits. Consideration was given to a variety of factors including engineering, economics, costs, and environmental impacts for the Gate and No-Gate Alternatives; however, cost of the Gate Alternative was approximately $865 million more expensive than the No-Gate Alternative. The Gate Alternative also include significant Operation, Maintenance, Repair, Replacement and Rehabilitation (OMRR&R) concerns associated with crossing the Neches River. Therefore, the Gate Alternative was dropped from further consideration in the study.

As discussed above, the final recommendation was to pursue a $4.4 million comprehensive assessment of the six-county study area and focus the current evaluation on two sub-regions, Sabine and Brazoria for CSRM project implementation. This feasibility study will be followed by future studies recommending CSRM projects in the Galveston region, as well as ER opportunities throughout the entire six-county region. In accordance with the exemption request approval, the Sabine and Brazoria CSRM alternatives were carried forward into detailed feasibility analysis. The Final Array of Alternatives is presented in Table ES-1. This list presents the project area for the final array. The "Optimization Alternatives" embedded in the project areas listed in Table ES-1 are the actual final array evaluated, compared and presented in the DIFR-EIS released in Sept 11, 2015.

Table ES-1: Final Array of Separable Elements presented in DIFR-EIS

Initial Array Alternative Name	Final Array of Separable Elements / 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 DIFR-EIS presented the results of the alternatives analysis and selection of the TSP through an iterative process based on economic, environmental, regional economic, social, and engineering factors (i.e. the four accounts – 1) National Economic Development; 2) Environmental Quality; 3) Regional Economic Development; and 4) Other Social Effects). From evaluation of 59 Optimization Alternatives within 20 Alternative Reaches, the performance of Final Array of Alternatives was measured, then evaluated and compared against each other to determine a TSP. The evaluation included a comparison of the future without-project condition (FWOP) and the with-project condition. Since the release of the TSP, the USACE conducted a detailed feasibility analysis of the elements listed in Table ES-1.

AFFECTED ENVIRONMENT

The affected natural environment is a large and complex region that includes approximately 6,865 square miles and two environmentally sensitive and economically important bay systems (Sabine Lake and Galveston Bay), and the coastal portions of several large watersheds (Sabine, Neches, Trinity, San Jacinto and Brazos Rivers). It covers about 120 miles of the Texas coast. Diurnal tidal ranges are small, ranging from 1.3 to 2.0 feet. The study area lies within the Western Gulf Coastal Plain ecoregion, which extends along the Texas Gulf Coast from the Sabine River south to the Rio Grande. The prominent features of this coastal ecosystem include fresh, intermediate, brackish and saline marshes; bays and lagoons that support extensive seagrass beds, tidal flats, and reef complexes; barrier islands; tallgrass prairie with small depressional wetlands, riparian forests, oak mottes, and dense brush habitats. The Sabine and greater Galveston Bay estuaries and extensive coastal wetlands in the coastal Brazos River region are a vital habitat for 75 percent of the fish and shellfish species found in the Gulf of Mexico. The marshes and rice fields over the entire study area are a major wintering area for waterfowl of the central flyway. On average, 1.3 to 4.5 million ducks, or 30 to 71 percent of the total flyway population, winter annually on the Texas Gulf coast. On average, 180,000 pairs of colonial-nesting waterbirds nest annually in Texas coastal habitats. Near coastal forests are critically important for the nation's songbird resources, as the vast majority utilize this habitat during their trans- and circum-Gulf migrations. A string of refuges and wildlife management areas (WMAs) along the coast serve as critical staging areas for waterfowl migrating to and from Mexico.

The affected human environment encompasses six coastal counties of the upper Texas coast. Over five million people reside in the six counties, which includes the fourth largest U.S. city (Houston), and three other metropolitan areas (Beaumont/Port Arthur/Orange, Galveston/Texas City, and Freeport/Surfside). In addition to the population at risk, three of the nine largest oil refineries in the world, 40 percent of the nation's petrochemical industry, 25 percent of the nation's petroleum-refining capacity, and three major U.S. seaports based on tonnage (Port of Houston, Port of Beaumont, and Texas City) are also located in the study area. The growing population, communities, and nationally significant industries are severely vulnerable to risks from coastal storm events. Approximately 2.26 million people across the study area live within storm-surge inundation zones, and estimates for a one-month closure of the Houston Ship Channel alone are upwards of $60 billion in damages to the national economy.

NO ACTION/FUTURE WITHOUT-PROJECT CONDITION

Before the Final Array of Alternatives were evaluated, additional details of the future without-project conditions were gathered for the project areas. Based on the evaluation of the No Action/FWOP conditions, there is the potential for significant economic damages in the Orange-Jefferson CSRM, Port Arthur and Vicinity CSRM, and Freeport and Vicinity CSRM project areas. There are also concerns for life-safety, damages to critical infrastructure, sea level changes, and impacts on significant environmental resources. Storm surge associated with Hurricane Rita flooded much of southern Orange County, causing significant damages in Bridge City, Rose City and the City of Orange. While the existing Port Arthur and Vicinity Hurricane Flood Protection Project (HFP) prevented surge from entering that city, it was nearly overtopped. Changing conditions associated with relative sea level change would result in increasing risks of loss of life and surge damages in the areas currently served by the Port Arthur and Freeport HFP projects. Opportunities to provide life-safety benefits, and other non-traditional secondary or ancillary economic benefits were identified, including preventing disruptions in business and increases in reducing disruption to significant industrial and manufacturing facilities located in the project areas.

FINAL ARRAY EVALUATION RESULTS

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. The alternatives were again evaluated for the NED objectives. Life-safety, critical infrastructure, and consideration of RSLC were also evaluated qualitatively. The decision criteria for selecting a Recommended Plan 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) consistent with the Federal objective of protecting the Nation's environment. In addition, separable elements of each project area had to be incrementally justified to be included in the final plan. The table below shows how the TSP has been further optimized since the DIFR-EIS was released in Sept 11, 2015.

Table ES-2: 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. There were also OSE concerns with leaving communities exposed. Improvements to risk reduction system near these communities could potentially induce stages in the local communities.

RECOMMENDED PLAN

The Recommended Plan was developed in conformance with decisions resulting from the Agency Decision Milestone (ADM) based on responses from public, policy, and technical reviews of the DIFR-EIS. The Recommended Plan consists of three elements – construction of the new Orange 3 CSRM levee/floodwall system, and levee raising/floodwall improvements in the Port Arthur and Freeport CSRM Plans. A region wide systems approach for construction of Orange 3, Port Arthur and Freeport CSRM Plan, is being recommended to ensure that all of the benefits would be achieved. Construction and completion of a region wide risk reduction system would help to lessen the financial and social impacts that tropical storms and hurricanes can cause by reducing the risk of property damage that displaces residents, shuts down commercial and industrial services, and disrupts livelihoods. The risk reduction system has been designed to provide a risk reduction against a 1% probability storm based on the 2080 intermediate relative sea level rate (RSLR) forecast condition within current data and modeling capabilities. The current design elevations varies across the system but utilizes the 2080 intermediate RSLR forecast condition to obtain a 1% level of risk reduction throughout the length of the system. It is important to note that the system should be monitored on a frequent basis to determine if there have been any changes from the initial level of risk reduction stated. The total first cost of the project is estimated to be $3,248,607,000.

- The Orange 3 CSRM Plan would add approximately 15.6 miles of new levees, at elevations ranging from 12.0 to 17.5 feet NAVD88 and approximately 10.7 miles of new floodwalls and gates at elevations ranging from 13.5 to 16 feet NAVD88. New pump stations, a total of 7, would be constructed to mitigate interior flooding during surge events, and navigable sector gates would be constructed in Adams and Cow Bayous to reduce surge penetration. A mitigation plan is included that fully compensates for all impacts of this plan, and a monitoring and adaptive management plan has been developed to ensure that mitigation outcomes are consistent with performance standards, and corrective actions are taken as needed. The total first cost of project construction and mitigation is estimated to be

$1,926,224,000 and the average annual cost of OMRR&R (including mitigation monitoring costs) is $4,565,000.

- The Port Arthur and Vicinity CSRM Plan would raise approximately 5.5 miles of the existing 27.8 miles of earthen levee to elevations ranging from 14.4 to 17.2 feet NAVD88, and construct or reconstruct about 5.7 miles of floodwall to elevations ranging from about 14.4 to 19.4 feet NAVD88. A separate 1,830 feet of new earthen levee would be constructed in the Port Neches area northwest of the existing northern terminus. Numerous vehicle closure structures would be replaced and erosion protection would be added. Environmental impacts of this plan are negligible and no mitigation is needed. The total first cost of project construction is estimated to be $729,069,000 and the average annual cost of OMRR&R is $195,000.
- The Freeport and Vicinity CSRM Plan would raise approximately 13.1 miles of the existing earthen levee system and construct or reconstruct about 5.5 miles of floodwall, improving approximately 43 percent of the existing 43-mile long system. Final elevations would range from 15.8 to 23.8 feet NAVD88. Navigable sector gates would be installed in the Dow Barge Canal to reduce surge penetration in that area. Numerous vehicle closure structures would be replaced and erosion protection would be added. Other project features include raising and reconstructing the Highway 332 crossing, installation of a drainage structure at the head of the Dow Barge Canal, and raising the floodwall at Port Freeport's Berth 5 dock. Environmental impacts of this plan are negligible and no mitigation is needed. The total first cost of project construction is estimated to be $593,313,000 and the average annual cost of OMRR&R is $708,000.

The Recommended Plan is the environmentally preferable alternative. Because the Port Arthur Freeport and Vicinity CSRM Plan is generally the lowest height of all action alternatives that were evaluated and because the Orange 3 CSRM Plan follows the wet/dry interface of the marsh in the area, it would result in the narrowest footprint and the fewest environmental impacts, while reasonably maximizing coastal storm risk reduction to the affected communities. The No Action Alternative would provide no coastal storm risk reduction to the vulnerable populations and infrastructure of the study area.

ENVIRONMENAL CONSEQUENCES

The Orange 3 CSRM element of the Recommended Plan would have significant environmental impacts and, therefore, an EIS has been prepared and integrated with the feasibility report. The Port Arthur and Vicinity and Freeport and Vicinity CSRM Plans would result in only negligible impacts. The Recommended Plan has been determined to be the least environmentally damaging practicable alternative. The Orange 3 project would result in the loss of 69.5 acres of forested wetlands (cypress-tupelo swamp and bottomland forest) and 203.0 acres of estuarine emergent marsh, as well as indirect functional impacts to 2,137.2 acres of estuarine marsh. Ecological modeling of the Orange 3 project impacts has determined that 143 average annual habitat units (AAHUs) would be lost due to direct and indirect impacts to fresh, intermediate and brackish marsh, and 43 AAHUs would be lost due to direct and indirect impacts to cypress-tupelo swamp and bottomland hardwood forests, over the 50-year period of analysis. A $19,635,000 mitigation plan is proposed that restores 453 acres of estuarine marsh in four proposed areas and preserves 559.5 acres of forested wetlands in perpetuity in two proposed areas, providing 263 AAHUs to fully compensate for these impacts. A monitoring and adaptive management plan has also been prepared to determine if the mitigation outcomes are consistent with performance standards and to take corrective actions in case monitoring demonstrates that mitigation measures are not achieving ecological success. The monitoring plan identifies the ecological success criteria for the mitigation, and describes the cost and duration of the monitoring. Orange County, the non-Federal sponsor, would be responsible for the monitoring, resource agency coordination and adaptive management. All monitoring reports prepared by the NFS would be provided to USACE for upward reporting.

ENVIRONMENAL COMPLIANCE

Project impacts were assessed and the mitigation plan was developed in consultation with numerous Federal and state resource agencies. The U.S. Fish and Wildlife Service (USFWS) actively participated in the impacts evaluation and environmental modeling, and has prepared a Final Fish and Wildlife Coordination Act Report (Appendix K). Their recommendations have been incorporated into this proposed project to the greatest extent possible. Formal consultation with the National Marine Fisheries Service regarding impacts to essential fish habitat (EFH) have been concluded, and the mitigation plan has been accepted as providing appropriate compensation for functional losses to fisheries habitat associated with construction of navigable sector gates in Adams and Cow Bayous (Appendix G). The USACE prepared a Biological Assessment (BA) that determined that the Recommended Plan would have no effect on listed species that may occur in the project area (Appendix J) and this assessment was accepted by USFWS and NMFS. The Texas Coastal Management Program has conducted a Federal consistency review and determined that the proposed project is consistent with the Coastal Management Plan goals and policies (Appendix M). The Texas Commission on Environmental Quality (TCEQ) has reviewed the proposed project for general conformity and has determined that the general conformity rules do not apply to the project elements located in Orange and Jefferson Counties, as this area is currently in attainment with National Ambient Air Quality Standards. The proposed Freeport and Vicinity CSRM Plan is located in a current nonattainment area. However, projected emissions are below the threshold that would require a general conformity analysis (Appendix I). USACE has prepared a Clean Water Act §404(b)(1) evaluation of the proposed action, (Appendix H) and TCEQ has provided water quality certification. The U.S. Department of Agriculture has confirmed that the proposed project site need not be given further consideration for protection of prime farmland soils in the area (Appendix G). USACE has executed a Programmatic Agreement among USACE, the Texas State Historic Preservation Officer (SHPO), and non-Federal implementation sponsors to address the identification and discovery of cultural resources that may occur during the construction and maintenance of proposed or existing facilities (Appendix L). There is a potential for new construction and improvements to existing structures to cause effects on historic properties; however, the numbers of properties that may be affected are not extensive. Intensive cultural resources investigations to identify and evaluate any historic properties within proposed construction areas will be conducted prior to construction. Coordination with Federal and state resource agencies will continue throughout the study process as required by the National Environmental Policy Act (NEPA) and Fish and Wildlife Coordination Act.

PUBLIC COORDINATION

Extensive public scoping, stakeholder communication, and resource agency coordination have been maintained throughout development of the Recommended Plan. Four scoping meetings were held in early 2012, which assisted identifying CSRM problems and ER opportunities in the original six-county study area. Two stakeholder briefings were held in the spring of 2014 that focused primarily on communicating the goals and progress of the study with local governments and agencies. Resource agency meetings were held in 2013 and 2014 to update agencies on the progress of the study, and intensive WVA modeling meetings were held through 2015 and the first half of 2016 to model impacts and mitigation associated with the Orange 3 CSRM Plan. Continuous contact has been maintained with outside organizations that have been working to address the same problems as those addressed by this study. In particular, close communication has been maintained with the team at Texas A&M Galveston, which has been working to develop the Ike Dike proposal, the Severe Storm Prediction, Education and Evacuation from Disasters (SSPEED) Center (a consortium of several universities headquartered at Rice University in Houston) which has been assessing a number of other CSRM, ER and recreation initiatives for the Galveston Bay region, and the Gulf Coast Community Protection and Restoration District (GCCPRD) which is preparing a report evaluating CSRM opportunities in the six-county study area.

The majority of the public and agency scoping comments pertained to the Galveston Bay Region and to ecosystem restoration opportunities in general, and are summarized in the report. In the Sabine region, the majority of comments pertained to the need for storm surge risk reduction in Orange County. Industrial interests and the general public emphasized the need to protect petro-chemical facilities in the area. The general public was also concerned about maintaining or improving evacuation routes during storm emergencies. County governments, non-governmental organizations (NGOs), and the public were interested in maintaining and restoring marsh systems in the area. In the Brazoria region, the majority of comments related to the need to address hydrologic/erosion impacts of existing navigation projects, and the need for restraint in the construction of structural systems that would encourage more development. Resource agencies and NGOs urged restoration of natural coastal shoreline features and working with nature and natural processes, as well as protecting shoreline features that provide natural erosion protection.

Public comments on the DIFR-EIS focused on the potential for construction to interfere with port, municipal or industrial operations, and the need for a detailed, final mitigation plan. While supportive of the project, individuals and companies expressed concerns over impacts to their properties or operations during construction, or maintaining access through the structures after construction. One organization requested that the report provide additional explanations regarding screening of structural and non-structural alternatives, induced impacts, cumulative impacts, operations and maintenance concerns, and effect of relative sea-level rise on the proposed project. Changes to the TSP subsequent to public review of the draft report were not significant enough to require a second NEPA review. Additional information on these topics has been included, as appropriate, in this final report.

NON-FEDERAL SPONSOR SUPPORT

The existing Port Arthur and the Freeport HFPPs local sponsors have expressed interest in cost sharing for the Recommended Plan identified for the Port Arthur and Vicinity CSRM and the Freeport and Vicinity CSRM plans. The local sponsors responsible for OMRR&R are the Jefferson Country Drainage District No. 7 and the Velasco Drainage District (VDD), respectively. The local sponsor for Orange 3 CSRM Plan would be Orange County. They have also expressed interest in cost share for construction.

AREAS OF CONTROVERSY AND UNRESOLVED ISSUES

There are no known controversies regarding the Recommended Plan at this time. This study's comprehensive treatment of CSRM concerns for Galveston Bay and ER concerns for the entire study area, which was questioned by some comments on the DIFR-EIS, is being superseded by the ongoing USACE Coastal Texas CSRM and ER Feasibility Study, which is addressing all of these issues.

There are several unresolved issues that will require resolution during Preconstruction Engineering and Design (PED) or construction phases.

- Fill material for levee system construction was assumed to come from approved, commercial borrow sources. If new borrow areas are identified during PED, review of potential environmental impacts would be required.
- Some of the construction areas in all three project elements are located in or immediately adjacent to industrial sites that have a history of generating, handling or storing hazardous or toxic materials. Because of this proximity, additional hazardous, toxic and radioactive waste (HTRW) risk information would be collected with Phase I HTRW assessments during the PED phase to determine if there is potential for construction to disturb previously unknown contaminated sediments or groundwater. In addition, submerged water bottoms to be disturbed by construction of the Adams and Cow Bayou sector gates would be tested for contaminants prior to construction.
- The USACE would evaluate the results of O&M sediment testing of the Neches River Channel maintenance material, and if warranted based upon the results of this testing and evaluation, conduct additional sediment testing prior to construction to confirm the suitability of SNWW sediments for use in marsh mitigation features. The risk of identifying insufficient quantities of suitable sediment for the mitigation features is considered to be low based on the large quantity of shoaled sediments available in adjacent navigation channels, routine O&M water and sediment testing results, and the acceptability of this material for several recent Neches River beneficial use projects.
- Design and construction of the Adams and Cow Bayou sector gates should adopt “fisheries friendly design considerations” provided by NMFS, and the final design of the sector gates should result in no more than a 50 percent constriction of each. If the constriction exceeds this amount, additional impact analysis and resource agency consultation would be required.
- Intensive cultural resource investigations of the Orange 3 CSRM Plan alignment must be completed prior to construction and coordinated with the Texas SHPO.
- The Recommended Plan would impact a total of 80.1 acres of property owned by the Texas Parks and Wildlife Department (TPWD). TPWD has agreed that the feasibility-level impact analysis is sufficient at this time, pending additional study and consultation during the PED phase as planned by USACE. Final approval or concurrence by TPWD cannot occur until requirements of Chapter 26 of the Parks and Wildlife Code are met, and that process cannot be initiated until after the FIFR-EIS is complete and the project is authorized. At this time, no significant obstacles to this approval have been identified. Two of the mitigation areas identified as Best Buy Plans and selected as part of the overall mitigation plan are located on TPWD property. TPWD would consider accepting any and possibly all of the private properties acquired for mitigation purposes, as long as the properties are readily accessible to TPWD staff and the public, and practically manageable. USACE anticipates that these conditions could be met.

MAJOR FINDINGS AND CONCLUSIONS

A diligent effort was made to coordinate and collaborate with resource agencies, local industry, and environmental interests throughout the study process and public meetings. Environmental resource concerns were addressed throughout the study process to ensure that adverse impacts were avoided to the maximum extent practicable. The recommendations contained herein reflect the information available at this time. To ensure that all applicable laws and policies are addressed for the Recommended Plan, this FIFR-EIS will undergo a final state and agency review. The study team will address any outstanding issues raised during this review and confirm the Recommended Plan in the Record of Decision.

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TABLE OF CONTENTS

APPENDICES*

FIGURES

Page

TABLES

Page

List of Acronyms

AAHU	Average Annualized Habitat Units
ACE	Annual Chance Exceedance
ADCIRC	Advanced Circulation
ADM	Agency Decision Milestone
APE	Area of Potential Effects
AQCR	Air Quality Control Region
BA	Biological Assessment
BCR	Benefit-to-cost ratio
BiOp	Biological Opinion
BPA	Beaumont-Port Arthur
BUDM	Beneficial Use of Dredged Material
CAA	Clean Air Act
CAR	Coordination Act Report
CBBEP	Coastal Bend and Bays Estuary Program
CBRA	Coastal Barrier Resources Act
CEQ	Council on Environmental Quality
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CIP	Channel Improvement Project
CR	Conservation Recommendation
cfs	Cubic feet per second
CO2	Carbon dioxide-equivalent
CO2e	Carbon dioxide-equivalent
CR	Conservation Recommendation
CSRM	Coastal Storm Risk Management
CWA	Clean Water Act
CY	Cubic yards
CY/YRr	Cubic yards per year
dBA	Logarithmic A-weighted decibel
DIFR-EIS	Draft Integrated Feasibility Report and Environmental Impact Statement
DOE	Department of Energy
EC	Engineer Circular
EFH	Essential fish habitat
EIS	Environmental Impact Statement
EJ	Environmental Justice
ETN	Emergency Tracking Network
EOP	Environmental Operating Principles

EO	Executive Order
EPA	U.S. Environmental Protection Agency
EQ	Environmental quality
ER	Ecosystem Restoration
ERDC	Engineer Research and Design Center
ESA	Endangered Species Act
ºF	Degrees Fahrenheit
FCSA	Feasibility Cost Sharing Agreement
FEMA	Federal Emergency Management Agency
FIFR-EIS	Final Integrated Feasibility Report and Environmental Impact Statement
FPPA	Farmland Protection Policy Act
FM	Farm to Market Road
FWCA	Fish and Wildlife Coordination Act
FWOP	Future Without-Project
FY	Fiscal year
GHG	Greenhouse Gases
GIWW	Gulf Intracoastal Waterway
GLO	General Land Office
HCD	Habitat Conservation Division
H&H	Hydraulics and Hydrology
HFPP	Hurricane Flood Protection Project
HGB	Houston, Galveston and Brazoria Airshed
HPTRM	High performance turf reinforcement mattress
HSC	Houston Ship Channel
HTRW	Hazardous, Toxic and Radioactive Waste
HQUSACE	Headquarters U.S. Army Corps of Engineers
IDC	Interest during construction
IPCC	Intergovernmental Panel on Climate Change
LERRs	Lands, easements, rights-of-way, and relocations
LF	Linear Feet or Foot
LNG	Liquid Natural Gas
MBTA	Migratory Bird Treaty Act
MCACES	Micro Computer Aided Cost Engineering System
MCY	Million cubic yards
MLLW	Mean lower low water
MLT	Mean low tide
MOVES	Motor Vehicle Emissions Simulator
MPRSA	Marine Protection, Research, and Sanctuaries Act
MSA	Metropolitan Statistical Area

MSL	Mean Seal Level
NAAQS	National Ambient Air Quality Standards
NAICS	North American Industry Classification System
NAVD	North American Vertical Datum
NED	National Economic Development
NEPA	National Environmental Policy Act
NFS	Non-Federal Sponsor
NGO	Non-Governmental Organizations
NMFS	National Marine Fisheries Service
NPL	National Priority List
NRHP	National Register of Historic Places
NOAA	National Oceanic and Atmospheric Administration
NOx	Nitrous oxides
NNBF	Natural and nature-based features
NRC	National Research Council
NRCS	Natural Resource Conservation Service
NSI	National Structure Inventory
NWR	National Wildlife Refuge
O&M	Operation and Maintenance
OMRR&R	Operation, Maintenance, Repair, Replacement and Rehabilitation
OSE	Other social effects
P&G	Principles and Guidelines
PA	Placement area
PCB	Polychlorinated biphenyl
PDT	Project Delivery Team
PED	Preconstruction Engineering and Design
PGL	Planning Guidance Letter
P.L.	Public Law
PMP	Project Management Plan
PSD	Prevention of Significant Deterioration
RCRA	Resource Conservation and Recovery Act
RED	Regional economic development
RSLC	Relative sea level change
RSLR	Relative sea level rate
RSM	Regional Sediment Management
SIP	State Implementation Plan
SAV	Submerged aquatic vegetation
SHPO	State Historic Preservation Officer
SOC	Species of Concern

SPR	Strategic Petroleum Reserve
SNWW	Sabine-Neches Waterway
SWL	Still Water Level
TCEQ	Texas Commission on Environmental Quality
TCMP	Texas Coastal Management Program
TEEX	Texas Engineering Extension Service
TPWD	Texas Parks and Wildlife Department
TWDB	Texas Water Development Board
TxDOT	Texas Department of Transportation
US	United States
USACE	United States Army Corps of Engineers
USCG	U.S. Coast Guard
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
VDD	Velasco Drainage District
VE	Value Engineering
VOC	Volatile organic compounds or
WMA	Wildlife management areas
WRRDA	Water Resources and Reform Development Act

1 STUDY INFORMATION

1.1 INTRODUCTION

This is a Final Integrated Feasibility Report and Environmental Impact Statement (FIFR-EIS) examining coastal storm risk management (CSRM) and ecosystem restoration (ER) opportunities within six counties of the upper Texas coast (Orange, Jefferson, Chambers, Harris, Galveston, and Brazoria Counties). Report sections required for compliance with the National Environmental Policy Act (NEPA) are indicated with an asterisk following the section heading. The Feasibility Cost Sharing Agreement (FCSA) for this study was signed on January 10, 2013, with the non-Federal sponsor, the Texas General Land Office (GLO). The study has identified and screened alternatives to address CSRM and ER problems in the study area. A Draft Integrated Feasibility Report and Environmental Impact Statement (DIFR-EIS) presenting a tentatively selected plan (TSP) was released in Sept 11, 2015. Since the DIFR-EIS the report has undergone public review, policy review, Agency Technical Review (ATR), and Independent External Peer Review (IEPR). This FIRR-EIS documents revisions to the detailed feasibility design, analysis and impacts analyses of the Recommended Plan on significant resources. Revisions from the Revised Integrated Draft Feasibility Report and Environmental Impact Statement are present at the end of Chapter 5.

1.2 STUDY AUTHORITY

1.2.1 General Authority

Authorization for the study is derived from a resolution from the Committee on Environmental and Public Works dated June 23, 2004, entitled "Coastal Texas Protection and Restoration Study".

> *By resolution dated June 23, 2004 entitled "Coastal Texas Protection and Restoration Study", the Committee on Environment and Public Works, U.S. Senate has requested that in accordance with Section 110 of the Rivers and Harbors Act of 1962 the Secretary of the Army develop a comprehensive plan for severe erosion along coastal Texas for the purposes of shoreline erosion and coastal storm damages, providing for environmental restoration and protection, increasing natural sediment supply to coast, restoring and preserving marshes and wetlands, improving water quality, and other related purposes to the interrelated ecosystem along the coastal Texas area.*

The study fits into the overall concept of the authorization to conduct an integrated and coordinated approach to locating and implementing opportunities for CSRM and ER. The purpose of the study is to recommend for Congressional approval a regional CSRM and ER project that encompasses the six coastal counties of the upper Texas coast between Sabine Pass and Galveston Bay. Pursuant to NEPA, an EIS was be integrated into the report.

1.2.2 Additional Study Guidelines

The request for re-scoping the Sabine Pass to Galveston Bay Shoreline Erosion Feasibility Study was granted November 21, 2011. A Planning Charette was performed in August 2012. Memorandums were prepared for In-Progress Reviews (IPR) throughout the study to document discussions with the vertical team and for input into the decision log and decision management plan. The documents provided guidance to the study team as the study progressed. Most importantly, an exemption approval to the 3x3x3 Rule was provided in a CECW-SWD memorandum, dated February 25, 2014. The memorandum provided guidance on the scope of the study. This is discussed further in the next section, “Study Purpose and Scope.”

1.3 STUDY PURPOSE AND SCOPE*

The purpose of this report is to present the findings of the feasibility investigations and analyses conducted to determine if there is a Federal interest in potential CSRM and ER projects within the coastal areas of the six-county study area. This study is an interim response to the “Coastal Texas Protection and Restoration Study,” authority. Originally, the study was intended to develop recommendations for regional CSRM and ER projects for Congressional approval across a study area encompassing six counties along the upper Texas coast between Sabine Pass and Galveston Bay. The 3x3x3 Rule exemption approved February 25, 2014, approved a revision to the study scope to focus full feasibility planning efforts on CSMR projects in the northern (Orange and Jefferson) and southern (Brazoria County) parts of the study area. Accordingly, the feasibility study effort described here has focused on CSRM recommendations for the Sabine Region (Orange and Jefferson Counties) and the Brazoria Region (the Freeport metropolitan area in southern Brazoria County). An FCSA amendment was executed on March 9, 2015, to modify the scope of the study.

In the exemption approval, it was agreed that this report would present a comprehensive overview of CSRM problems and opportunities in the central Galveston region (Galveston, Harris, and Chambers Counties) and a comprehensive assessment of ER opportunities for the entire six-county study area. Using work already accomplished to date, the comprehensive assessment is a listing and screening of alternatives identified as having high potential to demonstrate Federal interest and result in successful CSRM and ER projects. Potential CSRM and ER measures are described and illustrated in individual measure sheets presented in Appendix A. The measures were evaluated, combined into potential alternatives, and screened as explained in Appendix B. The alternatives evaluated include an extensive list of CSRM alternatives for Galveston Bay and ER alternatives for the entire six-county area. Future feasibility studies, including the ongoing coastal Texas comprehensive study, will leverage this work and ongoing work by others to develop and recommend future CSRM or ER projects. In addition, these alternatives will be used to develop projects that could be completed under other existing authorities. This EIS will also serve as a vehicle from which future Environmental Assessments of the evaluated alternatives could be tiered.

1.4 NON-FEDERAL SPONSOR

The USACE Galveston District was responsible for the overall management of the study and the report preparation. As the non-Federal sponsor of the study, the GLO was actively involved throughout the study process. As this time GLO is not expected to be the implementation sponsor. The existing Port Arthur and the Freeport HFPPs local sponsors have expressed interest in cost sharing for the Recommended Plan identified for the Port Arthur and Vicinity CSRM and the Freeport and Vicinity CSRM. The local sponsors responsible for operation, maintenance, repair, replacement and rehabilitation (OMRR&R) are the Jefferson Country Drainage District No. 7 and the Velasco Drainage District (VDD), respectively. The local sponsor for Orange 3 CSRM Plan would be Orange County. They have also expressed interest in cost share for construction.

1.5 STUDY AREA

The study area encompasses six coastal counties of the upper Texas coast (Figure 1-1). Over five million people reside in the six counties, which includes the fourth largest U.S. city (Houston), and three other metropolitan areas (Beaumont/Port Arthur/Orange, Galveston/Texas City, and Freeport/Surfside). The population of the counties is projected to increase to over nine million within the next 50 years. In addition to the population at risk, three of the nine largest oil refineries in the world, 40 percent of the nation’s petrochemical industry, 25 percent of the nation’s petroleum-refining capacity, and three major U.S. seaports based on tonnage (Port of Houston, Port of Beaumont, and Texas City) are also located in the study area. The growing population, communities, and nationally significant industries are severely vulnerable to risks from coastal storm events. Approximately 2.26 million people across the study area live within storm-surge inundation zones, and estimates for a one-month closure of the Houston Ship Channel (HSC) alone are upwards of $60 billion in damages to the national economy. All of these characteristics of the study area are important to note from a planning and environmental setting perspective; however, the six-county study area was refined in the study process, which ultimately focused on direct damages to structures in an economic evaluation.

The study area was broken down into regions. The Sabine region includes the Sabine Lake system and Gulf shoreline from Sabine Pass to High Island and the Sabine-Neches Waterway, serving the Ports of Beaumont, Port Arthur, and Orange. The Galveston region includes all of the Galveston Bay system including the Gulf shoreline from High Island to San Luis Pass and Bolivar Peninsula. The Houston-Galveston Navigation System provides access to the Ports of Galveston, Texas City, and Houston. The Brazoria region includes the Brazos River system and the Gulf shoreline in Brazoria County, as well as the Freeport Harbor Channel (FHC), serving Port Freeport. The major landmarks listed above are noted in Figure 1-1 to show general locations of the regions. All three regions include heavily industrialized areas of strategic importance to the nation, as well as navigation channels, including the Gulf Intracoastal Waterway (GIWW), that are critical infrastructure.

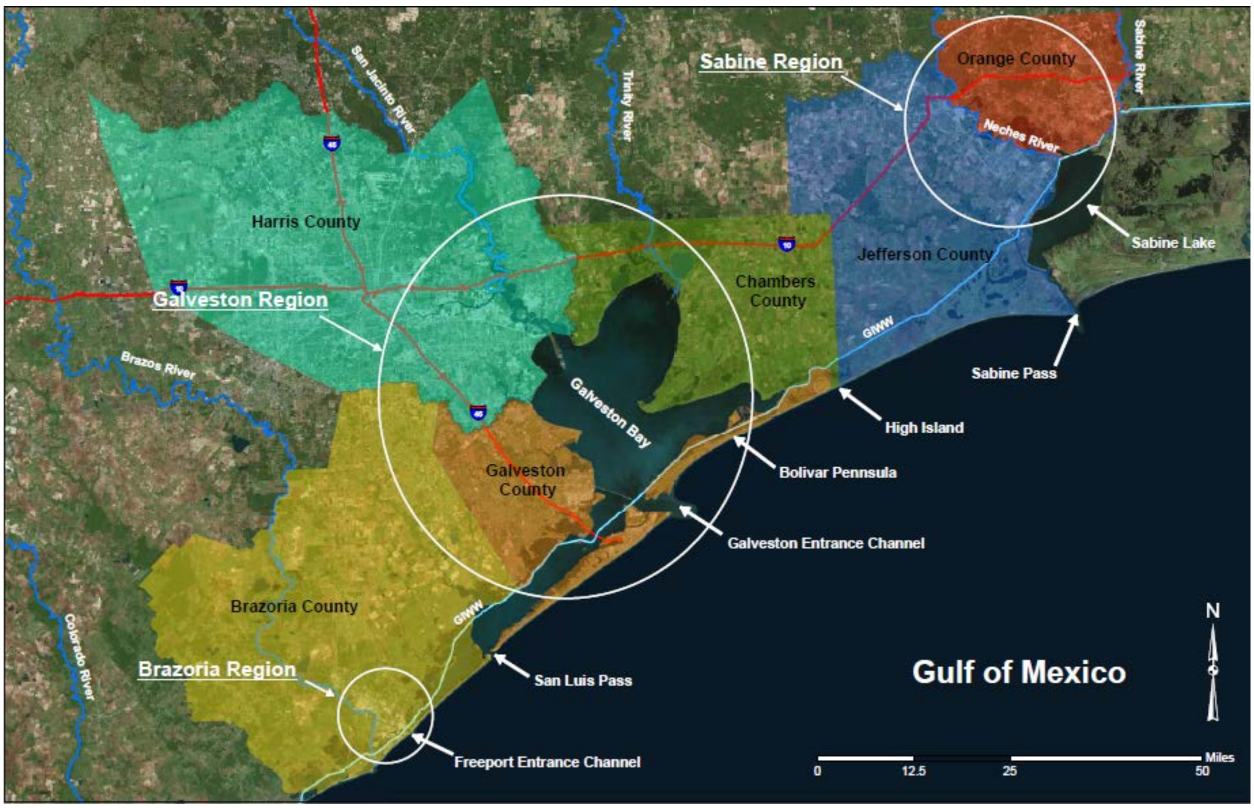

Figure 1-1: Sabine Pass to Galveston Bay, Texas Study Area

1.6 PROJECT AREA

The regions were refined in the study within the Sabine and Brazoria regions located in Orange, Jefferson, and Brazoria Counties into project areas. These project areas are focal points where the study team identified alternatives. The geographical extent of the study was large at the beginning of the study. The project areas were not defined until the “Final Array of Alternatives” was developed; therefore, the project areas are defined in the future without-project (FWOP) section where important details of resources were investigated to define the FWOP. The following represent the project areas: Senators John Cornyn and Ted Cruz, and Representatives Randy Weber (District 14), Sheila Jackson Lee (District 18), Pete Olson (District 22), Gene Green (District 29), and Brian Babin (District 36).

1.7 PROJECT DATUMS

All elevations referred to in this report, unless specifically noted otherwise, are based on the North American Vertical Datum of 1988 (NAVD 88). All depths used in this report are at Mean Lower Low Water (MLLW) datum unless otherwise specified.

1.8 MAJOR HISTORICAL SURGE EVENTS IN THE STUDY AREA

The study area has seen several major historical surge events in the past 120 years. The storm surge levels in this section are presented in Mean Sea Level (msl). The most notable is perhaps the 1900 Storm, which inundated most of the island city of Galveston, Texas, and adjacent areas on the mainland. The storm was responsible for over 8,000 deaths and up to $30 million in property damage. Storm surge values for Jefferson and Orange Counties are not available (Weems).

Other major events include the 1915 Storm, which made landfall across western Galveston Island and, due to its large size, resulted in storm surge of 16 feet in Galveston, partially ameliorated by the newly built 17-foot Galveston Seawall, and a surge of 9 to 11 feet across coastal areas of Jefferson and Orange Counties. Hurricane Audrey made landfall from Sabine Pass to Cameron in June 1957. Storm surge heights exceeded 6 feet in coastal areas north of Galveston, with storm surge of 8 to 10 feet recorded across eastern Jefferson and Orange Counties. Hurricane Carla (1961) made landfall across the Central Texas coast and caused 7- to 8-foot storm surge across coastal Jefferson and Orange Counties.

In 1983 during Hurricane Alicia, Baytown, Texas, had 10- to 12-foot tides, with Morgan Point, Texas, seeing the highest tides at 12.1 feet. Hurricane Bonnie (1986) was a very small Category 1 hurricane that made landfall between High Island and Sea Rim State Park in Jefferson County. Storm surge was 6 to 7 feet across Jefferson County. Hurricanes Chantal and Jerry (1989) were very small Category 1 hurricanes that made landfall at High Island and Galveston, respectively, and caused storm surge values of 4 to 5 feet across Jefferson County.

Tropical Storm Frances in 1998 made landfall across the central Texas coast. Nearly every road in Sabine Pass was underwater. Highway 87 flooded south of Port Arthur to Sabine Pass, and north of Port Arthur to Bridge City. Many locations further inland across western Jefferson County were also underwater. The extensive flooding was due to tides running 3.5 to 5 feet for 2.5 days.

Hurricane Rita in 2005 resulted in storm surge of 9.24 feet in Port Arthur, Texas, and just over 8 feet in Sabine Pass. Hurricane Ike in 2008 produced storm surges from 14 feet near Sabine Pass with 11 to 12 feet across Sabine Lake. Port Arthur was spared the storm surge thanks to its 14- to 17-foot seawall. However, the remaining southern half of Jefferson County was inundated, with estimated high water marks reaching 18 to 19 feet to the south and east of High Island (Southeast 2013).

Hurricane Ike was the third-costliest storm in U.S. history, causing an estimated $29 billion in property damage. Storm surges of 15-20 feet above normal tide levels occurred along the Bolivar Peninsula of Texas and in much of the Galveston Bay area. Impacts on an eight-county region's economy have been estimated at $142 billion over the four yearly quarters following the storm.

1.9 HISTORY OF THE INVESTIGATION

Investigation of surge damage impacts in the Galveston and Jefferson County region began in 2004 after the initiation of a Feasibility Study with the intent of evaluating plans to develop CSRM and ER features. The team had completed the development of the expected condition of the area if no action were taken over a 50-year period. Almost immediately after completion of that effort, the region was impacted by Hurricane Ike. At the request of local study sponsors the study was put on hold until the determination was made in late 2011 to rescope the study to include surge reduction measures for a six-county region to include Orange, Jefferson, Chambers, Galveston, Harris, and Brazoria Counties.

This re-scoped study began under the 3x3x3 guidelines developed under the recent USACE planning modernization. Under these guidelines, planning studies are limited to a duration of 3 years and cost of $3 million dollars, and are managed through a 3-tier vertical team (VT). These planning guidelines were revised to emphasize risk-based decision-making and early vertical team engagement while further developing and enhancing our planning capability.

Four scoping meetings were held in early 2012. A total of 285 distinct ideas were collected, collated and screened by the Project Delivery Team (PDT) to a detailed list of measures. These measures were considered during the SMART (Specific, Measurable, Attainable, Risk Informed, and Timely) Planning Charette held August 6 through 10, 2012.

At the Charette, the full Vertical Team (USACE District, Division, Headquarters, and Office of Water Project Review) including the local sponsor 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. After the Charette, a Project Management Plan was developed and a FCSA with the GLO (non-Federal sponsor) was executed on January 10, 2013.

In February 2014, an exemption request to allow the study to continue outside of the 3x3x3 guidelines was approved by HQUSACE, resulting in a $4.4 million study, which focused on the Brazoria and Sabine area CSRM problems and opportunities. The Notice of Intent to prepare an EIS was published in the Federal Register on November 24, 2014.

1.10 PRIOR STUDIES AND EXISTING USACE WATER PROJECTS

1.10.1 Existing Coastal Storm Risk Management Projects

The following studies and projects were reviewed as part of the feasibility study investigations. These reports provided information on previous Federal and local evaluation of CSRM problems in the study area.

1.10.1.1 Port Arthur HFPP, Texas

The existing Port Arthur and Vicinity, Texas Hurricane Flood Protection Project (HFPP) was authorized by the Flood Control Act of 1962, Public Law 87-874. Construction began in March 1966, and was completed in April 1982. 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. There is also a wave barrier on Pleasure Island. The system was designed and constructed for a 1% Annual Chance Exceedance (ACE) storm event. It is operated by Jefferson County Drainage District No. 7.

1.10.1.2 Texas City HFPP, Texas

The Texas City and Vicinity, Texas HFPP was authorized by the Flood Control Act of July 3, 1958, Public Law 85-500, substantially in accordance with recommendations of the Chief of Engineers in the House Document No. 347, 85th Congress, 2nd Session. Construction began in 1962. Authorized modifications to the project were approved in the Flood Control Act of 1968, House Document No. 187, 90th Congress, 1st Session. Authorized modifications included an extension of the levee risk reduction system to protect the City of Hitchcock and La Marque. Construction was completed in April 1987. The Texas City, Texas HFPP is located on the southwest shore of Galveston Bay about nine miles northwest of Galveston, Texas. The system was designed and constructed for a 1% ACE event. The levee system consists of earthen embankment and floodwalls protecting an area of approximately 36 square miles. The levee consists of 21.85 miles of earthen embankment and floodwall. There are approximately 1.32 miles of floodwall on the system, consisting of nearly 0.92 mile of I-wall (0.64 mile of Braced Cantilever I-wall and 0.28 mile of Cantilever I-wall) and 0.4 mile of T-wall. One section of earthen embankment was constructed in 1930 and enlarged in the authorized project. There is a section of levee on the northwest side of the system which was constructed by local interests in 1947 and is also included as part of the system.

1.10.1.3 Freeport HFPP, Texas

The Freeport and Vicinity, Texas Hurricane Flood Protection Project (HFPP), was authorized by the Flood Control Act of 23 October 1962, Public Law 87-874, substantially in accordance with House Document No. 495, 87th Congress, 2nd Session. The authorization provides for construction of improvements at Freeport and Vicinity, Texas, for risk reduction against storm tides caused by tropical cyclones along the Gulf Coast of magnitudes up to and including the standard project hurricane. The Freeport and Vicinity HFPP is located in the coastal plains in southern Brazoria County, about 48 miles southwest of Galveston, Texas. The system was designed and constructed for a 1% ACE event. The VDD, a subdivision of the State of Texas, is the local sponsor of the Freeport and Vicinity HFPP. The system consists of approximately 43 miles of levees and wave barriers, seven pump stations and multiple gates, culverts and related appurtenances. Additionally, the line of risk reduction includes multiple structures that also serve as control structures and docks for the DOW Chemical Co., BASF, Conoco Philips, Exxon and Port Freeport. As a part of this Project, the USACE upgraded and incorporated existing levees into the HFPP in addition to extending and constructing a new levee reach northward along Oyster Creek to the high bank of Oyster Creek just east of the City of Clute, Texas. This created a coherent HFPP extending from the 7-mile "river system", which connects to the HFPP at Brazos River mile 11, and extends to the high bank on Oyster Creek just east of the City of Clute, Texas.

1.10.2 Navigation Projects in the Study Area

There are multiple deep-draft navigation channels in the study area including: the Sabine-Neches Waterway (SNWW), the Houston Ship Channel (HSC), the Texas City Channel (TCC), the Galveston Ship Channel (GSC) and the Freeport Ship Channel (FSC). Additionally there are shallow-draft channels in the area including the Gulf Intracoastal Waterway (GIWW), Chocolate, Cow, and Adams Bayous.

The SNWW is an approximately 64-mile Federally authorized and maintained waterway located in Jefferson and Orange Counties in southeast Texas and Cameron Parish, Louisiana. The deep-draft portion of the authorized Federal project generally provides for a channel 42 feet deep and

800 feet wide at the entrance to the Gulf of Mexico, a channel 40 feet deep and 500 feet wide to Port Arthur, and a channel depth of 40 feet MLLW and 400 feet wide to Beaumont by way of the Neches River. Authorization for deepening the SNWW to 48 feet MLLW was included in the Water Resources and Reform Development Act (WRRDA) of 2014.

The FSC provides deepwater access from the Gulf of Mexico to Port Freeport. In 1929, the Brazos River was diverted to control excessive dredging requirements in Port Freeport, resulting in the jettied channel entrance being separated from the river mouth. The waterway extends from deep water in the Gulf through a 0.83-mile jettied channel to the Lower Turning Basin, then westerly approximately 1.5 miles to and including the Brazosport Turning Basin, then westerly approximately 2.2 miles through the Upper Turning Basin to and including a turning basin at Brazos Harbor. The Stauffer Channel extends 1.15 miles from the Upper Turning Basin to the Stauffer Turning Basin. Authorized project widths of the channel range from 400 feet from the Gulf to the Brazosport Turning Basin to 200 feet for the Brazos Harbor Channel. The majority of the Freeport channel has been constructed of a depth of 46 feet MLLW. Brazos Harbor Channel and Turning Basin are 37 feet MLLW. The deauthorized Stauffer Channel measures 200 feet wide with a depth of approximately 19 feet MLLW. Authorization for deepening Freeport Channel varying depths of 56 feet, 51 feet, and 26 feet MLLW was included in the WRRDA of 2014.

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2 EXISTING CONDITIONS/AFFECTED ENVIRONMENT*

2.1 GENERAL

The six-county study area is a large and complex region that includes approximately 6,865 square miles and two environmentally sensitive and economically important bay systems (Sabine Lake and Galveston Bay), and several large watersheds (Sabine, Neches, Trinity, San Jacinto and Brazos Rivers). It covers approximately 120 miles of the Texas coast. The following description provides a brief overview of existing conditions (i.e. affected environment) for the entire six-county area. However, since the study scope was revised to focus full feasibility planning efforts on CSMR projects in the northern (Orange and Jefferson Counties) and southern (Brazoria County) parts of the study area only, geopolitical maps are provided for the general project areas in each county as Figures 2-1, 2-2, and 2-3 respectively.

2.2 PHYSICAL DESCRIPTION OF THE EXISTING AREA

2.2.1 Tides

NOAA's Center for Operational Oceanographic Products and Services also provides tide data for the Texas coastline. The datum for these tide levels is MLLW.

Table 2-1: Diurnal tide ranges within the StudyArea

Station	Diurnal Range (feet)
Texas Point NWR, Sabine Pass, Texas	1.98
Galveston Pleasure Pier, Texas	2.04
Pier 21, Galveston, Texas	1.41
Morgan's Point, Texas	1.31
U.S. Coast Guard (USCG) Freeport, Texas	1.80

In both the Port Arthur area and Galveston, there are tide gages on both the Lake/Bay side of the coast and on the Gulf side. At Port Arthur/Sabine, tides must travel up miles of Sabine Pass and across Sabine Lake to get to the Port Arthur tide gage. Likewise, tides at Galveston have to travel through Bolivar Pass and halfway along Galveston Island to get to the Pier 21 gage on the Bay side of Galveston Island. Thus tides at these two interior gages (Port Arthur and Pier 21) are subject to reduction in both amplitude and phase, compared to the open-coast gages (Sabine Pass and Pleasure Pier). Their magnitude/range is less, and the timing lags that of the gages on the open coast of the Gulf.

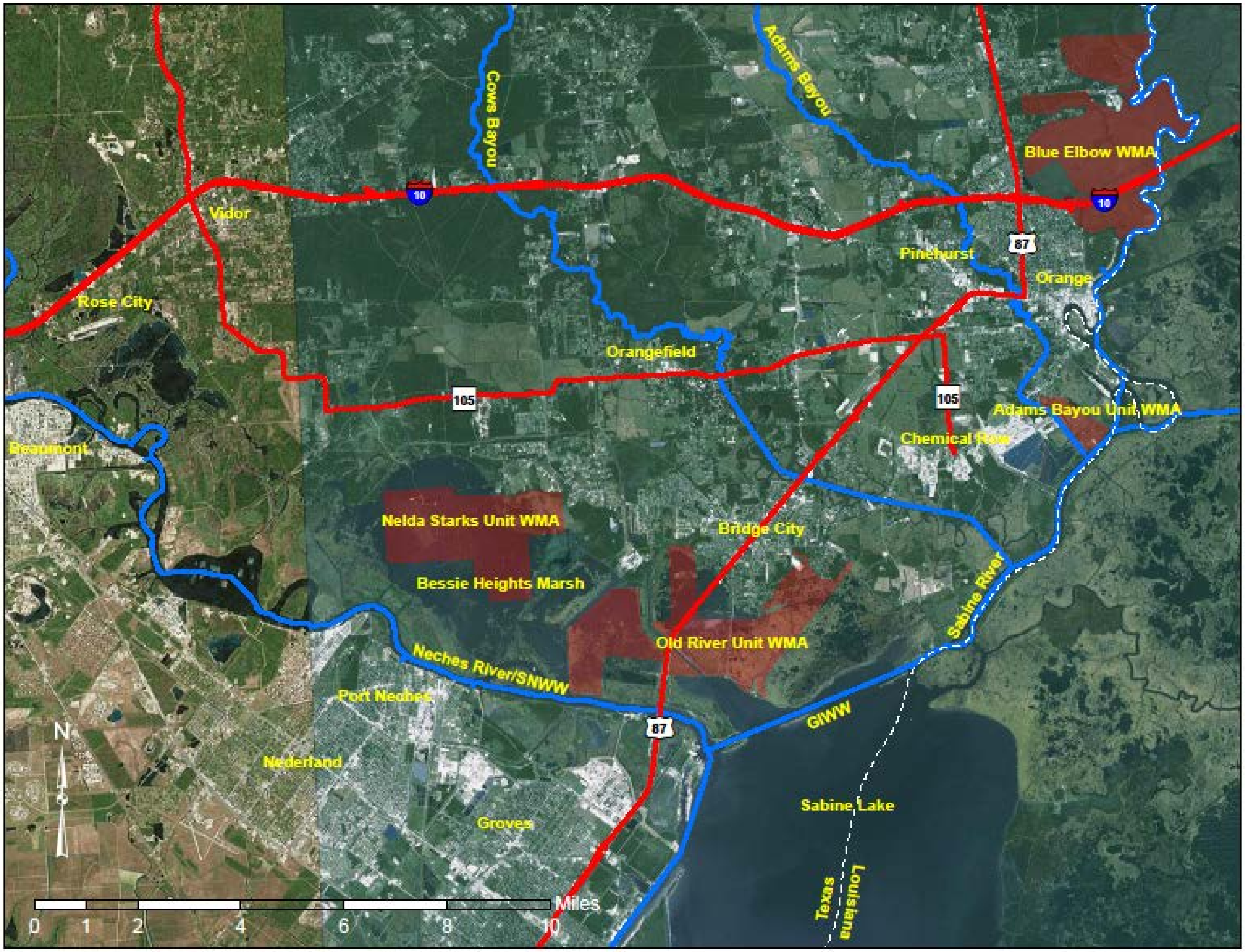

Figure 2-1: Geopolitical Map of Sabine Region (Orange County)

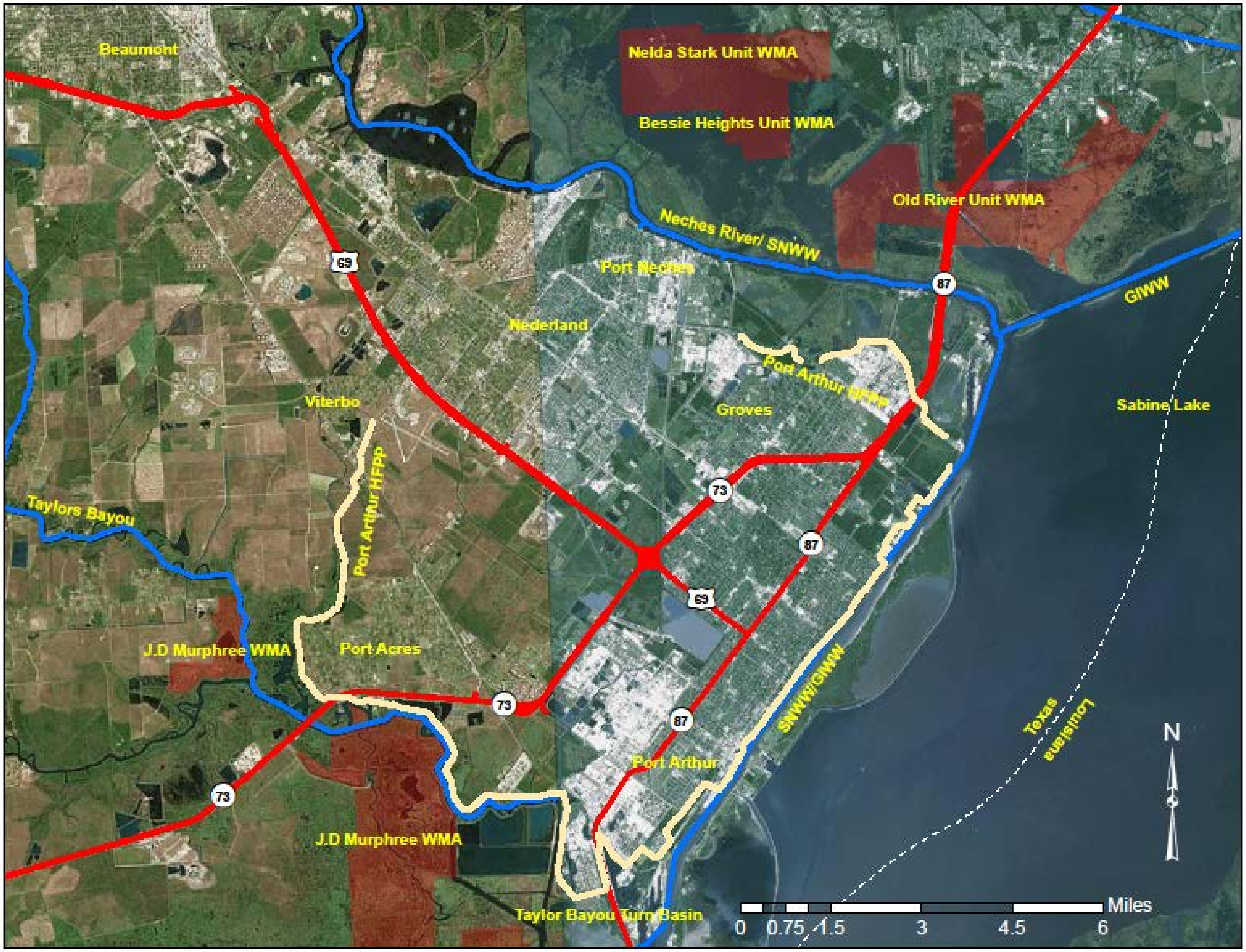

Figure 2-2: Geopolitical Map of Sabine Region (Jefferson County)

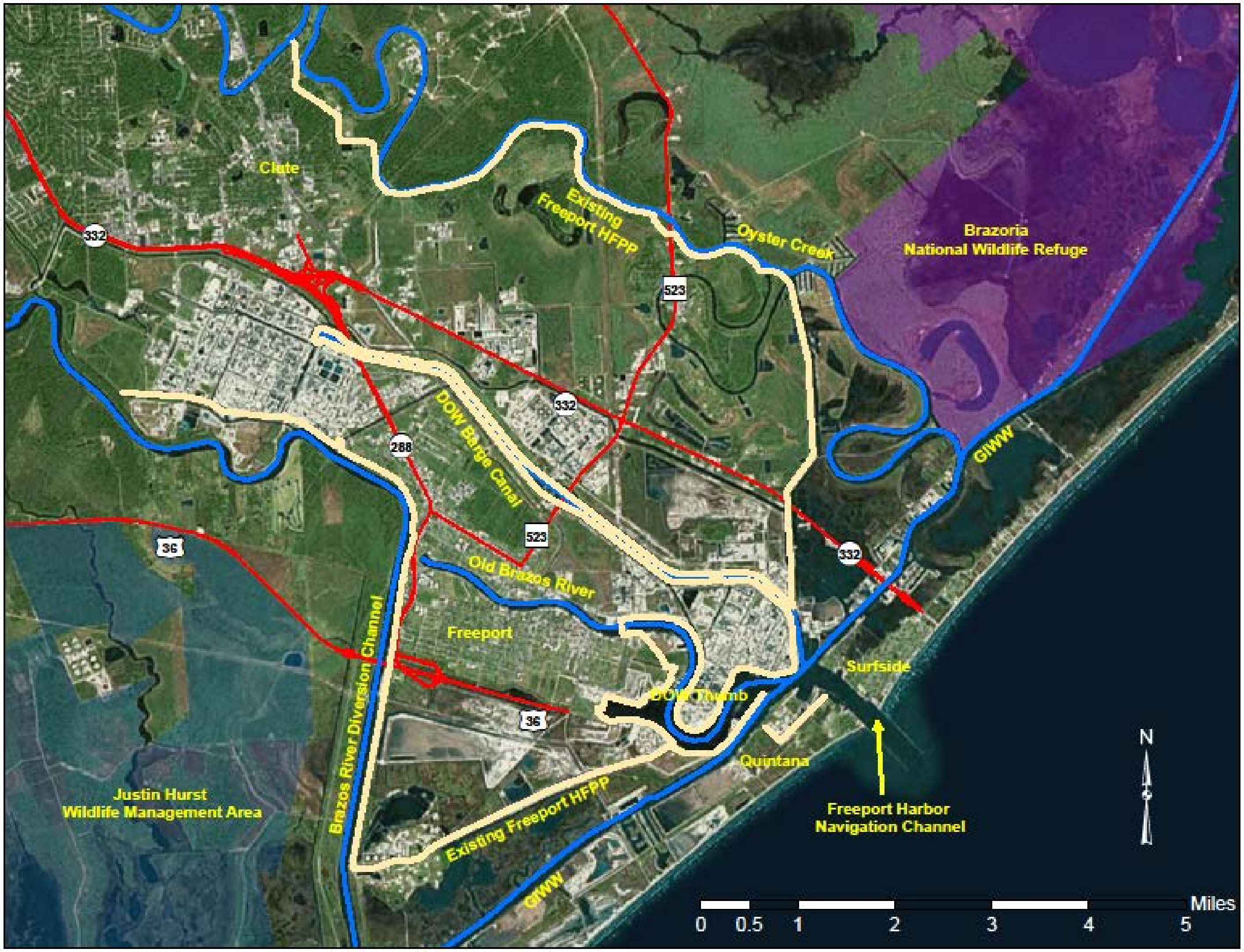

Figure 2-3: Geopolitical Map of Brazoria Region (Freeport)

2.2.2 Currents and Circulation

There are two major estuarine systems (Sabine Lake and Galveston Bay) and one major river system (the Brazos River) in the six county study area. Additionally, the GIWW passes through the entire study area adding additional complexity to the movement of water. Each of these systems, along with other waterways in the study area, is discussed in detail below.

2.2.2.1 Sabine Lake Estuary

The Sabine estuary's circulation and salinity patterns are complex. Fresh water enters the system through several tributaries, including the Sabine and Neches Rivers. The Sabine and Neches Rivers flow into Sabine Lake and into the Gulf of Mexico through Sabine Pass.

The Sabine-Neches Waterway (SNWW) Navigation Channel system serves as a pathway for both freshwater from the inflowing rivers and the saltwater wedge coming up the deep draft channel through Sabine Pass. This combination results in highly stratified conditions in the navigation channel, bringing saltwater up the SNWW and into the northwest corner of Sabine Lake and the lower reaches of the Neches River. As a result, the observed salinity in Sabine Lake is highest at both the southern end, where the lake connects to Sabine Pass, and the northern end, where the lake connects to the SNWW. The lowest salinities are observed in the central and eastern portions of the lake, which are furthest from sources of salt water (USACE 2009).

2.2.2.2 Galveston Bay Estuary

The San Jacinto River runs from its headwaters in several counties north of Harris County to Lake Houston and from there to Galveston Bay. Continuing southward, the river merges with Buffalo Bayou before the mouth of the bayou at Galveston Bay. The San Jacinto River drains an area of 3,976 square miles with almost 2 million acre-feet of runoff. Discharges into Galveston Bay vary considerably due to reservoirs, water supply constraints, and the complexity of the watershed.

The Trinity River is a 710-mile-long river that is the longest river flowing entirely within Texas. It rises in extreme north Texas, a few miles south of the Red River, and flows onward to the south, discharging into Trinity Bay, an arm of Galveston Bay, near the town of Anahuac east of Houston.

The Buffalo Bayou watershed is a 102-square-mile watershed primarily located in west-central Harris County with a small portion crossing into Fort Bend County. Near downtown Houston, White Oak Bayou flows into Buffalo Bayou. Just east of downtown Houston near the Turning Basin, Buffalo Bayou becomes the HSC. Buffalo Bayou and the HSC receive discharged water from several major tributaries, such as White Oak, Brays, Greens, Halls, Sims, and Vince Bayous. Buffalo Bayou mean discharge varies considerably, and is estimated to be 20,000 cubic feet per second (cfs) at its outfall into the HSC.

The HSC, built in 1914 to link the Port of Houston with Galveston Bay and the Gulf of Mexico, runs through Buffalo Bayou and the lower course of the San Jacinto River into Galveston Bay. The San Jacinto River proper is navigable for about 20 miles above its mouth.

2.2.2.3 Brazos River System

The Brazos River watershed begins in the State of New Mexico and then runs approximately 840 miles across Texas to its mouth at the Gulf of Mexico, two miles south of Freeport in Brazoria County. It is the longest river in Texas and has one of the largest discharges. Discharges at the mouth have been recorded as high as 120,000 cfs (USGS).

2.2.2.4 GIWW

The GIWW spans the entire study area from Sabine Lake to Freeport (and beyond). The salinity of the water varies dramatically from reach to reach. Spans that are open to the Gulf of Mexico and to large bays like Galveston Bay tend to have a higher salinity. Spans of the GIWW more closed off and protected, like in Jefferson County and near Freeport, tend to have better access to freshwater sources, and therefore, a lower salinity.

2.2.2.5 Additional Waterways

In addition to the major waterways mentioned previously in this section, several other waterways exist within the study area. These include (but are not limited to) Oyster Creek, Taylors Bayou, Chocolate Bayou, Cedar Bayou, Cow Bayou, Adams Bayou, Little Cypress Bayou, Dickinson Bayou, Halls Bayou, Austin Bayou, and Bastrop Bayou.

2.2.3 Relative Sea Level Change

Relative Sea Level Change (RSLC) was calculated following USACE guidance provided in ER 1100-2-8162 “Incorporating Sea Level Change” dated 31 December 2013, and ETL 1110-2-1 “Procedure to Evaluated Sea Level Change Impacts, Responses and Adaptation” dated 30 June 2014. For the study area, all of the sea level rise is due to a combination of an eustatic component of ocean water rising and subsidence along the Gulf Coast. Projections of low, moderate, and high levels of RSLC at the end of the 50-year period of analysis are estimated to range from 1.26 foot to 4.51 feet within the study area. Detailed discussion on RSLC is included in Section 3.6.

2.3 ENVIRONMENTAL AND HISTORIC RESOURCES

2.3.1 Description of the Ecological Region

The study area lies within the Western Gulf Coastal Plain ecoregion, which extends along the Texas Gulf Coast from the Sabine River south to the Rio Grande (Griffith 2004). The prominent features of this coastal ecosystem include fresh, intermediate, brackish and saline marshes; bays and lagoons that support extensive seagrass beds, tidal flats, and reef complexes; barrier islands; tallgrass prairie with small depressional wetlands, riparian forests, oak mottes, and dense brush habitats. Wetland habitats provide several important functions, including flood storage, water quality maintenance, and fish and wildlife habitat and forage. The study area is an important wintering and migration stopover habitat for migratory birds, including the Central Flyway waterfowl, shorebirds, wading birds, and marsh and waterbirds. A string of refuges and wildlife management areas (WMAs) along the coast serve as critical staging areas for waterfowl migrating to and from Mexico (TPWD 2013; USFWS 2013).

Natural forces, which shape the system, include dominant south to southeast winds, tropical weather systems, and a substantial rainfall amount of roughly 45 to 60 inches per year. Flooding and freshwater inflows are key systemic processes, which buffer salinity and provide nutrients and sediments to extensive estuaries in the Sabine and Galveston regions. In contrast to these regions, the Brazos River discharges directly into the Gulf of Mexico, but deltaic and barrier island processes have formed extensive coastal wetlands along the coast in Brazoria County. While highly impacted by human activities, this ecosystem remains very productive for a wide variety of fish and wildlife.

The Sabine and greater Galveston Bay estuaries and extensive coastal wetlands in the coastal Brazos River region are a vital habitat for 75 percent of the fish and shellfish species found in the Gulf of Mexico. Marshes and rice fields over the entire study area are a major wintering area for waterfowl of the central flyway. On average, 1.3 to 4.5 million ducks, or 30 to 71 percent of the total flyway population, winter annually on the Texas Gulf coast (Stutzenbaker and Weller 1989). On average, 180,000 pairs of colonial-nesting waterbirds nest annually in Texas coastal habitats. Near coastal forests are critically important for the nation's songbird resources, as the vast majority utilize this habitat during their trans- and circum-Gulf migrations (USFWS 2008).

2.3.2 Storm Surge Effects on the Study Area

Storm surge has had both long-term positive and negative effects on the ecosystem of the region. Storm overwash deposits help shape and maintain coastal environments affected by relative sea level rates (RSLR). In some areas, storm surges cause shoreline accretion by depositing sediment on beaches and within marshes behind the shore. Hurricane Rita's surge resulted in shoreline accretion along some sections of Bolivar Peninsula of up to 170 feet (Andrews et al. 2006). Sediment carried on and over barrier islands such as Follets Island helps to maintain the natural transgressive development of this barrier island. In other areas, storm surges had erosive effects. Far more of the Gulf shoreline in southeast Texas suffered erosion as a result of Rita's surge than experienced accretion. In the Chenier Plain, Hurricane Ike caused the complete loss of a sand veneer between the low tide line and the slight dune ridge that bordered the shore from Sabine Pass to High Island, and even more importantly, removed much of this ridge which once protected the freshwater wetland and coastal prairie complex in the Texas Point NWR, J.D. Murphree WMA, and McFaddin NWR (Williams et al. 2009). On Bolivar Peninsula, Hurricane Ike removed nearly all traces of sand dunes, which had stood 4 to 5 feet in height, and exposed underlying Pleistocene mud deposits. Bolivar Peninsula is too wide at most locations for sand overwash to be deposited in marshes along the backside of the barrier island; most was deposited mid-island. On Galveston Island, marshes are rapidly shrinking due to RSLR and wave erosion. Hurricane Ike did not provide supplementary material to fill this accretion deficit. Instead, erosion rates 1.5 times greater than normal were recorded (Williams et al. 2009).

Coastal marshes and swamps in some parts of the study area were flooded with storm surge for weeks after Hurricanes Rita and Ike, while coastal marshes in the Galveston Bay area drained quickly, reducing the potential for long term-impacts (FEMA 2008). Coastal marshes around Galveston Bay contain salt-tolerant vegetation, are formed on mineral soils and are sloped toward the bay. However, it is expected that the Chenier Plain marshes surrounding Sabine Lake will experience significant, long-term impacts. These marshes are concave in shape, and under normal conditions, do not drain as rapidly as tidal fringe marshes. The drainage of these marshes is also impaired by numerous human-caused hydrologic modifications within and adjacent to these marshes, such as the GIWW, the SNWW, intentional and inadvertent marsh impoundments, numerous roads, and other infrastructure (FEMA 2008). In addition to inundating salt marshes near the coast, these surges resulted in significantly increased salinities in large areas of swamp and freshwater marsh in the Sabine system for months after the storms (Steyer et al. 2007; FEMA 2009). The marshes of Sabine Lake are composed of generally brackish and intermediate vegetation communities, which were not tolerant of the higher salinity of Ike's storm surge. Therefore, the high salinity water was either lethal to these plants or had sub-lethal effects ranging from reduced seed production, vegetative stress, and increased vulnerability to disease (Smart and

Barko 1980; Linthurst and Seneca 1981; Howard and Mendelssohn 1999). Further compounding the problem are the organic soils that are typical of these marshes, and when exposed to saline waters, can produce high amounts of hydrogen sulfide, which can lead to sulfide toxicity and death in marsh plants. Organic soils are also dependent on plant roots for cohesion; therefore, upon plant death, these soils are subject to rapid erosion and dissolution in normal marsh conditions (FEMA 2008).

In addition to significant marsh loss from shoreline erosion and saltwater stress, other direct impacts on coastal wetlands include scouring and compression, as well as downed trees from surge and winds (FEMA 2008). Oyster beds and fishing grounds were covered by sediment from the retreating storm surge in Galveston Bay, Trinity Bay, Sabine Lake, and the Chenier Plain. The loss of oyster reefs not only impacts the oyster fishery, but also can result in bay-wide ecological impacts.

2.3.3 Attenuation of Storm Surge Impacts by Coastal Wetlands

It is generally believed that coastal wetlands provide critical risk reduction against incoming hurricane storm surges, and that restoration of lost wetlands should be a key component of any strategy to protect vulnerable regions such as the Sabine Pass to Galveston Bay study area. However, few studies have evaluated the value of wetlands in protecting against storm surge in this area. Furthermore, studies of the attenuation effects of coastal marshes and forests in Louisiana and Mississippi have yielded mixed results (Barbier et al. 2013; Costanza et al. 2008; Fitzpatrick 2008, Resio and Westerink 2008, Wamsley et al. 2007; Wamsley et al. 2010).

Historically, many studies have relied upon a USACE estimate of the degree to which marshes and coastal forests slow inland surge penetration (USACE 1963). This report analyzed seven storms occurring between 1909 and 1957 throughout southern Louisiana, producing a widely cited rule of thumb that each 2.7 miles of marsh knocks down the storm surge by 1 foot (1-meter reduction per 14.5 km of marsh). However, the data from this study varied by about a factor of three; attenuation rates as high as 1 foot per 1.3 miles of marsh was seen in one storm, and as low as 1 foot per 3.8 miles of marsh in another (Masters n.d.).

More recent storm surge studies have found that the inland penetration of the storm surge is an extremely complicated function of storm track, speed, duration, size, and associated waves; the regional topography, geometry of the shore, presence of barrier islands, and slope of the ocean bottom; plus the type and thickness of vegetation, and presence or absence of levees. Wetlands will slow down the inland penetration of a storm surge, so the surge will not be able to advance very far inland before the winds die down if a region is exposed to strong winds for a short period of time. One example of this was in western Louisiana during Hurricane Rita of 2005 (Resio and Westerink 2008). As the hurricane rapidly approached western Louisiana, Rita blew water away from the coast and then plunged water onto land as the eye of the storm passed rapidly. Maximum inland attenuation rates ranged from 1 foot per 2.1 miles to 1 foot per 3.6 miles of inland penetration, under conditions in which the coast was only subject to onshore winds for a few hours.

Hurricane Rita also provides an example of an opposite effect. For slow moving storms, or for portions of the coast subjected to strong winds for many hours, the wetlands may completely flood, and there would be no reduction of storm surge. During Rita, strong winds blew along the east side of the Mississippi for almost a full day, completely flooding the 25 miles of wetlands fronting the Mississippi River levee at English Turn. In fact, the model results show that the surge possibly increased in height, by 1 foot per 8.7 miles of inland penetration because the surge piled up against the levee (Resio and Westerink 2008).

Another storm surge simulation investigates what would happen if Louisiana wetlands were allowed to continue to deteriorate with no restorative efforts over the next 50 years (Wamsley 2007). Results suggest that storm surge heights would increase by 10 to 15 percent along Louisiana coastal areas to the east of New Orleans. These results held for both a severe Katrina-like hurricane, and a more modest hurricane. However, the authors cautioned that additional research is required because "the impact of landscape features on surge propagation is a relatively new application for surge models."

This summary indicates that the effect of wetlands in attenuating storm surge is situationally dependent. Wetlands can attenuate surge in many situations but may also be largely irrelevant in others. The effect of specific marsh restoration or preservation measures cannot be determined without studies and modeling based on fundamental underlying physics, forcing and dissipation mechanisms, adequate specification of the system geometry, and the evaluation of a wide array of storms, varying in direction, speed, and size (Resio and Westerink 2008).

2.3.4 Protected Lands in the Study Area

2.3.4.1 Sabine Region

McFaddin NWR covers about 58,861 acres in Jefferson and Chambers Counties (USFWS 2012 and 2013). Along with the J.D. Murphree WMA, it protects the largest expanse of remaining freshwater marsh on the Texas Coast and thousands of acres of intermediate marsh. The Refuge's southern boundary consists of over 15 miles of Gulf of Mexico shoreline. Remnant dune/beach systems exist along the coastline, although much has been lost through RSLC, erosion and shoreline retreat, leaving only a low-lying washover terrace (TPWD 2013).

J.D. Murphree WMA is 24,498 acres of fresh, intermediate and brackish marsh on the Chenier plain in Jefferson County (TPWD 2013). Extending north and south of the GIWW west of the Sabine-Neches Waterway, the WMA is highly diverse in coastal wetland communities.

Texas Point NWR in Jefferson County encompasses 8,952 acres of fresh to saline marshes and some wooded uplands and prairie ridges (USFWS 2012 and 2013). The Refuge's southern boundary consists of over 6 miles of Gulf of Mexico shoreline. The Chenier plain is characterized by relict beachfronts that form ridges paralleling the Gulf shore. The term derives from the French name for live oak trees (*chenier*), which typically are found growing atop these ridges.

Lower Neches River WMA has 7,998 acres located near Bridge City in Orange County (TPWD 2013). The WMA is composed of three separate units. The Nelda Stark and Old River units are located adjacent to the lower Neches River. The Nelda Stark Unit is primarily shallow open water, which resulted from the degradation of a former marsh system by subsidence and saltwater intrusion. The Old River Unit, near the mouth of the Neches River, is a mixture of intermediate marsh and open water. The Adams Bayou Unit is located on Adams Bayou, a tributary of the lower Sabine River. Formerly a meandering coastal stream and forested bottomland, it was channelized to allow oil field access but still contains a remnant of the Sabine River forested wetlands.

Tony Houseman WMA, managed as a cooperative effort between the Texas Department of Transportation (TxDOT) and TPWD, is located on the Sabine River at Interstate 10 (I-10) (TPWD 2013). A 600-foot boardwalk leads from the center into the swamp. Outdoor recreation includes public hunting opportunities, fishing, wildlife viewing, hiking, and canoeing. The WMA extends from the western bank of the Sabine River just north of the community of Echo down to the confluence of Little Cypress Bayou and the Sabine River south of I-10 at Orange. More than 80 percent is cypress-tupelo swamp.

Two USACE-approved mitigation banks are located on the Neches and Sabine rivers. The Neches River Cypress Swamp Preserve is located north of Interstate 10 below the Neches River Saltwater Barrier (USACE 2005a). Located north of Interstate 10 and west of the Sabine River, the 2,737-acre Blue Elbow Swamp Mitigation Bank is owned by the Texas Department of Transportation (TxDOT) and used to mitigate impacts of state highway projects.

2.3.4.2 Galveston Region

Anahuac NWR is located in Chambers County along the north shore of East Bay, within the Chenier plain region of southwestern Louisiana and southeastern Texas (USFWS 2013). The

Refuge's southern boundary consists of nearly 7 miles of Galveston Bay shoreline (TPWD 2013). Comprising 34,400 acres, it contains brackish and saline marshes, coastal prairie, and coastal woodlands (USFWS 2012).

Armand Bayou Nature Center and Preserve covers a total of 2,800 acres along Armand Bayou in southeastern Harris County (TPWD 2013). Armand Bayou, a tributary of Clear Lake, is a tidally influenced component of the Galveston Bay system. The Preserve is unique in that it is a remnant natural system still existing within a heavily developed, densely populated region. The brackish water bayou bounded by riparian hardwood forest is surrounded by 900 acres of remnant coastal prairie currently under restoration. The Armand Bayou Coastal Preserve is leased from the GLO by the TPWD.

Atkinson Island WMA is on the southern portion of Atkinson Island, a long, narrow island in the very northern tip of Galveston Bay, on the edge of Harris and Chambers Counties (TPWD 2013). The island was used as a case study for the construction of a wetland restoration project using dredged materials. Habitats on the island include a 40-acre woodlot and 90 acres of brackish marsh.

Candy Abshier WMA is located in Chambers County south of the community of Smith Point. This 209-acre WMA consists primarily of coastal prairie habitat with important coastal woodlot or oak mottes. Approximately 60 acres of the area are in this oak motte habitat with the remaining acreage in coastal prairie vegetation. It is owned and managed by TPWD.

Moody NWR is located on the north shore of East Bay (USFWS 2012). The refuge has approximately of 2 miles of bay shoreline and covers 3,517 acres. It took a direct hit and suffered extensive damages from Hurricane Ike. The USFWS holds a perpetual non-development conservation easement on the Moody NWR, which is otherwise entirely privately owned and managed.

North Deer Island Sanctuary is a 10-plus acre island in West Galveston Bay, one of the few natural islands left in this system. It is one of the most important colonial waterbird nesting islands on the upper Texas coast, used by 10,000 to 30,000 pairs of birds each year (TPWD 2013). Dredged material has been placed over approximately one-third of the island. Natural uplands are covered by a plant community unique on the upper Texas coast, composed of lime prickly ash, mesquite, paloverde, and mulberry trees, as well as lantana and cactus. High-quality salt marshes border the uplands on the southeast side of the island. The island is owned by three equal undivided interests the National Audubon Society, the Houston Audubon Society, and a private individual. It is a Houston Audubon/National Audubon Bird sanctuary.

The John O'Quinn Interstate 45 (I-45) Estuarial Corridor contains a wetland corridor gateway to Galveston Island and a mainland coastal prairie component at Virginia Point. The O'Quinn estuarial corridor runs along both sides of I-45 as it passes from the mainland to Galveston Island. This 900-acre area is composed of natural, undisturbed tidal marsh and about 70 acres that have been restored to historical marsh conditions. The 1,500-acre Virginia Point tract is predominantly coastal prairie with interspersed freshwater sloughs and ponds. Together, these tracts of land form a contiguous coastal preserve across the southern tip of the mainland from Jones Bay to the west, where the wetlands are adjacent to property across Highland Bayou managed by The Nature Conservancy and Galveston Bay Foundation, to Galveston Bay to the east. The preserve encompasses approximately 5 linear miles of Bay shoreline. Both areas are owned by Scenic Galveston.

2.3.4.3 Brazoria Region

The Brazoria NWR is a 44,414-acre wildlife conservation area along the coast in Brazoria County (USFWS 2012). It borders the GIWW, behind Follets Island in Brazoria County. Refuge habitats are made up of salt water, fresh water, and brackish wetlands. In addition, there are prairies, woody thickets, salt and mud flats, and lakes and streams. The refuge also contains 5,000 acres of rare, native bluestem prairie, representing one of the last coastal prairies in Texas. Brazoria NWR has a key location on the Texas Gulf, which helps Freeport draw one of the highest Audubon Christmas bird counts in the nation with more than 200 species.

Christmas Bay Coastal Preserve, in Brazoria County, encompasses a shallow 4,173-acre embayment in the southwestern portion of the Galveston Bay system (TPWD 2013). The preserve is one of the most ecologically productive bays of the Galveston complex and has not yet been greatly altered by human activity. The preserve totals approximately 5,700 acres in area. Nearly level prairies are contiguous to extensive fresh and saline marshes. Christmas Bay benefits from Brazoria NWR, a 42,000 acre protected wetland, which contributes to the preserve's productivity and helps protect its water quality. Owned by the GLO, the preserve is leased to TPWD and designated by the TPW Commission as a State Scientific Area.

Justin Hurst WMA (Bryan Beach Unit) is located on the Gulf shoreline on the eastern shore of the Brazos River Diversion Channel. The unit is 440 acres dominated by a 90 acre embayment, which is flooded by Gulf waters during high tides and storms. Large vegetated coastal dunes surround the embayment and separate it from the Gulf.

The Nannie M. Stringfellow WMA is comprised of approximately 3,664 acres in Brazoria County (TPWD 2013). Located in the floodplain of the San Bernard River, the dominant vegetation is coastal bottomland hardwood forest, which is subject to frequent flooding.

San Bernard NWR in Brazoria County serves as the end point of the Central Flyway for waterfowl in winter, and an entry point for neotropical migratory songbirds tired from a 600 mile Gulf crossing from the Yucatan Peninsula (USFWS 2012). The 57,698 acre refuge contains salt and freshwater marshes, sloughs, ponds, coastal prairies, and bottomland forest. Refuge bottomland forests and willow trees attract high numbers of warblers migrating north. Several remote islands in a sheltered bay between the GIWW and the Gulf come alive every nesting season with herons, egrets, terns, and gulls.

2.3.5 Physical and Hydrological Characteristics of the Study Area

The study area, situated in the Western Gulf Coastal Plain, can be divided into two distinct physiographic areas. The surface topography of the project area is mainly flat to gently rolling and slopes to the southeast toward the Gulf. The coastal areas of the eastern- and westernmost sections (Jefferson, Chambers and western Brazoria counties) are barrier headlands consisting of beach or eroding marsh shores, dune and supratidal habitats that naturally decrease in elevation toward fringing intertidal marshes, lakes, and ponds. On the east, Sabine Lake formed in the elongated drowned river valley of the Sabine River; it empties into the Gulf through a narrow constriction at Sabine Pass. The Sabine and Neches Rivers flow into Sabine Lake. On the west, the Brazos River flows directly into the Gulf through a diversion channel constructed by the USACE in 1929 (USACE 2012). A diversion dam about 7.5 miles above the original Brazos River mouth was constructed as part of this navigation improvement project, and the diversion channel rerouted the Brazos River from the dam to an outlet in the Gulf about 6.5 miles southwest of the original mouth. The San Bernard River, the westernmost river in the study area, meanders through a landscape of coastal marshes and lakes on its way to the Gulf (USACE 2008). Its mouth is now frequently closed due to sand accretion from the Diversion Channel delta.

In between, the coastal areas of Galveston, Harris, and eastern Brazoria counties are characterized by a nearly continuous series of marginal marine embayments separated from the Gulf by a system of barrier islands and peninsulas (Lankford and Rehkemper 1969). Coastline features are typically the result of several active, geologic processes including longshore drift, beach wash, wind deflation and deposition, tidal currents and waves, delta outbuilding, and river point bar and flood deposits. The Trinity and San Jacinto rivers, Clear Creek, and Chocolate Bayou are the largest inflows to the Galveston Bay system. Important tributaries in these watersheds include Buffalo, Cedar and Dickinson Bayous.

The coastal zone is underlain by sedimentary deposits that originated in ancient but similar coastal systems - Recent and Holocene-age alluvium containing thick deposits of clay, silt, sand, and gravel, overlying the Pleistocene Beaumont Formation (Barnes 1982, 1987; McGowen et al. 1976). These formations consist mainly of stream channel, point bar, natural levee, and back swamp deposits associated with former and current river channels and bayous.

Probably of most significance in relation to potential storm surge impacts, the widest part of the continental shelf in the northern Gulf of Mexico lies offshore of the study area. At its widest point, offshore of Sabine Pass, the bottom slope averages 6 feet per mile until roughly 1 mile offshore, after which it steadily decreases to an average of 1 foot per mile through roughly 10 miles offshore (White et al. 1987). Thus, for most of its extent the shelf is gently sloping and (with the exception of a few topographically high features such as the Sabine, Heald, and Shepard banks, and relict Sabine, Trinity, and Brazos river valleys) is relatively featureless. Sandy muds and clay muds predominate the surface inner shelf region; however, the surface of virtually the entire area is covered by a sheet of sand approximately 2 feet thick (Anderson and Wellner 2002; PBS&J 2004; White et al. 1988). Storm surges are strongly influenced by the geometry of the basin and continental shelf leading up to the coastal floodplain, especially the depth of water and shelf width. Shelves with a larger shallow-water area will produce larger surges than those with steep offshore slopes (Resio and Westerink 2008).

2.3.6 Biological Communities in the Study Area

2.3.6.1 Coastal prairies

Remnant tracts of tall grass and salty prairies are present in the study area, often interspersed within coastal marshes. Slightly higher in elevation, the grass and prairie tracts offer a different type of habitat (USFWS 2008). Wooly rosemallow, bushy bluestem, and gulf cordgrass thrive there and provide important nesting habitat for mottled ducks, dickcissels, and other species. Black rails, short-eared owls, and LeConte’s sparrow find shelter and feed within these prairie habitats. Almost all of the region’s historic native coastal tall grass prairie and its associated prairie wetlands have been lost through conversion to agricultural uses and urban development (USFWS 2008). This community is considered critically imperiled by the Texas Natural Heritage Program (USGS 2000).

2.3.6.2 Coastal marshes

Salt marsh is located close to the Gulf shoreline and higher salinity areas of the estuarine systems. Subjected to regular tidal inundation, low saline marsh is dominated by smooth cordgrass/oystergrass (*Spartina alterniflora*) and often accompanied by seashore saltgrass (*Distichlis spicata*), blackrush (*Juncus romerianus*), saline marsh aster (*Aster tenuifolius*), and marsh hay cordgrass/wiregrass (*S. patens*). The dominant species in high salt marsh, which is subject to less-frequent tidal inundation, is glasswort (*Salicornia* spp.). Brackish marshes grade inland from salt marsh. The dominant species in low brackish marsh is saltmarsh bulrush (*Scirpus robustus*); seashore salt grass and marsh hay cordgrass are co-dominant species in high brackish marsh. Intermediate marshes are subjected to periodic pulses of salt water and maintain a year-round salinity in the range of 0.5 to 4 ppt. They grade inland from brackish marshes and dominate interior marshes of the Sabine and Galveston Bay systems. The diversity and density of plant species are relatively high with marsh hay cordgrass the most dominant species in high marsh. Co-dominant species in low marsh are seashore paspalum (*Paspalum vaginatum*), Olney bulrush (*S. americanus*), California bulrush/giant bulrush (*S. californicus*), and common reedgrass/roseau cane (*Phragmites australis*); bulltongue (*Sagittari lancifolia*) and sand spikerush (*E. montevidensis*) are also frequent. Freshwater marshes dominate in upstream reaches of the Sabine, Neches, Trinity, San Jacinto, and Brazos Rivers. They are heterogeneous, with local species composition governed by frequency and duration of flooding, topography, substrate, hydrology, and salinity. Co-dominant species in low marsh are maidencane (*P. hemitomen*), giant cutgrass (*Zizaniopsis milacea*), and bulltongue. Co-dominant species in high marsh are squarestem spikerush (*E. quadrangulata*) and marsh hay cordgrass. Other characteristic species include American lotus (*Nelumbo lutea*), watershield (*Brasenia screben*), duckweed *(Lemna* spp.), and fanwort (*Cabomba caroliniana*). Salinity rarely increases above 2 ppt, with a year-round average of approximately 0.5 to 1 ppt. Tidal fresh marshes support extremely high densities of wildlife, such as migratory waterfowl. Marsh serves as nursery areas for many important commercial and recreational fish and shellfish species including white and brown shrimp, blue crab, red drum, flounder, and speckled sea trout. Coastal marsh habitats provide important functions of improving water quality in the estuarine ecosystem, providing flood control benefits, and buffering inland habitats from tropical storm-generated tidal surges. In addition, marshes are extremely biologically productive and diverse and provide detrital input, which is the basis for the estuarine food chain (USFWS 2008).

2.3.6.3 Forested Wetlands

Upstream of the coastal marshes in Sabine, Neches, and Trinity estuaries, the study area is dominated by dense bottomland hardwood forests and cypress-tupelo swamps. These wetland forests cover an intricate network of sloughs and sandy ridges formed within the rivers' relict meander belts. Bald cypress (*Taxodium distichum*) – tupelo-gum (*Nyssa aquatica*) swamps grow in the inundated areas between the ridges, and floodplain hardwood forest of oaks (*Quercus nigra, Q. phellos, Q. alba, Q. lyrata*), sweetgum (*Liquidambar styraciflua*), hickories (*Carya* spp.), American elm (*Ulmus americanus*), maple (*Acer rubrum*), green ash (*Fraxinus pennsylvanica*), American holly (*Ilex opaca*), and loblolly pine (*Pinus taeda*) grow atop the sandier ridges and on the Pleistocene terrace uplands that border the floodplains. In general, these are healthy, stable habitats. The hardwoods, and especially the cypress trees, have been logged repeatedly since the turn of the century and as recently, perhaps, as the 1950s (USACE 1998). Though much of the forest is secondary growth, the swamp and bottomland hardwood habitats have medium to high value for food and cover to resident and migratory fish and wildlife. Forested wetlands in the San Jacinto and Brazos River system are dominated by bottomland hardwood communities.

Oak woodlot habitats (also known as oak mottes) can be found on higher ridges and mounds scattered across coastal marshlands. They are vital for resident and migrant species of wildlife, especially neotropical migrant passerine species.

2.3.6.4 Other Aquatic Habitats

Extensive freshwater aquatic habitats are present in the upstream reaches of rivers and bayous in the study area. Large estuarine aquatic habitats are present in the Sabine Lake area and the greater Galveston Bay area; somewhat smaller estuarine aquatic habitats are present in Chocolate Bayou, and the San Bernard River delta area. Approximately 36,000 acres of oyster reefs are present in the Sabine and Galveston Bay systems. The Texas oyster fishery is the second largest in the country, with Galveston Bay accounting for approximately 18 percent of total oyster landings. The average annual catch value of Galveston Bay oysters for the period between 2005 and 2007 was in excess of $10.4 million (FEMA 2008). Sabine Lake is currently closed to commercial oyster harvesting (USACE 2011). In addition to supporting a large commercial fishery, oyster reefs provide important habitats for numerous commercially and recreationally important fishery species, such as red drum and brown shrimp. Oysters are also vital to maintaining the water quality of estuarine systems. Through their filter-feeding activities, oysters remove nutrients, pollutants, and algae from the water column. The shallow Gulf of Mexico waters, tidal flats, and beaches provide important shallow water feeding, breeding and nesting habitat utilized by killdeer, black-necked stilt, and willet (USFWS 2008). This transition from land to sea contains a combination of salt-tolerant marsh and beach plants, which are adapted to shifting sands, high winds, and rising waters and help protect the dunes from erosion.

2.3.7 Essential Fish Habitat

Essential fish habitat (EFH) consists of those habitats necessary for spawning, breeding, feeding, or growth to maturity of species managed by Regional Fishery Management Councils, as described in a series of Fishery Management Plans, pursuant to the Magnuson-Stevens Fishery Conservation and Management Act. Gulf of Mexico managed species and habitat types in the study area designated as EFH for each species' life stages are presented in Table 2-2.

Table 2-2: Estuarine EFH for Gulf Managed Species in S2G Study Area

Common and Species Name	Eggs	Larvae	Post Larvae	Early Juvenile	Late Juvenile	Adult
Estuarine Emergent Marsh						
Red drum (*Sciaenops ocellatus*)			●	●		●
Gray snapper (*Lutjanus griseus*)						●
Brown shrimp (*Penaeus aztecus)*				●		
White shrimp *(Penaeus setiferus*)				●		
Estuarine Submerged Aquatic Vegetation						
Red drum (*Sciaenops ocellatus*)		●	●		●	●
Lane snapper (*Lutjanus synagris*)			●	●	●	
Brown shrimp (*Penaeus aztecus)*				●		
Estuarine Mud/Soft Bottom						
Red drum (*Sciaenops ocellatus*)		●	●	●		●
Gray snapper (*Lutjanus griseus*)						●
Lane snapper (*Lutjanus synagris*)				●	●	
Brown shrimp (*Penaeus aztecus)*				●		
White shrimp *(Penaeus setiferus*)				●		

2.3.8 Threatened and Endangered Species

Federally-listed species potentially occurring within Orange, Jefferson and Brazoria Counties study area include wintering populations of the piping plover (*Charadrius melodus*), red knot (*Calidris canutus rufa*), whooping crane (*Grus americana*), West Indian manatee (*Trichechus manatus*) several species of whales (fin [*Balaenoptera physalus*], humpback [*Megaptera novaeangliae*], sei [*Balaenoptera borealis*], and sperm [*Physeter macrocephalus*]), swimming green, hawksbill, Kemp's ridley, leatherback, and loggerhead sea turtles (*Chelonia mydas*, *Eretmochelys imbricata*, *Lepidochelys kempii*, *Dermochelys coriacea*, *and Caretta caretta*), and Texas prairie dawn-flower (*Hymenoxys texana*) (USFWS 2013; NOAA 2013). National Marine Fisheries Service has also designated the following four species of corals as endangered for this area – lobed star (*Orbicella annularis),* mountainous star *(Orbicella faveolata),* boulder star *(Orbicella franksi),* and elkhorn (*Acropora palmata).* USFS has identified three Candidate species – Sprague's pipit (*Anthus spragueii*), the smooth pimpleback clam (*Quadrula houstonensis*) and the Texas fawnsfoot clam (*Truncilla macrodon*). Descriptions of these species and their habitats are provided in the Biological Assessment (Appendix J).

Critical habitat for wintering populations of the piping plover is present in Galveston and Brazoria Counties. In Galveston County, shoreline areas around Rollover Pass, near Fort Travis at the Galveston East Jetty, Big Reef at the Galveston West Jetty, and on the east side of San Luis Pass have been designated. In Brazoria County, critical habitat has been designated for the western Brazoria County shoreline, beginning at Bryan Beach State Park and extending west to beyond the county line.

2.3.9 Water and Sediment Quality

Water and sediment quality in the study area are generally of good quality, although some stream segments in each area are identified as impaired. Testing of water and sediments in conjunction with maintenance dredging of existing navigation channels and proposed modifications for the Sabine-Neches Waterway (USACE 2011), the GIWW from High Island to Brazos River (USACE 2003), the Houston-Galveston Navigation Channels and associated projects (USACE 2003, 2010, 2013), the Texas City Channel (USACE 2008), the Freeport Harbor Channel (USACE 2012), and the mouth of the San Bernard River (USACE 2008) have generally identified few causes for concern. The Galveston Bay Foundation has recently issued a grade of “A” for water quality in Galveston Bay, but an overall grade of “C” for toxins in the sediments (Galveston Bay Foundation and HARC 2016). This is related primarily to concerns with Houston Ship Channel sediments inland of Galveston Bay. In the Sabine region, freshwater stream segments are generally of good quality, but tidal segments of several streams have depressed levels of dissolved oxygen and undesirable levels of bacteria, due in large part to low tidal flows (TCEQ 2014). Contaminated sediments and edible fish tissues have been reported for a few segments in and near the Neches and Sabine Rivers. In the Brazoria region, only one stream has been classified as non-supporting for recreation use due to undesirable levels of bacteria. Additional information is provided for the No Action Alternative description in section 7.7.1.

2.3.10 Air Quality

The Galveston and Brazoria regions are located within the Houston-Galveston-Brazoria (HGB) Air Quality Control Region (AQCR), consisting of Harris, Montgomery, Liberty, Chambers, Galveston, Brazoria, Fort Bend, and Waller Counties. This AQCR meets all of the U.S. Environmental Protection Agency (EPA) National Ambient Air Quality Standards (NAAQS), except for ozone. Exposure to ground level ozone in high concentrations can result in adverse effects on humans, plants, and animals. Urban areas typically have high levels of ground level ozone. The HGB AQCR is classified as marginal nonattainment for the 2008 ozone NAAQS, and severe nonattainment for the 1997 ozone NAAQS.

Jefferson and Orange counties are located in the Beaumont-Port Arthur (BPA) AQCR. On October 20, 2010, the EPA published a final rule in the *Federal Register* (75 FR 64675), effective November 19, 2010, approving a redesignation request and finalizing a determination that the BPA area is in attainment for the revoked one-hour ozone standard. The EPA's determination to redesignate signifies that the BPA area has met all of the applicable Federal Clean Air Act requirements for the purpose of redesignation to attainment.

2.3.11 Hazardous, Toxic, and Radioactive Waste Concerns

Hundreds of petrochemical plants, oil storage facilities, hazardous waste facilities, aboveground tanks, and underground storage tanks are located in storm surge-vulnerable regions of the numerous industrial centers in the study area (Orange, Beaumont, Port Arthur, Texas City, Pasadena/Deer Park, Houston, Baytown, Chocolate Bayou, and Freeport). In the Houston Ship Channel area alone, about 20,000 acres along lower Buffalo Bayou contain industrial facilities with potential for toxic environmental releases as a result of storm surge (Rifai and Burleson 2012). Hurricane Ike caused hundreds of localized oil and other toxic spills that threaten fish and wildlife throughout the affected area (FEMA 2008). As of Oct. 1, 2008, the multi-agency task force for spill response had assessed more than 200 pollution reports, which include more than 180 sites in the Houston-Galveston area and 47 in the area from Port Arthur to Lake Charles, Louisiana. The type and amount of pollution included oil and diesel from vessels, as well as industrial chemicals.

2.3.12 Cultural Resources

Numerous cultural resource surveys in the area have documented over 1,000 cultural resource sites in the study area, ranging from prehistoric shell middens to numerous historic sites including houses, buildings, bridges, tunnels, and lighthouses. The area includes several National Historic Landmarks, including the San Jacinto Battlefield, the Battleship Texas, the Tall Ship Elissa, and the Spindletop Oil Field, as well as National Historic Landmark Districts, such as the Galveston Strand Historic District and the Galveston East End Historic District. The Galveston Strand District contains many Victorian-era National Register structures from the city’s historic heyday when Galveston’s national prominence resulted in it being called “the Wall Street of the Southwest”. There are over 100 National Register Properties within the study area. Sixty of the historic properties are located in the city of Galveston, and are primarily historic houses, commercial and government buildings. Other National Register sites and districts located throughout the area include the Apollo Mission Control Center, the Space Environment Simulation Laboratory, the Saturn V Launch Vehicle, the Point Bolivar and Sabine Pass Lighthouses, the Beaumont Commercial District, the Jefferson Historic District, the Port Arthur-Orange Bridge, the W. H. Stark House, the Old Wallisville Townsite, Fort Anahuac, and the Chambers and Jefferson

County Courthouses. The majority of these cultural resources are vulnerable to damage or destruction from hurricane storm surge.

2.3.13 Energy and Mineral Resources

Hundreds of pipelines cross the waterways and marshes of the study area. Pipelines crossing beneath the navigation channels are generally buried deeply enough that they would not be affected by storm surge scouring. However, it is likely that pipelines are present in many areas where storm surge barriers or ER measures such as marsh restoration or breakwaters have been proposed. In-depth research and surveys would be needed to identify pipelines for detailed preconstruction planning and design.

2.3.14 Socioeconomic Considerations

The Sabine Pass to Galveston Bay study area encompasses six coastal counties of the upper Texas coast. Over five million people reside in the six counties, which include the 4th largest U.S. city (Houston) and three other large metropolitan areas (Beaumont/Port Arthur/Orange, Galveston/Texas City and Freeport/Surfside). The population of these counties is projected to increase to over nine million within the next 50 years. In addition to the at risk population, three of the nine largest oil refineries in the world, 40 percent of the nation's petrochemical industry, 25 percent of the nation's petroleum-refining capacity, and three of the ten largest US seaports are also located in the study area. The growing population, communities and nationally significant industries are severely vulnerable to risks from coastal storm events. Approximately 2.26 million people across the study area live within a storm-surge inundation zone, and estimates for a one-month closure of the Houston Ship Channel alone are upwards of $60 billion in damages to the national economy.

Hurricane Ike is an example of the types of socioeconomic disruptions that could be expected when another major hurricane strikes the area. Numerous industries, including the petrochemical, health care, agriculture and forestry, fishing, tourism, nonprofit, and small business sectors would be adversely affected, both during and after the storm. Shipping would be disrupted and port facilities damaged in three of the four primary Texas ports (Kraus and Lin 2009). According to USACE records, in 2006 these four port areas cumulatively accounted for nearly 500 million short tons (454 million metric tons) of waterborne tonnage and handled 25 percent of all foreign (imports and exports) tonnage traveling on U.S. waterways. Crude petroleum tonnage was 35 percent of the national total. Other significant commodity totals include gasoline (19.8 percent of national coastwise total), distillate fuel oil (24.3 percent of national coastwise total), wheat (22.4 percent of national coastwise total), and benzene and toluene (72 percent of national coastwise total). Clearly, recovery of the coastal navigation channels and associated waterways was of national urgency after Hurricane Ike (Tirpak 2009). During Hurricane Ike, hundreds of thousands of homes along the upper Texas coast were severely damaged or destroyed as a surge of up to 20 feet hit in conjunction with the high tide (FEMA 2008). It has been estimated that 75 percent of the 24,000 structures on Galveston Island flooded during Ike to a maximum height of 10 to 12 feet (Tirpak 2009). Entire cities were inundated with the mud and debris that accompanied the surge. In the small town of Bridge City, only 14 of its 3,400 homes were habitable after the storm. In Gilchrist, located on the Bolivar Peninsula, only one home was left standing when the winds stopped. Months after the storm, thousands of families across the region continued to struggle with finding places to live near their jobs and children’s schools in an effort to restore some normalcy to their lives (FEMA 2008). Hurricane Ike also placed immediate and long-term strains on the ability of impacted communities to provide access to health care and specialty health services, and basic services, like childcare, public education, and public utilities.

3 NO ACTION ALTERNATIVE (FUTURE WITHOUT-PROJECT CONDITIONS)*

The USACE is required to consider the No Action Alternative during the planning process and assessment of impacts to comply with the NEPA and CEQ guidance (40 CFR §1502.14) as well as USACE regulations (ER 200-2-2) for implementing the NEPA. The No Action Alternative is a forecast of the future without-project (FWOP) conditions which provide the basis for plan formulation and eventual comparison to all other alternative plans. The terms “No Action Alternative”, “future without-project” or “future without-project condition” is used synonymously or interchangeably throughout the FIFR-EIS. With the No Action Alternative, it is assumed that no project would be implemented by the Federal Government or by local interests to achieve the planning objective. The No Action Alternative forms the basis against which all other alternative plans are measured.

The No Action Alternative condition assumes the continuation of existing conditions for the resources listed above; no improvement of existing HFPPs at Port Arthur, Texas City, and Freeport; no intervention to reduce the impacts of storm surge on the vulnerable populations and infrastructure of the study area; and no large-scale ER efforts to improve the sustainability of fragile coastal systems and attenuate storm surge.

3.1 PROJECT AREA

The regions described in Section 1.5 were 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 to show more detail on the No Action Alternative conditions for storm surge flood risk. The project areas generally align with the 0.2% ACE (500-year floodplain) and locations of economic damages analyzed in the study. Figures 3-1 and 3-2 show the project areas. The Orange-Jefferson CSRM and Port Arthur and Vicinity CSRM projects areas are in the same general vicinity. In Figure 3-1, the highlighted areas shown in red are located on the Orange County side and structures 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.

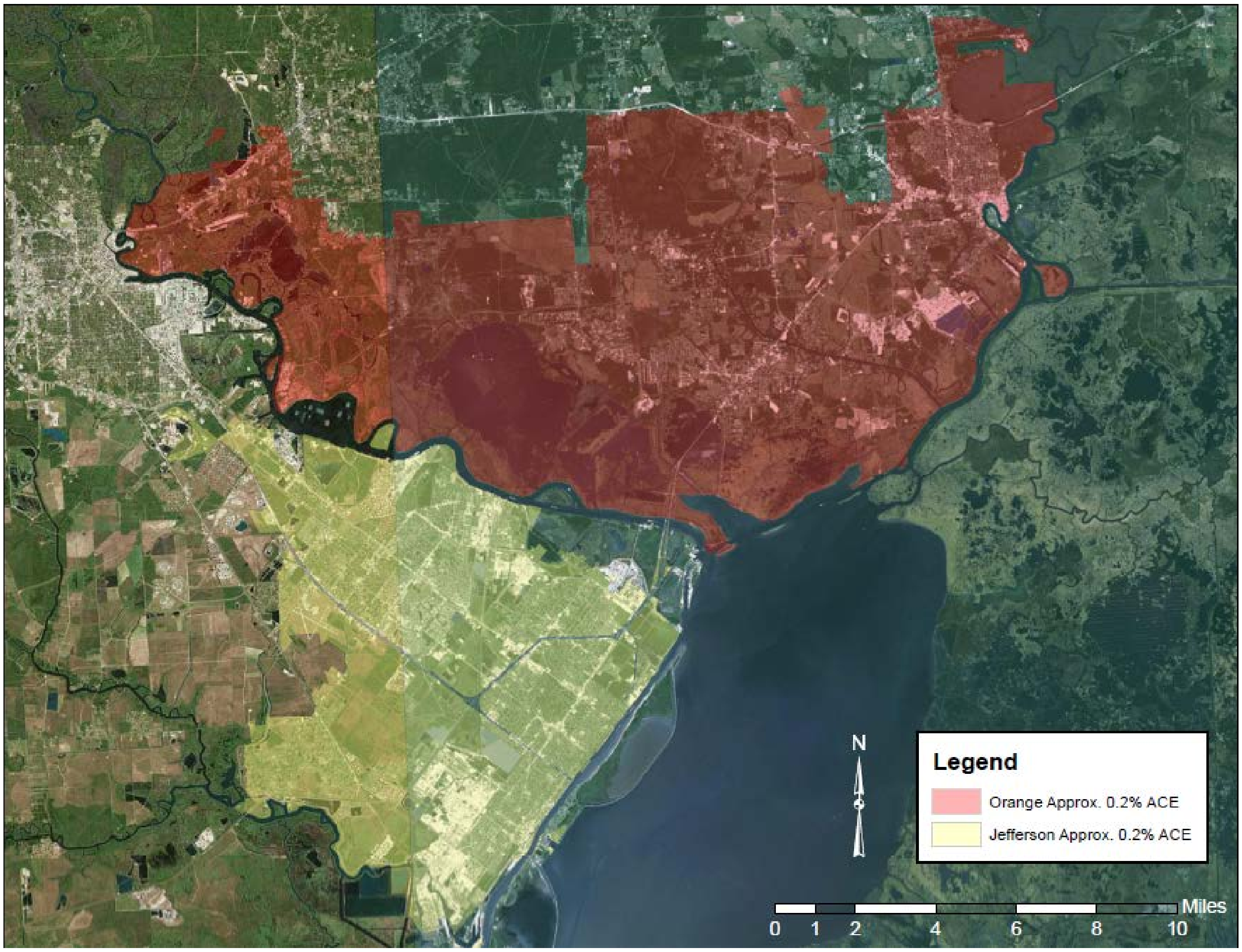

Figure 3-1: Orange-Jefferson CSRM and Port Arthur and Vicinity CSRM Project Areas

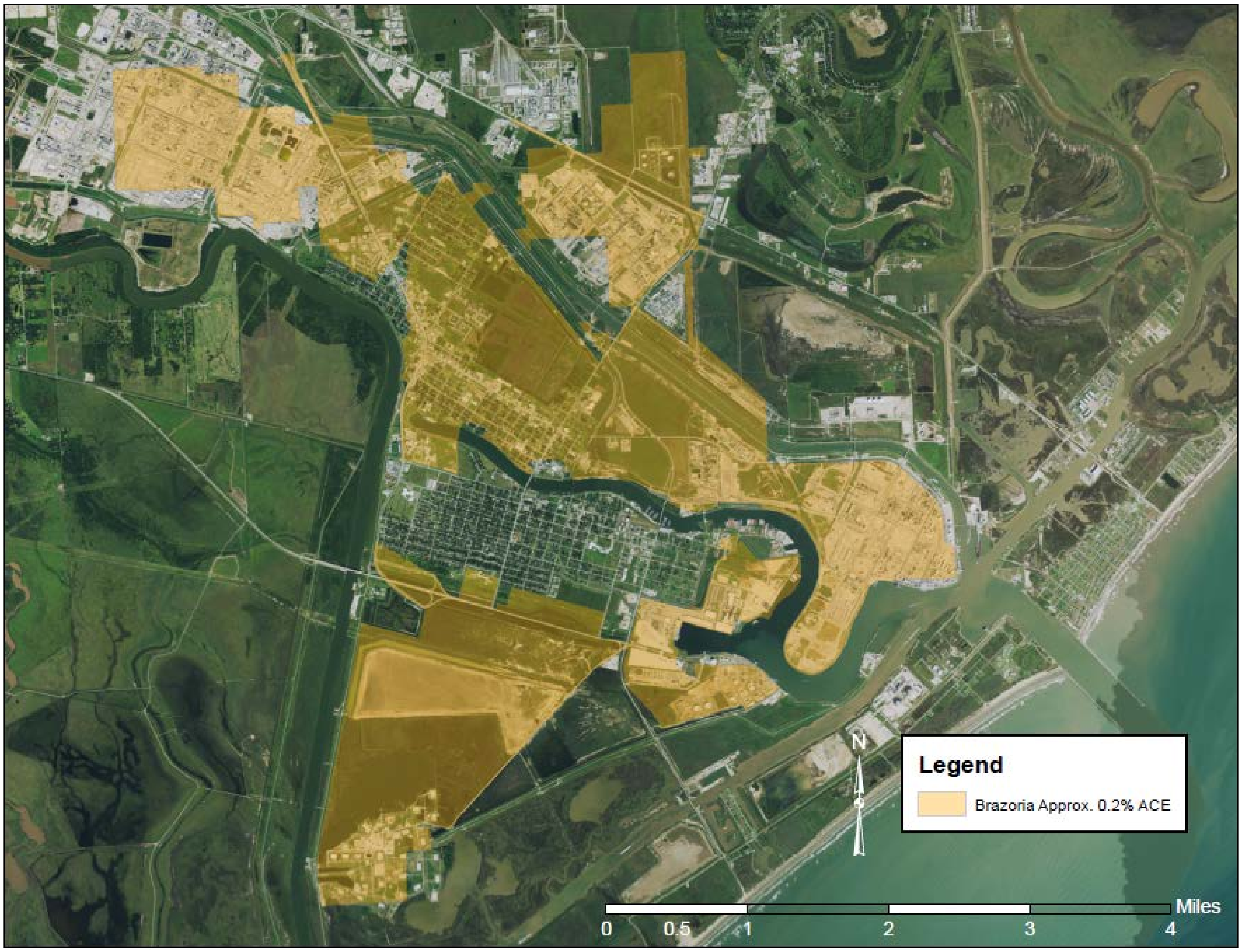

Figure 3-2: Freeport and Vicinity CSRM Project Areas

In order to define the No Action Alternative for life-safety, economic damages, and critical infrastructure, 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 this 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.

Orange-Jefferson CSRM Project Area

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

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

Port Arthur and Vicinity CSRM Project Area

The existing HFPP 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 with 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 3-4); 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’s P.L. 84-99 program. A Periodic Inspection was completed for the Port Arthur system in 2012, and 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 concerns in the FWOP condition. It is assumed in the No Action Alternative that no other actions to reduce the risk will take place by others.

Figure 3-4: Port Arthur and Vicinity CSRM Failure Locations

Freeport and Vicinity CSRM Project Area

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, generally depicted in Figure 3-5. Additionally, the line of risk reduction includes multiple structures that also serve as control structures and docks for the DOW Chemical Co., BASF, Conoco Philips, Exxon, and Port Freeport.

Figure 3-5: Existing HFPP in Freeport and Vicinity CSRM

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 risk reduction (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 No Action Alternative 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 0.7% ACE event.

3.2 ECONOMIC CONDITIONS

The FWOP economic conditions were evaluated throughout plan formulation in greater levels of detail to screen measures and alternatives as the study progressed. It is important to note some level of detail regarding the plan formulation process used in this study to introduce how the FWOP economic conditions were estimated. First, management measures to address flood risk and ecosystem restoration were developed and screened. Then remaining measures were evaluated as stand-alone alternatives or in combination with each other and screened in an iterative process referred to as the Initial Array, Evaluation Array, and the Final Array of Alternatives. The economic screening performed during each iteration is described in detail in Appendix B (Plan Formulation) and summarized here for the all screening leading up to Final Array of Alternatives. More detail for the FWOP economic conditions for the Final Array Alternatives is described in this section.

3.2.1 Initial and Evaluation Array of Alternatives

For the Initial and Evaluation Array Alternatives, FWOP economic damages and benefits were estimated using the Hydrologic Engineer Center Flood Impact Analysis model (HEC-FIA) for the 1% ACE event (or 100-year). HEC-FIA is a software package developed by USACE that analyzes the consequences of flood events. The economic damage estimates are roughly equivalent to insured losses, and do not include damages to the economy as a whole. Economic and cost criteria were applied to screen the alternatives.

3.2.2 Final Array of Alternatives

This is a summary of the FWOP economic conditions for the Final Array of Alternatives. 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 based on hydraulic, geotechnical, and environmental considerations. The EADs for the FWOP conditions are presented in detail in Appendix B for each alternative reach along with the engineering inputs and assumptions into the model. The results are summarized here. Tables displaying structure and content values by reach, detailed tables of the EAD calculations, 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 Array and Evaluation Array Alternatives. This screening used HEC-FIA with 1% ACE depth grids in conjunction with HAZUS-MH data to determine FWOP economic damages as described previously in Section 3.1.1. This analysis 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 was 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 HFPP 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. Additional detail of the fragility curve development for the economic evaluation for the FWOP condition is 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 Alternative Reaches:

- Orange 1, Orange 2 and Orange 3
- Jefferson Main
- Beaumont A, Beaumont B, 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 3-6 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 No Action Alternative Reaches.

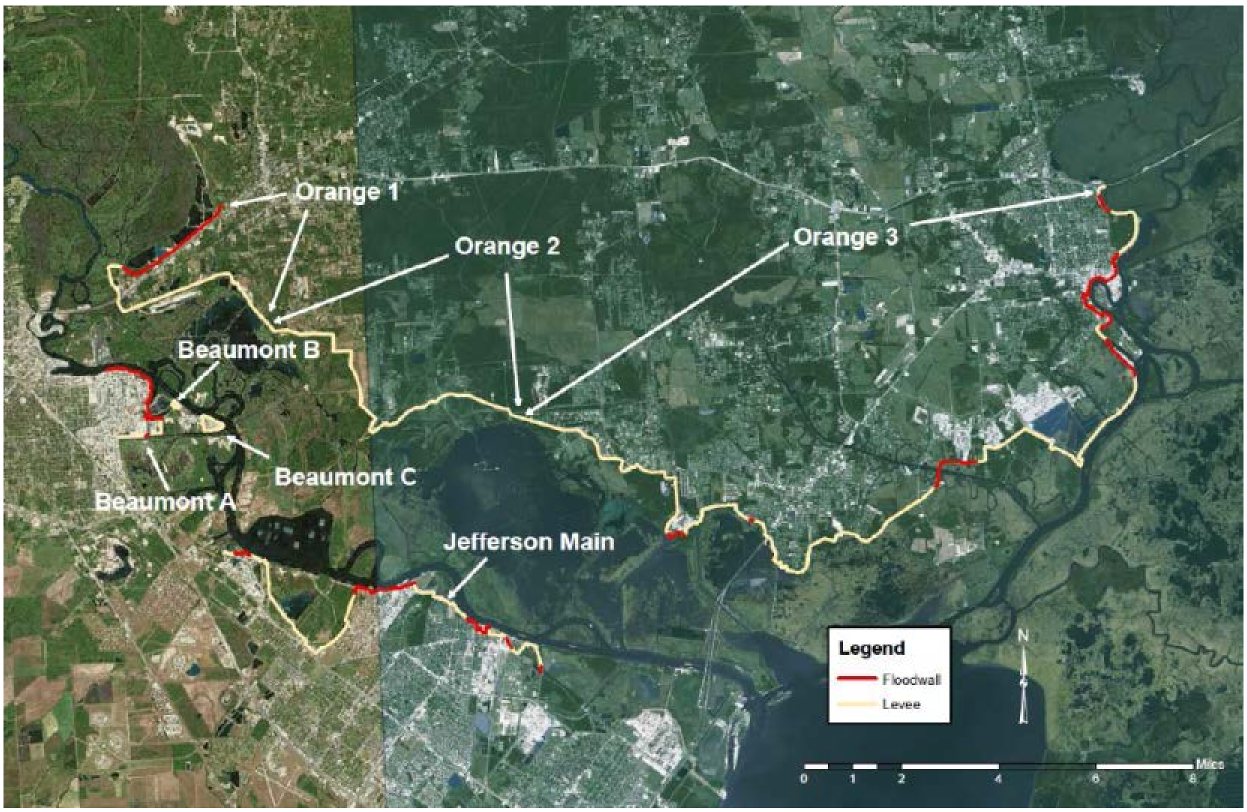

Figure 3-6: Orange-Jefferson CSRM Alternative Reaches

For the Orange 1, Orange 2, and Orange 3 alternative reaches, significant damages start at approximately the 1% ACE; the depth of flooding at the 1% ACE is approximately 8 feet. In the Jefferson Main alternative reach, significant damages start between the 2% and 1% ACE; the depth of flooding between the 2% and 1% ACE is approximately 6.5 feet and 7.5 feet. For the Beaumont A, Beaumont B, and Beaumont C reaches, 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 project area, in Jefferson County, is $8,120,438,000 ($3,998,788,000 structure value and $4,121,650,000 in content value).

Table 3-1 estimates the FWOP EADs for the damage reaches in the Orange-Jefferson CSRM. Damage categories such as commercial or industrial are provided in Appendix C, Economics.

Table 3-1: Expected Annual Damages
FWOP for the Orange-Jefferson CSRM Project Area by Alternative Reaches
(2015 price level)

Orange-Jefferson CSRM Alternative Reaches	Total
Orange 1	$312,000
Orange 2	$68,000
Orange 3	$29,987,000
Beaumont A	$6,937,000
Beaumont B	$23,000
Beaumont C	$262,000
Jefferson Main	$28,231,000

Port Arthur and Vicinity CSRM

The draft findings of the SQRA for the Freeport system were applied to the plan formulation for Port Arthur because one has not yet been done. 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 3-7 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 risk reduction. The following lists the Alternative Reaches at Port Arthur:

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

Figure 3-7: 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 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 3-2 estimates the FWOP EADs for the damage reaches in the Port Arthur and Vicinity CSRM project area. Damage categories are defined in Appendix C, Economics.

Table 3-2: Expected Annual Damages
FWOP for the Port Arthur and Vicinity Project Area by Alternative Reaches
(2015 price level)

Port Arthur and Vicinity CSRM Alternative Reaches	Total
8-foot to 10-foot I-Wall Raise	$23,413,000
Closure Structure Raise	$3,784,000
I-Wall Raise Near Valero	$61,867,000
Raise Near Tank Farm	$38,009,000

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 project area began with defining reaches for the system. These were based on the failure locations identified in the SQRA (Figure 3-8). These locations were then narrowed during formulation to those locations where improvements would positively impact the system's capacity for risk reduction and to reduce any redundancies. For example, improvements to the DOW Barge Canal would negate any failures at the DOW Turning Basin.

Figure 3-8: Freeport and Vicinity CSRM Failure Locations

The following is the resulting list of Alternative Reaches at the Freeport and Vicinity CSRM:

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

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 3-3 estimates the FWOP EADs for the damage reaches in the Freeport and Vicinity CSRM. Damage categories are defined in Appendix C, Economics.

Table 3-3: Expected Annual Damages
FWOP for the Freeport and Vicinity Project Area by Alternative Reaches
(2015 price level)

Freeport and Vicinity CSRM Alternative Reaches	**Total**
DOW Barge Canal	$166,660,000
Oyster Creek Levee	$3,800,000
East Storm Levee	$1,701,000
South Storm Levee	$254,000
Freeport Dock Floodwall	$3,960,000
Old River Levee at DOW Thumb	$2,517,000
Tide Gate I-Wall	$2,785,000

3.3 ENVIRONMENTAL CONDITIONS

The repetition of tropical storm events, hurricanes, and human modification of hydrology and coastal features has increased ecosystem vulnerability on the upper Texas coast. Successive disturbance by storm events, reduced sediment inflows, RSLC and salt stress from interference with fresh water flows has put in jeopardy the process by which marsh sediment accretion and land accumulation occurs. "Without a healthy plant community, sedimentary deposition decreases due to the loss of plants in the water column, biogenic accretion ceases due to the lack of plant detritus, and the substrate becomes exposed, leading to rapid erosion. As a result, a tipping point may have been reached, or is about to be reached, where these wetlands will be unable to keep pace with rising sea level" (Williams et al. 2009). As a result, the extensive marshes along the upper Texas coast have reduced resiliency to storm surge impact, complicating their post-storm recovery. All of this is also occurring within the context of climate change, which is likely to result in an increase in the intensity of tropical storms, rising average annual temperatures, and an increase in the rate of RSLC (IPCC 2014).

The effects of hydrological alterations (from a variety of sources, including dams, deep draft ship channels, impoundments, reduced flows due to increasing human and agricultural use) that have decreased freshwater and sediment inflows and increased saltwater intrusion into coastal marshes are expected to continue. These alterations have resulted in the loss of coastal freshwater wetlands and the conversion of remaining fresh marsh systems to more brackish regimes, reducing native biological diversity and productivity. Increased marsh loss could alter the entire food chain in these areas, resulting in wide-reaching and long-term impacts on coastal habitats and fisheries production in terms of species like red drum, white shrimp, and blue crab.

The loss of 1.2 million acres of historic wetlands in Texas makes the remaining areas especially important for wildlife (USFWS 2013). Marsh losses like those on the Neches River, where approximately 9,500 acres of open-water areas have been created by marsh loss at Rose City, Bessie Heights, and Old River Cove, would continue. Subsidence associated with extraction of ground water, oil, and gas would continue, although possibly at a slower rate (Kennish 2001). Marshes behind the Gulf shoreline in the McFaddin and Texas Point NWRs are breaking and converting to open water as a result of subsidence and sea level rise, ultimately resulting in total loss of marsh. Hurricane Ike removed most of the natural beach berm on McFaddin NWR, creating a situation where salt water from the Gulf now washes regularly into intermediate and brackish marshes. Restricting saltwater intrusion into the Upper Salt Bayou system is critical to maintaining the Chenier Plain's continuum of fresh, intermediate, and brackish saline marshes. In addition to their significant ecological value, these marshes also serve to attenuate storm surge and provide a natural defense to shorelines.

3.4 LIFE SAFETY

The population at risk broken down by project area is included in Table 3-4. The 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. Defining the population at risk and the depth of flooding is evaluated in a risk assessment, which was not performed in this study. What is known about the project areas is the residential population that could be exposed to flood risk listed in Table 3-4. Other considerations include high-risk areas that have populations/residents with special needs, such as elderly populations over 65, hospitals, nursing homes, and schools. These types of populations were not fully defined in this study; however, the existing structures (hospitals, nursing homes, and schools) were inventoried in the project area. These structures are listed in Section 3.5 below. Additional information on the location of these structures is included in Appendix C, Economics. Flooding depths are also a consideration. Flooding depths are significant concern at approximately 15 feet where residents have limited ability to vertically evacuate. Approximate flooding depths for each project area were not developed outside of the economic analysis for the FWOP condition. The still-water level estimates for depth of flooding are included in Section 3.2.2 for the project areas.

Table 3-4: Population at Risk by Project Area and Alternative Reach

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

It is important to note the type of warning systems for the project areas in the FWOP condition. 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.

3.5 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 FWOP 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 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, Economics. 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. There is overlap in this discussion between the Orange-Jefferson CSRM and Port Arthur and Vicinity project areas since the Jefferson Main Alternative Reach (within the Orange-Jefferson CSRM project area) has overlapping structures located in the Port Arthur and Vicinity project area.

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
- 5 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
- 5 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 daily 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 in the No Action Alternative. Of note, if the refineries were closed down due to flood events, there could be significant impacts on gas supplies and multiplier effects on 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.

3.6 RELATIVE SEA LEVEL CHANGE (RSLC)

USACE expectations of climate change and RSLC, 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 requirements for RSLC in a feasibility study, per ER 1100-2-8162 and ETL 1100-2-1 include:

- At a minimum 20-, 50-, and 100-year planning horizons should be considered in the analysis.
- A thorough physical understanding of the project area and purpose is required to effectively assess the project's 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” (points where the functionality of a project is impaired or a no longer functions as intended) within the impacted project area. This will inform both the selection of anticipatory, adaptive, and reactive options selected and the decision/timing strategies.

Tables 3-5 through 3-6 present the estimated RSLC in the project areas for the 20-, 50- and 100-year for the Low, Intermediate, and High scenarios. Additional information on how the estimates were developed are included in Appendix D. The Sabine Pass, Texas, row corresponds to the sea level rise estimates for the Orange-Jefferson CSRM and Port Arthur and Vicinity CSRM project areas; and the Freeport, Texas, row corresponds to the Freeport and Vicinity CSRM project areas.

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.

Table 3-5: 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	1.08	1.38	2.38
Freeport, TX	4.35 mm/yr	.83	1.13	2.07

Table 3-6: 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	1.63	2.32	4.51
Freeport, TX	4.35 mm/yr	1.26	1.94	4.13

Table 3-7: 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	2.56	4.26	9.62
Freeport, TX	4.35 mm/yr	1.97	3.66	9.03

3.7 FUTURE WITHOUT-PROJECT CONDITIONS SUMMARY

Based on the evaluation of the FWOP conditions, there is the potential for significant economic damages in the Orange-Jefferson CSRM, Port Arthur and Vicinity CSRM, and Freeport and Vicinity CSRM project areas. There are also concerns for life-safety, damages to critical infrastructure, sea level changes, and impacts on significant environmental resources. These can be further characterized as problems and opportunities for the Federal Government or local interests to implement projects. The No Action Alternative forms the basis against which all potential projects are measured. Before a recommendation to implement a project can be identified, a plan formulation process in accordance with USACE policies needs to be followed. Definition of the FWOP is an important step in this process. The next sections describe the problems and opportunities, objectives and constraints, and the plan formulation process followed to identify a TSP and the subsequent Recommended Plan that meets USACE policies for implementation.

4 PROBLEMS AND OPPORTUNITIES

4.1 PROBLEMS AND OPPORTUNITIES/NEED FOR ACTION*

Problem and opportunity statements for the Sabine Pass to Galveston Bay study were initially developed after scoping comments were received from Federal, state, and local agencies, private groups, and the affected public. Four regional public scoping meetings were held across the study area during February to March 2012 jointly by USACE and the GLO. The problems and opportunities were revisited in the Planning Charette in August 2012, and were refined as the study progressed. Problems and opportunities were used to develop the planning objectives for the study and guide in selection of the TSP and the subsequent Recommended Plan as described in Sections 5 and Sections 6. The problems and opportunities listed here are the same developed in the early planning stages.

It is important to explain how a problem or opportunity led to a planning objective/constraint or whether it feeds into the comprehensive assessment of potential CSRM projects in the Galveston region (Galveston, Harris, and Chambers Counties) and potential ER projects in the entire six-county study area. For these reasons, a problem or opportunity is provided a reference code to track a problem or opportunity to an objective/constraint or to a comprehensive assessment project discussed in subsequent sections.

Due to stipulations of the 3x3x3 Rule exemption, the feasibility study effort described here has focused on CSRM recommendations for the Sabine Region (Orange and Jefferson Counties) and the Brazoria Region (the Freeport metropolitan area in southern Brazoria County). The following in-depth alternative analyses and recommendations do not include CSRM projects in the Galveston Region or ER projects throughout the six-county study area. The latter are handled comprehensively as described in Section 1.3 of this report.

4.1.1 Problem Statements

- (P1) Population at risk – Over six million people in six counties on the upper Texas coast, which include the fourth largest U.S. city (Houston), and three other metropolitan areas (Beaumont/Port Arthur/Orange, Galveston/Texas City, and Freeport/Surfside) are severely vulnerable to life safety and economic risks from coastal storm events. Approximately 2.26 million people reside within an identified storm-surge inundation zone. The population of the six-county region is expected to grow to over nine million by 2050.
- (P2) Three of the nine largest oil refineries in the world, 40 percent of the nation's petrochemical industry, 25 percent of the nation's petroleum-refining capacity, and their

associated infrastructure (pipelines, transportation networks, and utilities) will continue to be at risk without a comprehensive plan aimed at reducing susceptibility to flood and hurricane risk. Two of the nation's petroleum strategic reserves are within the surge zone.

- (P3) Three major U.S. seaports, approximately 150 miles of the GIWW (nation's 3rd busiest waterway), and associated infrastructure will continue to be susceptible to flood and hurricane storm damages. A 30-day closure of the HSC has been estimated to result in an economic loss of $60 billion to the nation.
- (P4) Storm-induced erosion is degrading nationally significant migratory waterfowl and fisheries habitats within the study area. The chenier ridges and marshes along the entire coastline of Jefferson County serve as a storm surge buffer to the GIWW, the city of Port Arthur, and several petrochemical facilities, including the largest oil refinery in the U.S. If the ridges and marshes disappear, the protective buffer would be eliminated.
- (P5) Three existing hurricane risk reduction systems at Port Arthur, Texas City, and Freeport were nearly overtopped during Hurricane Ike. These systems do not meet current design standards for resiliency and redundancy and will be increasingly at risk from storm damages due to relative sea level change and climate change. Critical infrastructure throughout the region, including hurricane evacuation routes, nationally significant medical centers, government facilities, universities, and schools were extensively damaged by recent storm events.
- (P6) This is a geologically sand-starved system; sediment removed from the system by human modifications such as jetties, navigation channels and reservoirs is not replenished. This results in continued shoreline retreat and accelerated shoreline erosion during storm events.
- (P7) The study area is located in an area with a high frequency of storm impacts and economic damages (second highest area of occurrence on Gulf coast). Environmental impacts on refineries are likely from storm damages (e.g., release of toxic substances).
- (P8) Potential damages of $100 billion could have resulted if the storm track of Hurricane Ike had been slightly to the south.
- (P9) The value of infrastructure associated with petrochemical/oil/gas refineries that could be impacted by storms is very high.
- (P10) Riverine Flooding along the lower Neches River cause life safety and economic risks when high periods of tides and high river stages occur simultaneously.

4.1.2 Opportunity Statements

- (Op1) Provide shoreline protection to reduce risks to commercial and residential property, real estate, and infrastructure within the six-county study area.
- (Op2) Enhance ecotourism and recreation opportunities.

- (Op3) Enhance public education related to coastal storm risk.
- (Op4) Reduce environmental damage associated with storm damage to refinery infrastructure.
- (Op5) Enhance or restore endangered species habitat.
- (Op6) Reduce risk for evacuation routes so they remain clear longer.
- (Op7) Manage regional sediment management for beneficial uses to navigation and other operations.
- (Op8) Increase reliability of the nation's energy supply.
- (Op9) Avoid or mitigate adverse natural resource impacts.
- (Op10) Leverage resources from multiple stakeholders for effective solutions.
- (Op11) Establish more resilient communities.

4.2 PLANNING GOALS AND OBJECTIVES

4.2.1 Planning Goals

The main goals of this project are to reduce the risk to lives and property associated with coastal storms within the Orange-Jefferson, Port Arthur and Vicinity, and Freeport and Vicinity CSRM project areas. In-depth alternative analyses for the Galveston region or ER were not performed beyond the Evaluation Array Alternatives; thus, there are no recommendations to construct ER or projects in the Galveston region as part of the Recommended Plan. As stated in the sections above, ER goals for the these project areas and the Galveston region will be addressed as part of the ongoing USACE Coastal Texas CSRM and ER Feasibility study, in conjunction with the Texas GLO.

4.2.2 Public Concerns

Public input was solicited at four public scoping meetings held in January and February 2012 in Beaumont, Seabrook, Galveston, and Freeport, Texas. During the scoping process, various members of the public voiced concern about the erosion of the GIWW shoreline, a preference that nonstructural solutions to storm surge damages be considered above all else, and a desire to keep the mouth of the San Bernard River open for recreational navigation.

4.2.3 Planning Objectives

The objectives listed in Table 4-1 were developed from the problem and opportunity statements and used to guide the plan formulation for the TSP and the subsequent Recommended Plan. It also ties the problem or opportunity to an objective as indicated by the reference codes. If a problem or opportunity is addressed in the comprehensive assessment, those fall within that respective column in the table. Some problems and opportunities cross over in the objectives. For example, the opportunity Op10 crosses over all objectives. The intent of this opportunity is to capture data, reports, outputs from SSPEED, Texas A&M Galveston, other risk reduction studies, etc. that have already been performed in the study area. The row highlighted in green in Table 4-1 is the previous ER objective developed for this study, but is not included in development of the TSP and subsequent Recommended Plan.

Table 4-1 is organized to align the study planning objectives to the "four accounts" listed in the Economic and Environmental Principles for Water and Related Land Resources Implementation Studies. These "principles" were established pursuant to P.L. 89-80, and amended. The four accounts are established to facilitate evaluation and display of effects of alternative plans. The four accounts are: 1) National Economic Development (NED); 2) Environmental Quality (EQ); 3) Regional Economic Development (RED); and 4) Other Social Effects (OSE).

- NED: account displays changes in the economic value of the national output of goods and services.
- EQ: account displays non-monetary effects on significant natural and cultural resources.
- RED: account registers changes in the distribution of regional economic activity that result from each alternative plan. Evaluations of regional effects are to be carried out using nationally consistent projections of income, employment, output, and population.
- OSE: account registers plan effects from perspectives that are relevant to the planning process, but are not reflected in the other three accounts.

Alternative plans were formulated to reduce the risk of damages from coastal storms, minimize impacts to floodplains, and avoid environmentally significant resources. Where impacts could not be avoided, environmental impacts were quantified and a mitigation plan was formulated. The location of potential ER projects relative to new levee system alternatives were considered during plan formulation. ER opportunities identified by this study are described and mapped in Appendix A. They are located outside of the new levee alternatives, in the floodplain of the Neches River and on the coastal plain south of the Orange-Jefferson CSRM project area. The location of the new levee alignment and the design of the culvert system minimized impacts on wetlands and floodplains, both inside and outside of the system, to the greatest extent practicable. The potential for marshes to migrate landward due to RSLC is low because of the abrupt 8- to 10-foot elevation change between the floodplain and the upland in most of project area. Therefore, there would be no impacts on potential future ER projects. Where impacts of the Recommended Plan could not be avoided, impacts were quantified and a mitigation plan was formulated. A mitigation estimate was developed and included as a project cost.

Table 4-1: Sabine Pass to Galveston Bay, Texas Planning Objectives and Measurements

Planning Objectives	**NED****		**OSE****	**RED****	**EQ****	**Comprehensive Assessment**
	Coastal Storm Surge Damage Benefits	Costs	Population at Risk	Critical Infrastructure Impacts	Ecosystem Functionality	
1. Reduce economic damage to business, residents and infrastructure for the Sabine and Brazoria region for the 50-year period of analysis. Problem/Opportunity Code: P7, P8, Op1, Op2, Op9, Op10, Op11	Benefits for coastal storm damages averted (ADCIRC floodplain and water elevation; CAD values)	First Cost of Construction; O&M Life Cycle Cost***; Mitigation & Monitoring Cost				Problem/Opportunity Code: P4, P6, Op5, Op7
2. Reduce risk to human life from storm surge impacts for the Sabine and Brazoria region for the 50-year period of analysis. Problem/Opportunity Code: P1, P8, Op3, Op10, Op11			Number of people for which risk is reduced (2010 census)			
3. Maintain and/or restore coastal habitat that contributes to storm surge attenuation where feasible for the 50-year period of analysis.					Average Annual Habitat Units (AAHUs)	
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. Problem/Opportunity Code: P2, P8, Op5, Op10, Op8	CAD value of facilities			Effect of transportation disruptions after storms		
5. Reduce risks to critical infrastructure (e.g., medical centers, ship channels, schools, transportation, etc.) for the Sabine and Brazoria region for the 50-year period of analysis. Problem/Opportunity Code: P3, P8, Op4, Op9, Op10, Op11				Number of critical facilities and evacuation routes for which risk is reduced		
6. Identify opportunities to enhance functionality of existing hurricane risk reduction system including evaluation of impacts due to sea level rise for the 50-year period of analysis. Problem/Opportunity Code: P5, P8, Op10	Benefits for coastal storm damages averted (ADCIRC floodplain and water elevation; CAD values)					

**These columns correspond to the Principle and Guidelines four accounts: National Economic Development (NED), Other Social Effects (OSE), Regional Economic Development (RED) and Environmental Quality (EQ)

*** Operation, Maintenance, Repair, Replacement and Rehabilitation (OMRR&R) costs were not included and are not expected to impact plan formulation since they would impact the alternatives proportionally

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4.2.4 Planning Constraints

The following constraint was developed from the problem and opportunity statements and used to guide the plan formulation for this study. Reducing life-safety risk is a planning objective of the study; however, careful consideration is required to ensure structural plans do not increase risk. As such, any features that increase risk to human life from storm surge impacts in the Sabine and Brazoria regions for the 50-year period of analysis was not be considered in the TSP or subsequent Recommended Plan.

4.3 RELATED PROJECT DOCUMENTS

Related project documents include the following:

- 1975 Final Environmental Impact Statement: Maintenance Dredging Gulf Intracoastal Waterway Texas Section, Main Channel and Tributary Channels. Volumes 1, 2, and 3. Galveston, Texas
- 2003 Final Environmental Assessment, Houston-Galveston Navigation Channels, Texas – Upper Barge Lanes. Galveston District, Galveston, Texas
- 2003 Final Feasibility Report and Environmental Assessment, Gulf Intracoastal Waterway, High Island to Brazos River, Texas, Section 216 Study. Galveston District, Galveston, Texas
- 2005 Draft Feasibility Report, Freeport and Vicinity, Texas Hurricane Flood Protection Project. Galveston District, Galveston, Texas
- 2008 Final General Reevaluation Report and Environmental Assessment, Texas City Channel Deepening Project. Galveston District, Galveston, Texas
- 2010 Final Environmental Assessment, Houston-Galveston Navigation Channels, Texas – Expansion of Placement Areas 14 and 15. Galveston District, Galveston, Texas
- 2011 Final Environmental Impact Statement, Sabine-Neches Waterway Channel Improvement Project, Southeast Texas and Southwest Louisiana. Galveston District, Galveston, Texas
- 2012 Final Environmental Impact Statement, Freeport Harbor Channel Improvement Project, Brazoria County, Texas. Galveston District, Galveston, Texas
- 2013 Draft Environmental Assessment, Galveston Harbor Channel Extension Post-Authorization Change Report, Galveston County, Texas (March 2013). Galveston District, Galveston, Texas

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5 FORMULATION AND EVALUATION OF ALTERNATIVE PLANS*

Note: This chapter describes the alternative development, formulation, and evaluation 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 that have occurred since the public review are briefly described at the end of this chapter. The changes to the TSP that resulted in the final Recommended Plan are presented in Chapter 6.

5.1 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.

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 meetings were held across the study area during February to March 2012.

5.2 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 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. A feasibility study completed in 1979 (USACE 1979) served as an important reference for the development of structural alternatives in the Galveston and Sabine regions. Viability of Gulf shoreline projects is dependent on the GLO's 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 Charette (Charette), the full Vertical Team (USACE District, Division, Headquarters, and Office of Water Project Review) and the local sponsor worked through an abbreviated version of the six-step planning process, considered 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 Charette, 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 Charette, 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 Charette that these criteria would be used to evaluate the five alternatives that were developed from the measures during the Charette. After the Feasibility Cost Share Agreement (FCSA) for the study 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 were considered as part of the study analysis and were developed to address study objectives previously presented in Section 4. These measures were combined with other measures, nonstructural or structural, to form alternatives to be evaluated in the study process. These alternatives are screened in the Plan Formulation Phase, as discussed in the next section. The majority of the measures developed were structural; however, it should be noted that nonstructural measures were carried forward to the Final Array of Alternatives. The structural measures included new coastal and inland structural barriers, reconstruction of existing and construction of new regional hurricane risk reduction systems, local surge risk reduction systems, raising roads as surge or overwash protection barriers, Gulf shoreline protection (beach and dune restoration, nearshore breakwaters, chenier ridge restoration), GIWW erosion protection, marsh restoration, and salinity/water control structures. Measure Information Sheets with descriptions and maps of each measure are presented in Appendix A. Table 2-1 of Appendix B includes the list of the 75 initial measures.

After the reformulation of the initial 75 measures, each measure was evaluated to determine whether it would address the planning objectives. If they did not, they were removed from further consideration. This screening process removed 15 measures from the study. Table 5-1 summarizes this process and the criteria used. Section 3.1.2 of Appendix B describes the reasons for elimination.

Table 5-1: Summary of Management Measures and Initial Screening of Measures

	Number of Measures	**Screening Criteria**
Management Measures	75 Measures in Sabine, Galveston, and Brazoria Regions	None, this was the initial array of management measures

	Number of Measures	Screening Criteria
Initial Screening of Measures	Resulted in elimination of 15 measures from the 75 measures	Economic Damages Reduces based on water surface elevations; Acres of habitat protected/restored by the plan; and order of magnitude parametric costs (Class 5 cost estimate)

5.3 SUMMARY OF ALTERNATIVES ANALYSES

The initial measures were screened to determine if they adequately addressed the problems and objectives of this study. The remaining measures were then formed into arrays of alternatives plans, which were screened to determine the most effective alternatives. The screening produced three iterations of alternatives including:

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

5.3.1 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 the task of formulating alternatives for such a large and diverse area more manageable. The alternatives were 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. The Initial Array of Alternatives included eleven alternatives for the Sabine Region, nine alternatives for the Galveston Region and five alternatives for the Brazoria Region, for a total of 25 alternatives considered in the Initial Array of Alternatives. A detailed description of the alternatives is included in Section 5.2 of Appendix B (note that each alternative was provided an Alternative Number). A summary of the alternatives is provided below.

For the Sabine Region, the eleven alternatives included evaluation of existing HFPPs in the region, 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.

Nine alternatives were developed for the Galveston region, including alternatives which addressed CSRM and ER in combination and individually. These alternatives included evaluation of the existing HFPP in the region, 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.

For the Brazoria Region, the five alternatives included plans for evaluating the existing HFPP, 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 Array of Alternatives was screened using three quantitative criteria (economic benefits, environmental benefits and implementation costs) and one qualitative criterion (environmental impacts) (Table 5-2) to develop the Evaluation Array of Alternatives.

Table 5-2: Criteria for Screening Initial Array of Alternatives

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 to wetlands and sensitive habitat; system-wide hydrologic impacts' and endangered species impacts

This screening process removed eight alternatives from the Sabine Region, five from the Galveston Region and two from the Brazoria Region. Section 5.5 of Appendix B summarizes the reasons for eliminating alternatives.

5.3.2 Evaluation Array of Alternatives

The screening process described in the previous section led to the identification of the Evaluation Array of Alternative Plans, which is composed of ten alternatives (three from Sabine Region, four from Galveston Region, and three from Brazoria Region) to be evaluated in more detail. The Evaluation Array of Alternatives are listed and described in Table 5-3.

The Evaluation Screening of Alternatives was used as a decision point to determine whether the data collected and utilized for this analysis is sufficient to make the determination of which alternatives to carry forward for detailed analysis or needed to be modified. For example, between alternatives S5 and S8 the CSRM measures included a gate across the Neches River vs a levee system paralleling both sides of the river. It was estimated the measures in the plans would provide roughly the same amount of benefits no matter which option was selected. Therefore, since the benefits are roughly the same, the primary determining factor was cost, allowing the measure with the lowest cost to be the measure to be carried forward into more detailed evaluation.

Table 5-3: Evaluation Array of Alternatives

Alternatives	**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	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
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. The Lone Star plan is an attempt fund the acquisition of large natural coastal areas in the study area's coastal zone that would serve as a natural buffer to tropical storm surge
B2	Brazoria Coastal Barrier CSRM	Freeport HFP
B3	Brazoria ER	Beach and dune restoration, groin, and GIWW shoreline protection

Alternatives	Name	Description
B5	Brazoria Nonstructural Alternative	Buyouts and Lone Star-like conservation plan. The Lone Star plan is an attempt fund the acquisition of large natural coastal areas in the study area's coastal zone that would serve as a natural buffer to tropical storm surge
Per a 25 February 2014 3x3x3 Rule Exemption memo, alternatives in grey were carried forward for future studies evaluating ER and CSRM projects in the region.		*Per a 25 February 2014 3x3x3 Rule Exemption memo, alternatives in blue were carried forward to focus the evaluation on two sub-regions, Sabine and Brazoria*

Consideration was given to a variety of factors including engineering, economics, costs, and environmental impacts for the two options between the gate and no-gate measures; however, the cost of the Gate measure is approximately $865 million more expensive than the no-gate measure. This cost difference is significant and further refinement and detailed analyses would not be expected to reduce this difference. Therefore, the alternative (S5) was modified to include the no gate option for further consideration in the study.

5.3.3 Scoping of Study under 3x3x3 Guidelines

In addition to evaluating the alternatives in more detail under Table 5-3, the USACE recently underwent a planning modernization which resulted in guidelines under which this study was to be developed at the time of screening of the alternatives. A scope was developed for completion of the study that would evaluate a final array of structural and non-structural alternatives in the six-county study area and that would be completed in 3 years for $3 million. However, it was determined that the level of detail would not be policy compliant. Therefore 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 comprehensive 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, including Coastal Texas, will leverage studies, data, and models currently under development by others in the Galveston region. The alternatives shown in grey on Table 5-3 will be taken into consideration by these future studies. 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, shown in blue.

5.3.4 Final Array of Alternatives

In accordance with the exemption request approval, the Sabine and Brazoria CSRM alternatives were carried forward into detailed feasibility analysis. The Final Array of Alternatives is presented in Table 5-4. These alternatives were evaluated in detail in the final evaluation to determine the TSP and the subsequent Recommended Plan.

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 5-4: Final Array of Alternatives

Alternative Number	Description
No Action	No Action or Future Without Project
S5 (1)	Orange-Jefferson CSRM
S5 (2)	Port Arthur and Vicinity CSRM
B2	Freeport and Vicinity CSRM
S11 & B5	Brazoria and Sabine Nonstructural

5.4 COMPARISON OF FINAL ARRAY OF ALTERNATIVE PLANS AND DECISION CRITERIA

The Final Array of Alternatives are listed in Table 5-4. This list is considered the project area for the remainder of the discussion of the evaluation and comparison of the final array. The "Optimization Alternatives" embedded in the project area listed in Table 5-4 are the actual final array evaluated and compared to determine the TSP. The Optimization Alternatives are defined in Table 5-5. As described in section 3.2.2, still water levels were used to determine the overall economic efficiency of the final array alternatives. The "11-, 12-, 13- and 14-foot New Levee" represents different still water levels evaluated. 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 5-5: 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

Project Area	Alternative Reaches	Optimization Alternatives
	Beaumont C	11-, 12-, 13- and 14-foot New Levee
Port Arthur and Vicinity CSRM	8-10 ft 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

5.4.1 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) 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 feasible 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 risk reduction systems 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. This screening criteria is 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 compilations 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 5.4.4.

5.4.2 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.

5.4.2.1 No Action/Future Without-Project Condition

The FWOP is defined in Section 3 of this report; this condition is the baseline EADs to show how well an alternative performs against the NED planning objective and to identify which plan reasonably maximizes net economic benefits, i.e., the NED plan.

5.4.2.2 Orange-Jefferson CSRM Project Area

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 5-1 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.

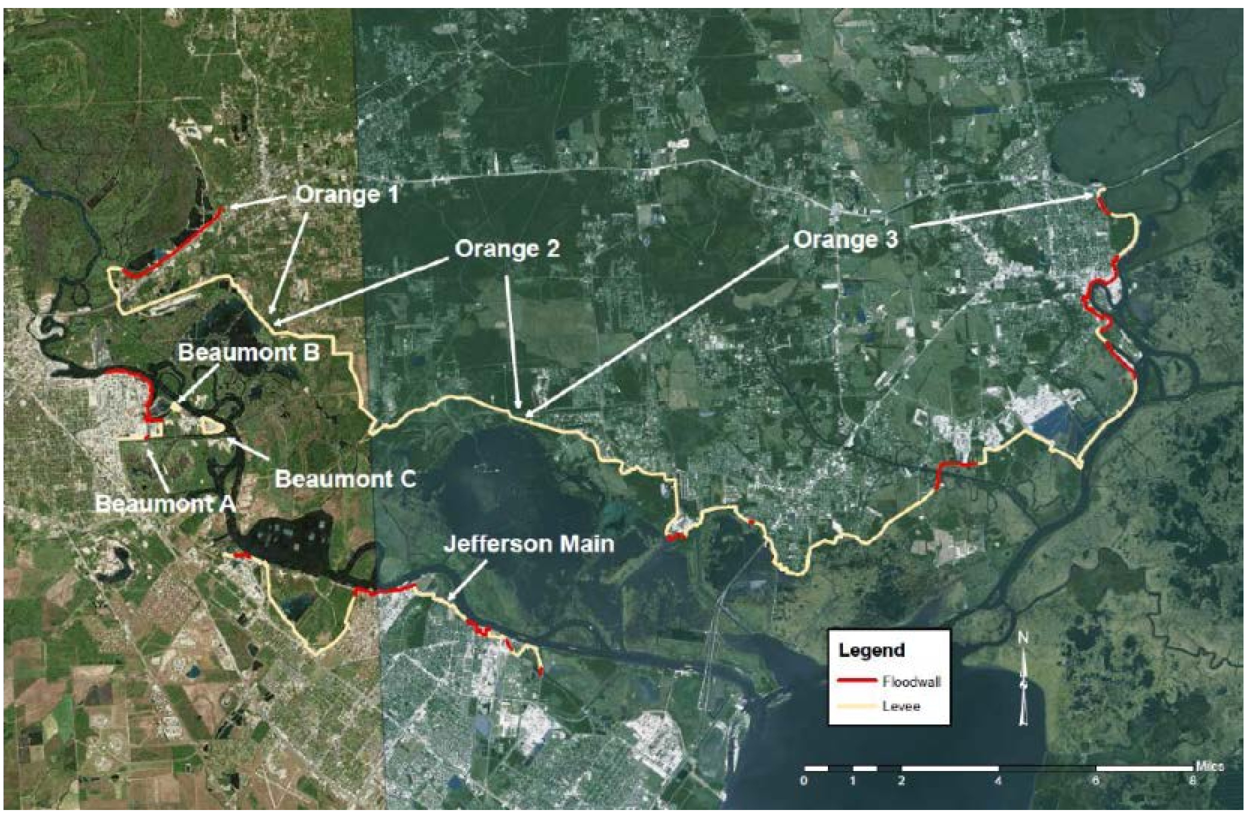

Figure 5-1: Location of Optimization Alternatives in the Orange-Jefferson CSRM Project Area

Economic Evaluation

The net benefits of Optimization Alternatives for the Orange-Jefferson CSRM project area are presented in Table 5-6. Negative net benefits are shown in red text. Fish and wildlife/wetland mitigation costs were included in the economic evaluation. The approved WVA model 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. Test cases of the WVA model were run to size potential mitigation areas that would compensate for the total AAHU impacts of each alternative. Costs per acre, taken from recent similar mitigation efforts, were multiplied by the

Table 5-6: Net benefits of Optimization Alternatives for the Orange-Jefferson CSRM project area

Alternative Reach	Optimization Alternatives	Net Benefits
Orange 1	11-foot New Levee	**($1,769,000)**
	12-foot New Levee	**($2,380,000)**
	13-foot New Levee	**($2,996,000)**
	14-foot New Levee	**($3,617,000)**
Orange 2	11-foot New Levee	**($1,757,000)**
	12-foot New Levee	**($2,112,000)**
	13-foot New Levee	**($2,467,000)**
	14-foot New Levee	**($2,822,000)**
Orange 3	11-foot New Levee	$9,851,000
	12-foot New Levee	$10,232,000
	13-foot New Levee	$9,804,000
	14-foot New Levee	$8,810,000
Jefferson Main	11-foot New Levee	$22,461,000
	12-foot New Levee	$22,580,000
	13-foot New Levee	$22,496,000
	14-foot New Levee	$22,123,000
Beaumont A	11-foot New Levee	$2,743,000
	12-foot New Levee	$2,992,000
	13-foot New Levee	$3,037,000
	14-foot New Levee	$2,942,000
Beaumont B	11-foot New Levee	**($58,000)**
	12-foot New Levee	**($82,000)**
	13-foot New Levee	**($106,000)**
	14-foot New Levee	**($131,000)**
Beaumont C	11-foot New Levee	**($442,000)**
	12-foot New Levee	**($449,000)**
	13-foot New Levee	**($574,000)**

acres needed to provide the target AAHUs. 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.

5.4.2.3 Port Arthur and Vicinity CSRM

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 5-2 shows the location of the Optimization Alternatives listed below.

- <u>8- to 10-foot I-Wall</u>
  - ➢ 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; and 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.

- *<u>Closure Structure</u>*
  - ➢ 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 likelihood of a brittle failure if the systems' capacity is exceeded.
  - ➢ 1-foot raise: This includes replacement of a vehicle closure structure that is 12 feet high by 30 feet wide. It also includes 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 vehicle closure structures/gate structures that are 12 feet high by 30 feet wide, including two 300 LF of 100-foot-wide 6-inch scour pad along both sides of each closure structure. This plan includes raising 12,000 LF of levee 2 feet and adding floodwalls at two pump stations, 500 LF total (7 feet tall) along with reinforcing pump station walls at four existing pump stations.

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

- No fail: Construction of 5,000 LF of 15-foot-wide 6-inch scour pad to provide additional structural integrity to the I-Wall and erosion protection to reduce the likelihood of failure.

Figure 5-2. Optimization Alternatives – Port Arthur and Vicinity CSRM Project Area

- 1-foot raise: Construction of 5,000 LF of 15-foot-wide 6-inch scour pad with a 1-foot levee raise over 3,000 LF to provide additional system capacity, increase structural integrity of the I-wall, and provide erosion protection to reduce the likelihood of system overtopping.
- 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 high and 20 feet wide, 3,000 LF of levee raised 2 feet along with the work specified in the I-wall near Tank Farm (2-foot raise) and 8- to 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 erosion protection to reduce the likelihood of a brittle failure if the systems' capacity is exceeded. Structurally reinforce the I-Wall to protect against wall failure.
  - ➢ 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 likelihood of a brittle failure if the systems' 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 19,400 LF of levee raised 2 feet. There would be construction of a floodwall at one pump station (200 LF at 7 feet tall), replacing an additional 12,000 LF of floodwall (15 feet tall). There would be rebuilding of four existing pump stations at 1,100 cubic feet per second (cfs).

Economic Evaluation

The net benefits of Optimization Alternatives for the Port Arthur and Vicinity CSRM project area are presented in Table 5-7. No environmental impacts were identified for this element and therefore no mitigation costs were included in the cost estimate.

Table 5-7: Net Benefits of Optimization Alternatives for the Port Arthur and Vicinity CSRM Project Area

Alternative Reach	Optimization Alternatives	Net Benefits
8- to 10-foot I-Wall	No Fail	$13,305,000
	1-Foot Raise	$17,292,000
	2-Foot Raise	$17,215,000
Closure Structure	No Fail	$2,622,000
	1-Foot Raise	$2,908,000
	2-Foot Raise	$2,628,000
I-Wall Near Valero	No Fail	$45,153,000
	1-Foot Raise	$50,662,000
	2-Foot Raise	$41,076,000
I-Wall Near Tank Farm	No Fail	$12,758,000
	1-Foot Raise	$20,932,000
	2-Foot Raise	$18,843,000

5.4.2.4 *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 5-3 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 would allow barge traffic to pass during routine operations and will have a pumping capacity of 2,000,000 gallons per min (gpm). The structure length would be approximately 500 feet long with two sector gates totaling approximately 80 feet wide for vessel traffic. Additional tidal circulation would be provided by two sluice gates approximately 15 feet wide each. The final configuration of this structure would match the proposed level of risk reduction for the system.

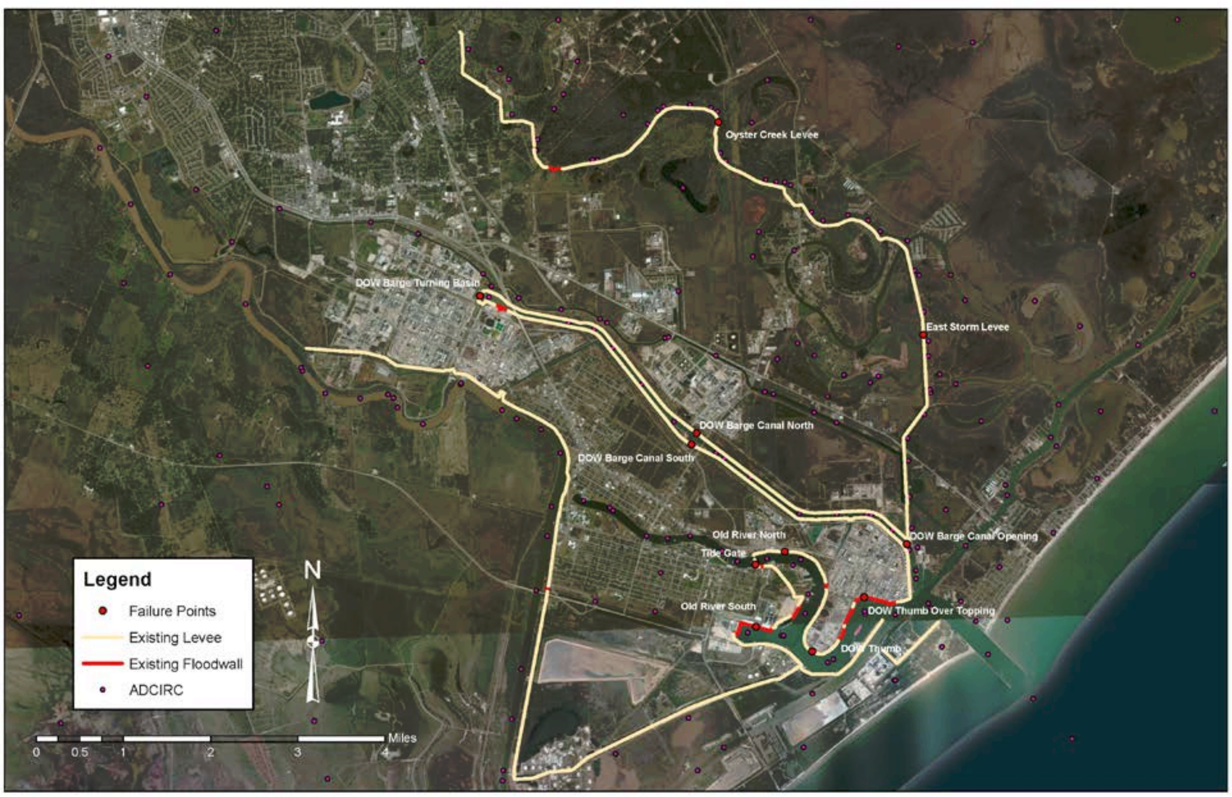

Figure 5-3: Location of Optimization Alternatives in the Freeport CSRM Area

- *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 would be raised 2 feet over 3,500 LF in order to correct the noted height deficiency. The construction procedure would include stripping topsoil, removal of a 12-foot-wide asphalt road, placement of fill, replacement of a 12-foot-wide road and turfing.
- 1-Foot Raise: Construction would include 3,500 LF of 3-foot levee raise and 10,000 LF of 1-foot levee raise for a total distance of 13,500 LF. The construction procedure would 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 would include 3,500 LF of a 4-foot levee raise and 33,000 LF of a 2-foot levee raise, replacing 1,000 feet of floodwall reconstruction at 8 feet high, raising 2,300 LF of Highway 523 at the levee crossing, construction of one pump station with 1,100 cfs capacity, 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, and 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 would include 13,115 LF of levee raised 1 foot with HPTRM
- 2-foot raise: Construction would include 19,115 LF of levee raised 2 feet with HPTRM, 800 LF of new floodwall at one pump station, reinforcing pump station walls and raising 2,500 LF of Highway 332 at the levee crossing.

- *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 material placement areas for the deep draft navigation channel in this low area. Continued use of the material placement areas has increased the elevation of the low area to a point that it is now higher than the South Storm Levee.

- ➢ 1-foot raise: Construction would include earth placement on top of the existing earth embankment for a 1-foot raise.
- ➢ 2-foot raise: 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 would include replacing the drop-in panels and anchor system.
- ➢ No Fail: Reinforcement 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 of the 1-foot raise would require complete reconstruction of 3,000 LF of 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 likelihood 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-foot-tall floodwall would be constructed. In areas that do not have stability issues 6,500 LF of levee would be raised 2 feet, one drainage structure would be replaced, and the saltwater intake at DOW A801 would be replaced.

- *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 would 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 net benefits of Optimization Alternatives for the Freeport and Vicinity CSRM project area are presented in Table 5-8. No environmental impacts were identified for this element and therefore no mitigation costs were included in the cost estimate.

Table 5-8: Net Benefits of Optimization Alternatives for the Freeport and Vicinity CSRM Project Area

Alternative Reach	Optimization Alternatives	Net Benefits
DOW Barge Canal	Levee Rehabilitation; Gate Structure	$113,914,000
Oyster Creek Levee	No Fail	$2,010,000
	1-Foot Raise	$2,314,000
	2-Foot Raise	$490,000
East Storm Levee	No Fail	$796,000
	1-Foot Raise	$835,000
	2-Foot Raise	$120,000
South Storm Levee	1-Foot Raise	**($74,000)**
	2-Foot Raise	**($164,000)**
Freeport Dock Floodwall	Partial Fail	$123,000
	No Fail	$2,093,000
	1-Foot Raise	**($3,944,000)**
Old River Levee at DOW Thumb	No Fail	$969,000
	1-Foot Raise	$1,241,000
	2-Foot Raise	**($2,196,000)**
Tide Gate I-Wall	No Fail	$1,526,000
	1-Foot Raise	$1,721,000
	2-Foot Raise	$549,000

5.4.2.5 Brazoria and Sabine Nonstructural

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 economically viable. Figure 11 of Appendix C shows the potential for buyouts in Orange County. Initially approximately 20 residential structures appeared to be economically viable, but some of the parcels appeared to have no structures located on them. Later inspections 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.

5.4.3 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 were applied to select a TSP. Table 5-10 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 that reasonably maximizes net benefits is the NED plan. Objective 4 is embedded within the NED and RED accounts. Specifically for the 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.

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 were screened from further consideration. The plans that reasonably maximized NED from each project area are highlighted in green in Table 5-10 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- to 10-foot 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 5-9 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 light blue show the Orange-Jefferson CSRM (NED plan) is deficient in height at the 50-year project life. Table 5-10 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 5-9 correspond to locations included in the H&H analysis.

The expectation for each project area would be that all plans would positively impact life-safety risk and reduce the likelihood of secondary impacts on critical infrastructure to meet Objectives 2 and 4. This is shown in Table 5-10 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. As stated in section 5.3.3 this study only focused evaluation on two sub-regions, Sabine and Brazoria for CSRM project implementation. Future studies recommending CSRM projects in the Galveston region, as well as ER opportunities throughout the entire six-county region would be pursued under different study authorizations. Future feasibilities, including Coastal Texas, will leverage studies, data, and models currently under development by others in the Galveston region.

Table 5-9: Average Recommended Relative Sea Level Change (RSLC), Feet NAVD

Location	Without RSLC	Low RSLC	Int.[1] RSLC	High RSLC	Height in Economic analysis[2]	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

[1]Note Int. – Intermediate

[2] Note heights listed are different under the recommended plan, due to final refinements under feasibility design

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Table 5-10: 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			
-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[3]						
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 airport
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						
No Fail	$12,758,000	Screened Out				
1-foot Raise	$20,932,000	$20,932,000				
2-foot Raise	$18,843,000	Screened Out				
Freeport and Vicinity CSRM[3]						
Dow Barge Canal				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
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		Screened Out				
Brazoria Nonstructural Buyout		Screened Out				

[3] 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

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5.4.4 Identifying a Tentatively Selective Plan (TSP)

The decision criteria for selecting a TSP 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 TSP is the NED plan for each project area, as it reasonably maximizes net national economic development consistent with the Federal objective of protecting the Nation's environment. The TSP presented in the DIFR-EIS included 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- to 10-foot 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)

5.4.5 Selection of the TSP for the DIFR-EIS

USACE guidance (ER 1105-2-100, Section 2-3(f)) requires selection of a single alternative plan or a decision to take no action. Since no ER alternatives were evaluated, the alternative CSRM plan that most reasonably maximizes net economic benefits consistent with protecting the Nation's environment, the NED plan, must be selected. The TSP was the environmentally preferable alternative. Because it is generally the lowest height of all action alternatives that were evaluated, it would result in the narrowest footprint and the fewest environmental impacts, while reasonably maximizing coastal storm risk reduction to the affected communities. The No Action Alternative would provide no coastal storm risk reduction to the vulnerable populations and infrastructure of the study area.

The DIFR-EIS underwent public, policy, Agency Technical Review (ATR), and Independent External Peer Review (IEPR), and the study team has addressed all comments from these reviews. The decision to select a plan other than the TSP was 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 discussions identified other compelling factors that might support a plan larger than the TSP for the Orange-Jefferson CSRM. This information was taken into consideration by the Senior Leader Panel Agency Decision Milestone (ADM) held after the release of the DIFR-EIS. The ADM was the decision point where a Senior Leader Panel confirmed the TSP and made a 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.

Table 5-11 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 1 foot among 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 does not make sense to recommend a plan that costs that much more for such minimal benefits.

Table 5-11: 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

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

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 5-4 and 5-5 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 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 percent 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 cleanup would be avoided. Most importantly, increased risk reduction would also avoid disruption of 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 percent 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.

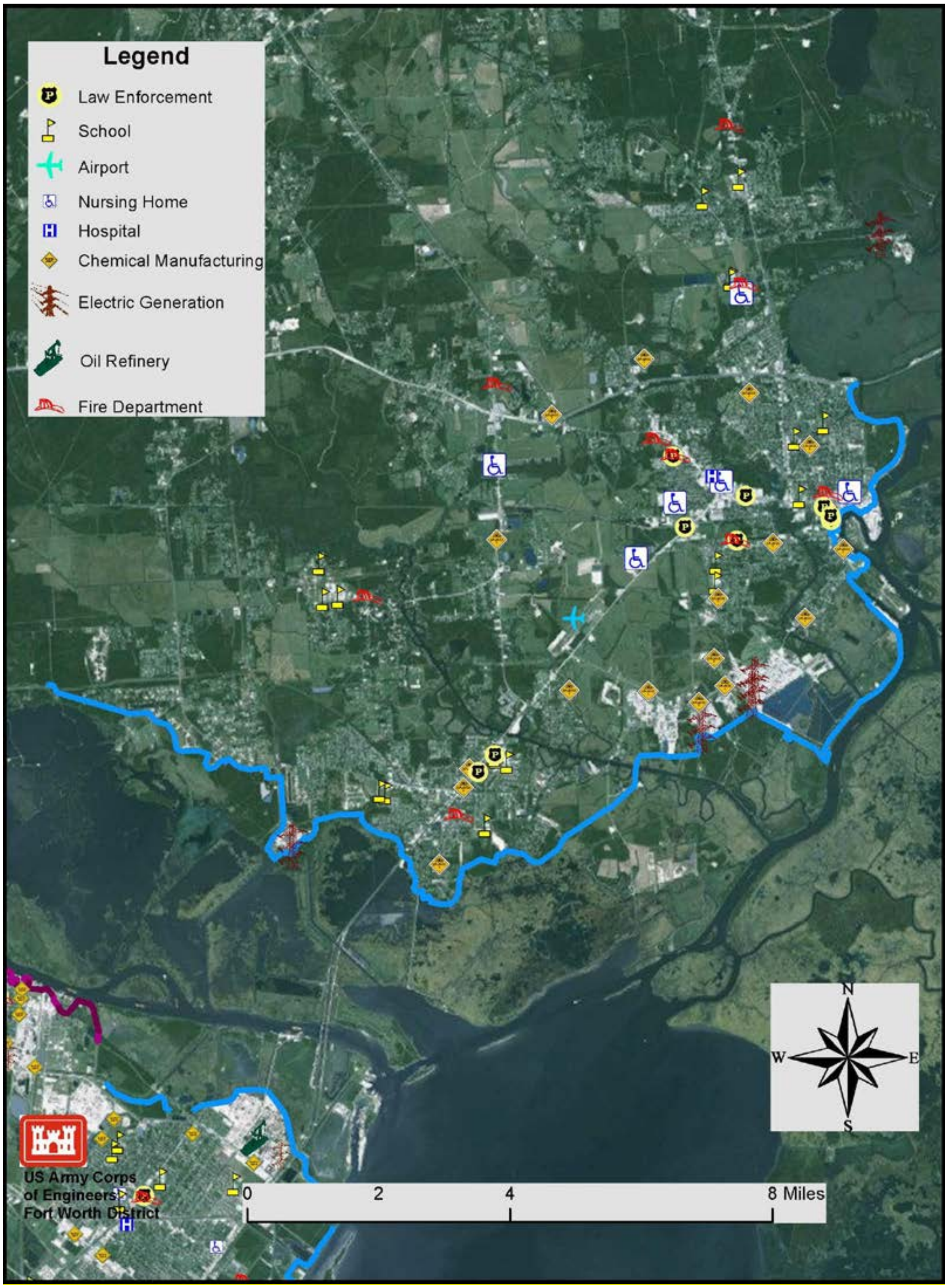

Figure 5-4: Orange County Critical Infrastructure

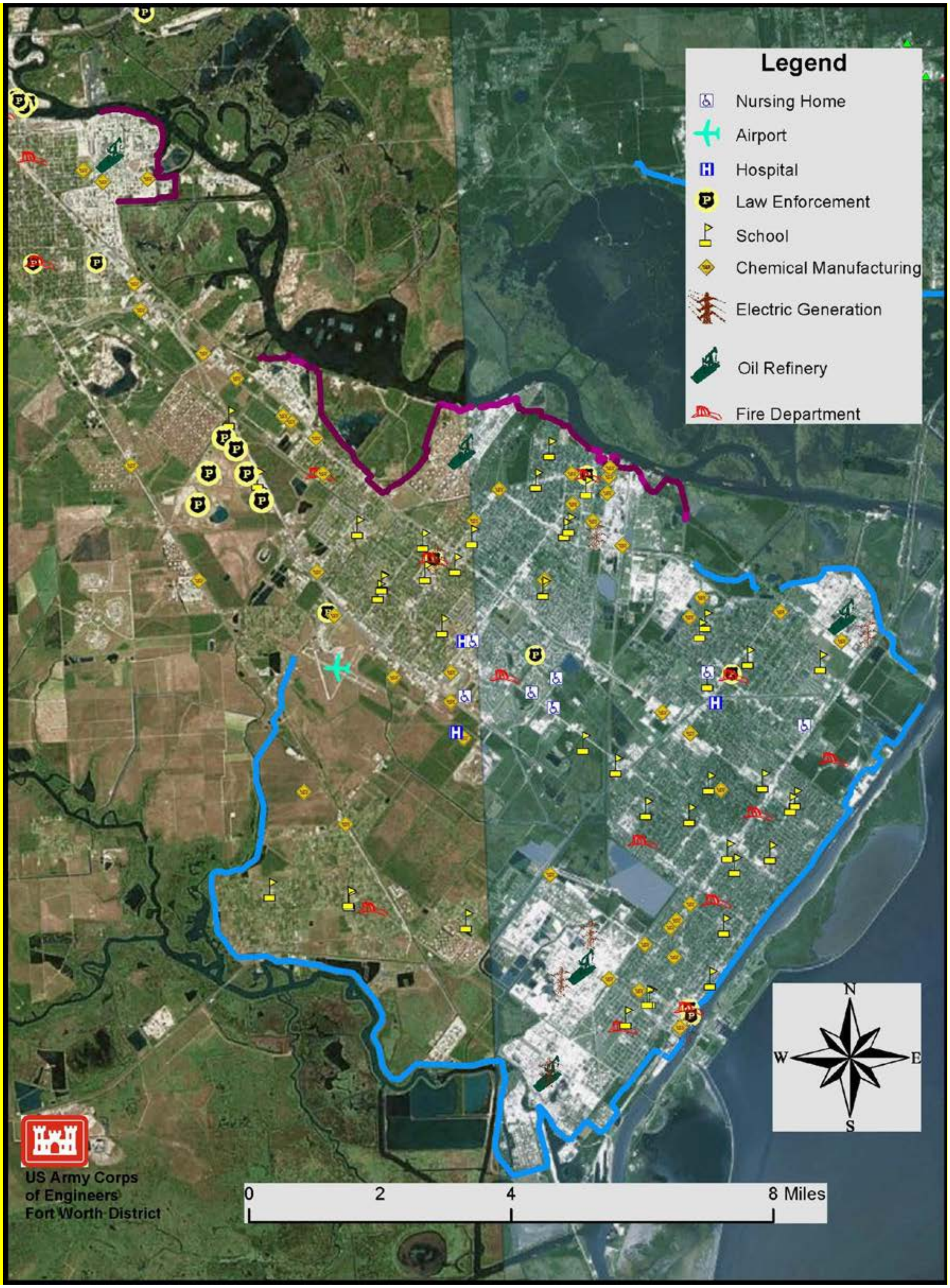

Figure 5-5: Jefferson County Critical Infrastructure

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 5-12 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 USACE 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. Additional discussion of design criteria for RSLC is provided in Section 6.2.2.

Table 5-12: 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

5.4.6 Comparison of Environmental Impacts for Final Array of Alternatives

5.4.6.1 WVA Modeling of Alternatives

WVA modeling was utilized to quantify impacts of the Final Array of CSRM Alternatives on marsh and forested wetlands. This modeling was conducted only for the Orange-Jefferson CSRM project area, as no wetland impacts were identified in the Port Arthur and Freeport and Vicinities CSRM project areas. The WVA Marsh Model was approved for use by HQUSACE memo dated May 6, 2014; WVA Swamp and Bottomland Hardwood models are certified. The approval memo, a description of the WVA model and a detailed description of the WVA application to this study, are presented in Appendix O. The WVA is a suite of habitat-based models originally developed by the USFWS that utilizes a community approach to quantify changes to fish and wildlife habitat quality and quantity, measured in AAHUs.

Direct impacts as quantified by the model reflect the assumed loss of all marsh and forested wetlands within the construction right-of-way of the Orange 1 ,2, and 3 Alternative Reaches, Jefferson Main, and Beaumont Alternative Reaches A, B, and C in the first year of construction. Staging areas would be situated to avoid impacts on wetlands or other significant environmental resources; numerous suitable areas are available. In previously disturbed areas, impacts were assessed for a conservatively-wide alignment right-of-way, which would accommodate construction of any of the four height alternatives and adjustments to account for RSLC. Construction rights-of-way for floodwalls and related direct impacts would be roughly the same for all height alternatives. Construction rights-of-ways for the 11, 12, and 13 feet levee height alternatives for all of the reaches would be proportionately lower than the 14 feet Alternative, as levee footprints would be slightly narrower. Differences would be small when compared to the overall width of the right-of-way assessed for impacts. The width of the construction right-of-way varies based on existing ground elevation and the type of structure proposed. In general, impacts were captured for earthen levee right-of-way segments from 200 to 325 feet in width; impacts for floodwall segments were captured for right-of-way segments ranging from 150 to 200 feet in width.

Given the small differences in right-of-way widths among the height alternatives, as well as uncertainties inherent in the preliminary engineering alignment and the future rate of RSLC, direct impacts were modeled using only the oversized width and applied to all RSLC scenarios. RSLC was considered in determining indirect impact areas for the 50-year period of analysis.

The general area of the levee alignment was carefully evaluated to identify areas into which wetlands would have migrated under the three RSLC scenarios in the FWOP condition. The NOAA Sea-Level Rise Viewer (NOAA 2015) was used to identify new tidally-influenced areas, and the NOAA marsh impacts/migration viewer was used to map changes in marsh type and extent for a 50-year sea-level rise approximating the low, intermediate, and high rates in this area.

The NOAA method for mapping marsh migration due to RSLC assumes that specific wetland types exist within an established tidal elevation range, based on an accepted understanding of what types of vegetation can exist given varying frequency and time of inundation, as well as salinity impacts from such inundation (NOAA 2012). The viewer maps changes associated with sea-level rise in 1-foot increments. The potential changes associated with projected 50-year intermediate and high RSLC in the Sabine region were evaluated using the 2- and 4-foot Sea Level Rise and Marsh Impacts views.

No FWP impacts were identified for most of the areas identified as vulnerable to RSLC in the FWOP condition. Increasing sea levels would be expected to increase the extent of tidal flow into the smaller bayous and streams, which cut from the upland to the floodplain. The higher water levels would flood low-lying bayou and stream bottoms, creating new wetlands in several areas shown in Appendix O. In general, however, relatively high valley walls along the upland terraces of the Sabine and Neches Rivers would prevent large-scale overland flooding over the period of analysis. Indirect impacts associated with installation of the levee system would be minimized by maintaining flows in tidal bayous and streams equivalent to the FWOP condition. Culverts would be sized and modified as needed to provide for increased tidal flows expected with RSLC. With tidal access maintained at FWOP flows, RSLC-related landscape and wetland changes to areas both inside and outside of the levee system would occur with the project in place, as they would have occurred in the FWOP condition.

Indirect impacts identified for the Orange 1 and 3 Reach Alternatives are related to two primary effects – those associated with fisheries access impacts on the extensive marshes in the lower Adams Bayou and Cow Bayou floodplains (a functional impact), and indirect impacts related to changes in hydrologic connectivity caused by the new levee system and the Cow Bayou structure, which would result in the loss of wetland acreage. Indirect impacts that would result in the loss of wetland acreage in Orange 1 and 3 were modeled separately for the three RSLC scenarios. Indirect fisheries impacts on marsh function associated with the surge gate impacts on fisheries access were modeled for the low RSLC scenario, and these impacts were applied to the intermediate and high scenarios for the Orange 3 reach only. Higher tidal inundation would improve fisheries access even with the structures in place; the low RSLC condition thus provides a conservatively high impact assessment.

5.4.6.2 Orange-Jefferson CSRM Project Area

The three reaches in Orange County (Orange 1, 2, and 3) and the four reaches in Jefferson County (Jefferson Main, Beaumont A, B, and C) were each evaluated with four separate height alternatives – 11, 12, 13, and 14 feet Alternatives. Direct and indirect impacts on marsh and forested wetlands, as quantified using the WVA model, for all of the Jefferson Main and Beaumont Alternatives are presented in Table 5-13, and impacts on Orange 1, 2, and 3 Alternatives are presented in Table 5-14. No impacts were identified for Beaumont B, and no indirect impacts were identified for the Jefferson Main or Beaumont A and C; impacts for each reach are limited to direct impacts which apply to all levee height alternatives and all RSLC scenarios. The impacts are minimal, reflecting the developed and industrialized nature of these project areas.

Table 5-13: Total Wetland Impacts of Jefferson Main and Beaumont Alternatives (All RSLC Scenarios)

Wetland Type	Jefferson Main		Beaumont A		Beaumont C	
	All Height Alternatives and All RSLC Scenarios					
	Acres	**AAHU**	**Acres**	**AAHU**	**Acres**	**AAHU**
Swamp	0.9	-0.4				
Bottomland Hardwood	13.9	-6.4	0.3	-0.2		
Forested Wetland Subtotal	14.8	-6.8	0.3	-0.2		
Fresh Marsh	13.4	-6.1	2.6	-1.6		
Intermediate Marsh	0.4	-0.2	0.6	-0.3	1.0	-0.6
Brackish Marsh	9.9	-4.9				
Marsh Subtotal	23.7	-11.2	3.2	-1.9	1.0	-0.6
Total Impacts	**38.5**	**-18.0**	**3.5**	**-2.1**	**1.0**	**-0.6**

Impacts for Orange 3 are much higher than for Orange 1 and 2 (Table 5-14). Orange 3 is about twice as long as Orange 1 and 2 combined, and this size difference is reflected in the higher direct impacts. In addition, direct and indirect wetland impacts related to construction of the Adams and Cow tidal surge gates are associated with Orange 3; surge gates are not required for Orange 1 and 2.

Orange 1 impacts (direct and indirect) would be the same for all RSLC scenarios (63.8 acres; -29.9 AAHUs). Indirect impacts in this reach are associated with wetland loss caused by the permanent alteration of tidal access, and thus the effects would be the same across all RSLR scenarios. Orange 2 impacts would also be the same for all RSLC scenarios (24.7 acres; -13.9 AAHUs); no indirect impacts were identified in this reach. Orange 3 impacts increase slightly with each higher RSLC scenario because wetland losses due to hydrologic modifications related to the location of the levee alignment increase with RSLC. For example, it was assumed that some swamp would convert to brackish marsh under intermediate and high RSLR because of changes to the salinity regime and higher water elevations. Likewise, some marsh areas would switch from intermediate to brackish or brackish to saline due to the changing salinity regime. At other locations, former uplands were assumed to convert to marsh as tides pushed into new areas due to intermediate and high RSLR.

Table 5-14: Direct and Indirect Wetland Impacts of Orange 1, 2, and 3 Alternatives (All RSLC Scenarios)

DIRECT IMPACTS																		
	Orange 1 (All Height Alternatives)						Orange 2 (All Height Alternatives)						Orange 3 (All Height Alternatives)					
	Low RSLR		Intmd RSLR		High RSLR		Low RSLR		Intmd RSLR		High RSLR		Low RSLR		Intmd RSLR		High RSLR	
Wetland Type	**Acres**	**AAHU**	**Acres**	**AAHU**	**Acres**	**AAHU**	**Acres**	**AAHU**	**Acres**	**AAHU**	**Acres**	**AAHU**	**Acres**	**AAHU**	**Acres**	**AAHU**	**Acres**	**AAHU**
Forested Wetlands																		
Swamp	18.9	-7.7	18.9	-7.7	18.9	-7.7	0.7	-0.4	0.7	-0.4	0.7	-0.4	18.0	-10.6	18.0	-10.6	18.0	-10.6
Bottomland Hardwood	13.4	-5.7	13.4	-5.7	13.4	-5.7	18.0	-10.1	18.0	-10.1	18.0	-10.1	94.1	-57.3	94.1	-57.3	94.1	-57.3
Subtotal	32.3	-13.4	32.3	-13.4	32.3	-13.4	18.7	-10.5	18.7	-10.5	18.7	-10.5	112.1	-67.9	112.1	-67.9	112.1	-67.9
Coastal Marsh																		
Fresh Marsh	25.0	-14.7	25.0	-14.7	25.0	-14.7	6.0	-3.4	6.0	-3.4	6.0	-3.4	34.4	-18.8	34.4	-18.8	34.4	-18.8
Intermediate Marsh													10.9	-6.2	10.9	-6.2	10.9	-6.2
Brackish Marsh													101.1	-48.8	101.1	-48.8	101.1	-48.8
Subtotal	25.0	-14.7	25.0	-14.7	25.0	-14.7	6.0	-3.4	6.0	-3.4	6.0	-3.4	146.4	-73.8	146.4	-73.8	146.4	-73.8
Total Direct Impacts*	**57.3**	**-28.1**	**57.3**	**-28.1**	**57.3**	**-28.1**	**24.7**	**-13.9**	**24.7**	**-13.9**	**24.7**	**-13.9**	**258.5**	**-141.7**	**258.5**	**-141.7**	**258.5**	**-141.7**
INDIRECT IMPACTS																		
Forested Wetlands																		
Swamp	4.4	-0.8	4.4	-0.8	4.4	-0.8							1.9	-0.8	0	-0.1	0.0	-0.1
Bottomland Hardwood	0.7	-0.3	0.7	-0.3	0.7	-0.3							12.7	-5.1	12.7	-5.1	12.7	-5.1
Subtotal	5.1	-1.1	5.1	-1.1	5.1	-1.1							14.6	-5.9	12.7	-5.2	12.7	-5.2
Coastal Marsh																		
Fresh Marsh	1.4	-0.7	1.4	-0.7	1.4	-0.7							785.2	-18.8	785.2	-18.8	785.2	-18.8
Intermediate Marsh													342.1	-14.2	322.5	-12.6	322.5	-13.8
Brackish Marsh													1075	-50.4	1130.4	-63.4	1092.6	-60.7
Saline Marsh																	49.7	-9.7
Subtotal	1.4	-0.7	1.4	-0.7	1.4	-0.7							2202.2	-83.4	2238.1	-94.8	2250.0	-103.0
Total Indirect Impacts*	**6.5**	**-1.8**	**6.5**	**-1.8**	**6.5**	**-1.8**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**2216.8**	**-89.3**	**2250.8**	**-100.0**	**2262.7**	**-108.2**
TOTAL IMPACTS BY REACH																		
Total Forested Wetlands	37.4	-14.5	37.4	-14.5	37.4	-14.5	18.7	-10.5	18.7	-10.5	18.7	-10.5	126.7	-73.8	124.8	-73.1	124.8	-73.1
Total Coastal Marsh	26.4	-15.4	26.4	-15.4	26.4	-15.4	6.0	-3.4	6.0	-3.4	6.0	-3.4	2348.6	-157.2	2384.5	-168.6	2396.4	-176.8
Total Impacts by Reach*	**63.8**	**-29.9**	**63.8**	**-29.9**	**63.8**	**-29.9**	**24.7**	**-13.9**	**24.7**	**-13.9**	**24.7**	**-13.9**	**2475.3**	**-231.0**	**2509.3**	**-241.7**	**2521.2**	**-249.9**

* Totals may not add exactly due to rounding.

The great majority of Orange 3 acreage impacts are due to indirect functional impacts related to reductions in fisheries access in the Adams and Cow Bayou floodplains. Under low RSLC, a total of 2,475.3 acres would be impacted, resulting in the loss of -236.0 AAHUs; under intermediate RSLC, 2,509.3 acres would be impacted, resulting in the loss of -241.7 AAHUs; and under high RSLC, 2,521.2 acres would be impacted, resulting in the loss of -249.9 AAHUs. Of these totals, functional impacts would affect roughly 2,137 acres and result in the loss of about -50.5 AAHUs for all RSLC scenarios.

The Orange-Jefferson CSRM Alternatives would result in the loss of EFH. Impacts on estuarine emergent marsh by Orange 1, 2, and 3, Jefferson Main, and Beaumont A and C are shown in Tables 5-2 and 5-3 above. Orange 1, 2, and 3 direct impacts would result in the loss of about 25.0, 6.0, and 146.4 acres of estuarine emergent marsh, respectively. Jefferson Main and Beaumont A and C would impact 23.7, 3.2, and 1.0 acre, respectively. Beaumont B would result in no EFH impacts. Orange 3 would also result in the loss of approximately 11 acres of estuarine soft bottom EFH.

This is the area estimated for the footings of the Adams and Cow Bayou surge gate structures. The structures themselves would provide artificial hard bottom habitat in the same area, increasing the diversity of EFH bottom types in the area. The net long-term loss of EFH bottom habitat from the Cow and Adams gate structures would therefore be negligible. Functional impacts on about 2,137 acres of estuarine emergent marsh along Adams and Cow Bayous in Orange 3 would result in the loss of about 50.5 AAHUs.

The potential HTRW impacts for all alternatives in the Orange-Jefferson CSRM project area have been determined to be low, as no unresolved current or recent hazardous materials releases were identified within 0.25 mile of the alternative alignments by the HTRW Assessment presented in Appendix N. Numerous facilities that produce or store hazardous materials were identified adjacent to Orange 3, Jefferson Main, and Beaumont A, B and C; none were identified adjacent to the Orange 1 and 2 reaches. Therefore, risks that currently unidentified HTRW sites may be impacted are higher for all height alternatives of the Orange 3, Jefferson Main, and Beaumont reaches than they are for Orange 1 and 2.

No other significant environmental impacts have been identified for the any of the Orange-Jefferson CSRM project area alternatives. Air emissions modeling (presented in Appendix I) was developed for a conservatively high estimate of construction equipment needs and durations. The modeling determined that total emissions for construction of all reaches would be below *de minimis* thresholds; and thus, construction would have no significant impacts on ambient air quality in the area. Emissions would be proportionately higher for each height alternative, assuming that the time needed to construct levee segments would be proportionately longer as the height increases. Impacts on prime farmlands were roughly similar across all reaches and would be differ proportionately by the height of each alternative. No ESA impacts have been identified for any of the project area reaches. Water and sediment quality impacts would be similar for all reaches/height alternatives with the exception of Orange 3. Fill material needed to construct earthen levees would be obtained commercially for all reaches and tested as needed to ensure suitability for use. Temporary sediment load and turbidity impacts would be minimized using best management practices (BMPs) as the levees are constructed. Orange 3 would have additional temporary turbidity and bottom sediment impacts during construction of the Adams and Cow Bayou surge gates. The potential for temporary noise impacts on sensitive receptors is greatest in Orange 3 since it passes through several communities; Orange 1 would create temporary noise impacts for the Rose City area; few sensitive receptors are located adjacent to the Orange 2 right-of-way. The potential for historic properties impacts on historic structures or cemeteries is greatest for Orange 3, since it passes through residential and business centers in the city of Orange and Bridge City; potential for impacts on prehistoric archeological sites may be higher in Orange 1 and 2, since much of those alignments remain undeveloped. Potential for historic properties impacts in all of the Jefferson County reaches is low because of the extensive industrial and residential development in the vicinity of those alignments.

5.4.6.3 Port Arthur and Vicinity CSRM Project Area

No direct or indirect impacts on wetlands would be expected with construction of any of the alternatives, as construction activities would be generally be undertaken within the existing Port Arthur HFPP right-of-way. Additional temporary and permanent rights-of-way would be needed for construction of modifications in the Taylor Bayou Turning Basin area; all of this additional area is previously disturbed by industrial development. Staging areas would be situated to avoid impacts on wetlands or other significant environmental resources; numerous suitable areas are available. The TSP 1-foot raise alternative for the four alternatives would require the raising of about 4.5 miles of levee, construction of about 2.8 miles of scour pads, the replacement of one vehicle closure structure and the reinforcement of the I-Walls near Valero and near the Tank Farm. Raising levees and floodwalls by 2 feet over all of the four alternative project areas, rather than 1 foot as described for the TSP, would require the raising of approximately 18 miles of levee, construction of about 1.5 miles of scour pads, replacement of about 3.8 miles of I-Walls, construction of about 0.25 mile of new floodwalls at pump stations, replacement of drainage structures, reconstruction of about 13 vehicle closure structures, elevation of about 1.5 miles of highways, and the rebuilding of four pump stations at higher elevations. While this is significantly more construction than that required for the 1-foot raise, most construction activity would be confined to the existing right-of-way; areas where additional right-of-way would be needed are previously disturbed. Additional staging areas would be situated to avoid environmental impacts.

No other significant environmental impacts have been identified for the any of the Port Arthur and Vicinity CSRM project area alternatives. Air emissions modeling (presented in Appendix I) was developed for a conservatively high estimate of construction equipment needs and durations, including the 2-foot raise described above. The modeling determined that total emissions for construction of all reaches would be below *de minimis* thresholds; and thus, construction would have no significant impacts on ambient air quality in the area. Emissions would be proportionately higher for each height alternative, assuming that the time needed to construct levee segments would be proportionately longer as the height increases. No ESA or prime farmland impacts were identified. Water and sediment quality impacts would be similar for all reaches/height alternatives. Fill material needed to construct earthen levees would be obtained commercially for all reaches and tested as needed to ensure suitability for use. Temporary sediment load and turbidity impacts would be minimized using BMPs as the levees are constructed. The potential for historic properties impacts on historic structures or cemeteries is greatest for the I-Wall Raise near Tank Farm (all height alternatives) because it passes adjacent to 43 residential structures in Port Arthur. There is a potential for temporary noise impacts on residents in the homes near the same reach.

Potential historic properties and temporary noise impacts would be greater for the 2-foot raise because much longer reaches of the levee/floodwall system, passing adjacent to about 180 residential structures, would be reconstructed.

The greatest potential impact is associated with the HTRW sites located in the vicinity of the I-Wall Raise Near Tank Farm, I-Wall Raise Near Valero, and 8-10 ft I-Wall Raise Alternatives. While no unresolved current or recent hazardous materials releases were identified within 0.25 mile of these reaches alignments (see Appendix N), industrial facilities that produce or store hazardous materials were identified adjacent to these reaches. Therefore, risks that currently unidentified HTRW sites may be impacted are higher for all height alternatives of the three reaches listed above.

5.4.6.4 Freeport and Vicinity CSRM Project Area

The TSP 1-foot raise for all of the alternative project areas would require the raising of about 6 miles of levee, reinforcement of about 2.75 miles of existing levee and 0.6 mile of floodwall, replacement of 700 LF of I-Wall, construction of about 0.75 mile of scour pads, and construction of the new surge gate on the DOW barge canal. A 2-foot raise for all of the alternative project areas would require the raising of about 11.2 miles of levee, reinforcement of about 0.6 mile of floodwall, replacement of 1.5 miles of floodwall, construction of 0.2 mile of new floodwalls, construction of the new surge gate on the DOW barge canal, reconstruction of the Tide Gate, construction of a new pump station, and the replacement of numerous gravity drains. No direct or indirect impacts on wetlands would be expected with construction of any of the alternatives, as construction activities would be generally be undertaken within the existing Freeport HFPP right-of-way. However, some additional temporary and permanent rights-of-way would be needed for construction of all alternative heights in the Oyster Creek Levee Raise, Tide Gate I-Wall Raise, Old River North at DOW Thumb Levee Raise, and Freeport Dock Floodwall Raise reaches. All but one of these reaches are previously disturbed by industrial development. The approximately 3-mile-long Oyster Creek Levee Raise may require a minor amount of additional right-of-way, estimated at this time to be about 10 feet wide. The area that would be disturbed is upland scrub-shrub and forest; no wetlands would be impacted. The DOW Barge Canal Gate Structure would be constructed within the existing project right-of-way and in areas already impacted by previous construction. No significant water quality or benthic impacts are anticipated with installation of a gate in this artificial canal. Staging areas would be situated to avoid impacts on wetlands or other significant environmental resources; numerous suitable areas are available.

No other significant environmental impacts have been identified for the any of the Freeport and Vicinity CSRM alternatives. Air emissions modeling (presented in Appendix I) was developed for a conservatively high estimate of construction equipment needs and durations, including the 2-

foot raise described above. The modeling determined that total emissions for construction of all reaches would be below *de minimis* thresholds; and thus, construction would have no significant impacts on ambient air quality in the area. A consistency determination would not be required. Emissions would be proportionately higher for each height alternative, assuming that the time needed to construct levee segments would be proportionately longer as the height increases. No ESA or prime farmland impacts were identified. Water and sediment quality impacts would be similar for all reaches/height alternatives. Fill material needed to construct earthen levees would be obtained commercially for all reaches and tested as needed to ensure suitability for use. Temporary sediment load and turbidity impacts would be minimized using BMPs as the levees are constructed. There is little potential for historic properties impacts for most of the reaches; however, three archeological sites near the Oyster Creek Levee Raise would need to be avoided by project construction. Construction of any of the height alternatives of the Tide Gate I-Wall Raise and the Oyster Creek Levee Raise would result in temporary noise impacts on approximately five residences each; the East Storm Levee Raise would result in temporary noise impacts on approximately 13 residences. The remainder of the reaches pass adjacent to industrialized areas where historic property and noise impacts are not likely.

The greatest potential impact is associated with the HTRW sites located in the vicinity of the Old River North at DOW Thumb, the Freeport Dock Floodwall Raise, and the Tide Gate I-Wall Raise Alternatives. While no unresolved current or recent hazardous materials releases were identified within 0.25 mile of these reaches alignments (see Appendix N), industrial facilities that produce or store hazardous materials were identified adjacent to these reaches. Therefore, risks that currently unidentified HTRW sites may be impacted are higher for all height alternatives of the three reaches listed above.

5.4.6.5 Environmentally Preferable Alternatives

The TSP for the Orange-Jefferson, Port Arthur and Vicinity, and Freeport and Vicinity CSRM Plans is the environmentally preferable alternative. Because it is generally the lowest height of all action alternatives that were evaluated, it would result in the narrowest footprint and the fewest environmental impacts, while reasonably maximizing coastal storm risk reduction to the affected communities. The No Action Alternative would provide no coastal storm risk reduction to the vulnerable populations and infrastructure of the study area.

5.4.6.6 Comparison of Socioeconomic Impacts of Final Array Alternatives

The Orange-Jefferson CSRM would impact roughly 31 acres of land currently classified as residential and 36 acres of commercial and industrial land in Orange County. In Jefferson County, about 3 acres of residentially zoned land would be impacted, but approximately 100 acres of commercial and industrial land would be impacted, as well as 63 acres of vacant land. Up to approximately 100 structures in Orange and Jefferson Counties, including private residences, could be impacted by the construction of the Orange-Jefferson CSRM Plan. Efforts will be made during final feasibility planning to reduce impacts on existing structures. The proposed Orange-Jefferson CSRM would provide risk reduction to a number of residential and commercial properties in the two counties. Improvements to the Freeport CSRM would further protect a large portion of Port Freeport where, as noted, a number of petrochemical facilities exist, as well as the importation of commodities such as crude, paper goods, and liquid natural gas. Freeport is also the location of a Strategic Petroleum Reserve site. Enhancements at the Port Arthur and Vicinity CSRM would provide additional risk reduction to key refineries in the area, including faculties operated by Valero, Premcor, Total, and Motiva Enterprises. The proposed TSP would also have beneficial impacts on a diverse population in the three counties. Jefferson, the more racially diverse of the three counties, has a population that is over 50 percent non-white according to the most recent Census Bureau data. Brazoria also has a substantial minority population, while Orange County is less diverse.

5.5 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 5.4.5., 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. At the time of the DIFR-EIS, the TSP selection followed ER-1105-2-100 which states that "Where two cost-effective plans produce no significantly different levels of net benefits, the less costly plan is to be the NED plan, even though the level of outputs may be less" (Appendix G, pp. G-7 to G-8). Based on this guidance, the 11-foot raise at Orange 3 was included in the TSP final recommendations under the DIFR-EIS. At the Agency Decision Milestone (ADM) the USACE reviewed additional considerations, such as qualitative risk assessment described in section 5.4.5 when making its final recommendations. Table 5-15 presents an overview of the TSP and changes from the DIFR-EIS with considerations included. 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. Changes to the TSP subsequent to public review of the draft report were not significant enough to require a second

NEPA review. The sections below explain the changes that have occurred since the release of the DIFR-EIS.

Table 5-15: 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.

5.5.1 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 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. 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.

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.

5.5.2 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 questions 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.

5.5.2.1 Revaluation of Orange 3 vs Gate

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 5-16, limited its viability.

Table 5-16: 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 Bayous, 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. 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.

5.5.2.2 Reevaluation of Orange 3 vs Ring Levees or Nonstructural Measures

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 the viability of removing these features was conducted. 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 and would have to be relocated out of the floodplain if a relocation plan was selected. 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. Also there are limited opportunities for mixed nonstructural and structural plans, such as raising structures and providing ring levees, due to the fact that there are limited damages to the residential structures associated with the Orange 3 project area. Only 15% of the total without equivalent annual damages are to residential structures. 65% of the damages in Orange 3 are to the industrial damage category, which are not conducive nonstructural measures. In addition there were also OSE concerns with leaving local communities exposed while trying to only address industrial damages. Developing risk reduction systems (i.e. levees and floodwalls) for only the industrial areas could potentially induce stages in the local communities. Even if nonstructural improvements were included (i.e. Flood proofing and Raising), the area would still face detrimental flooding depths, limiting their ability to recover post storm events.

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 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 5-17 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 5-17, would have limited this alternatives viability.

Table 5-17 Evaluation of Orange Ring Levees

<table>
<tr><th>Review Parameter</th><th colspan="3">Options Reviewed</th><th>vs</th><th>Recommendation: Orange 3</th><th>Comments</th></tr>
<tr><td></td><td colspan="3">System of Ring Levees</td><td></td><td></td><td></td></tr>
<tr><td rowspan="4">Cost</td><td>Ring 1 (Bridge City)</td><td>14.58 miles</td><td rowspan="3">Total of 55.6 Miles</td><td rowspan="4"></td><td rowspan="3">Total of 27 miles</td><td rowspan="3">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</td></tr>
<tr><td>Ring 2 (Industrial Area)</td><td>16.32 miles</td></tr>
<tr><td>Ring 3 (City of Orange)</td><td>24.7 miles</td></tr>
<tr><td colspan="3">12 Additional New Significant Roadway/Railroad Crossing</td><td>32 Closure Gates (Road/Railroad Crossings)</td><td>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.</td></tr>
<tr><td rowspan="3">Environmental</td><td>Ring 1 (Bridge City)</td><td>~ 3 miles of habitat along Cow Bayou</td><td rowspan="3">~ 6.5 miles of habitat</td><td rowspan="3"></td><td rowspan="3">Currently impacts are to less than 2 miles when crossing Cow and Adams Bayou.</td><td rowspan="3">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.</td></tr>
<tr><td>Ring 2 (Industrial Area)</td><td>~1 mile of habitat along Cow Bayou ~1.5 miles of habitat along Adams Bayou</td></tr>
<tr><td>Ring 3 (City of Orange)</td><td>~.1 miles of habitat along Adams Bayou</td></tr>
<tr><td rowspan="2">Life Safety Risk</td><td rowspan="2">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.</td><td colspan="2" rowspan="2">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.</td><td rowspan="2"></td><td>Under exceedance events the surge overtopping the system would be allowed to expand over the flat coastal flood plain.</td><td rowspan="2">Smaller ring levees would go against a key Constraint: <u>Structural plans do not increase life-safety risk.</u></td></tr>
<tr><td>Under the current plan there are limited structures outside of the proposed levee system, reducing the risk of induced stages and life safety risk.</td></tr>
</table>

All of these features would have doubled the size of the system that would have to be operated under storm event (Figure 5-6), making it an unreasonable alternative when compared to the Recommended Plan.

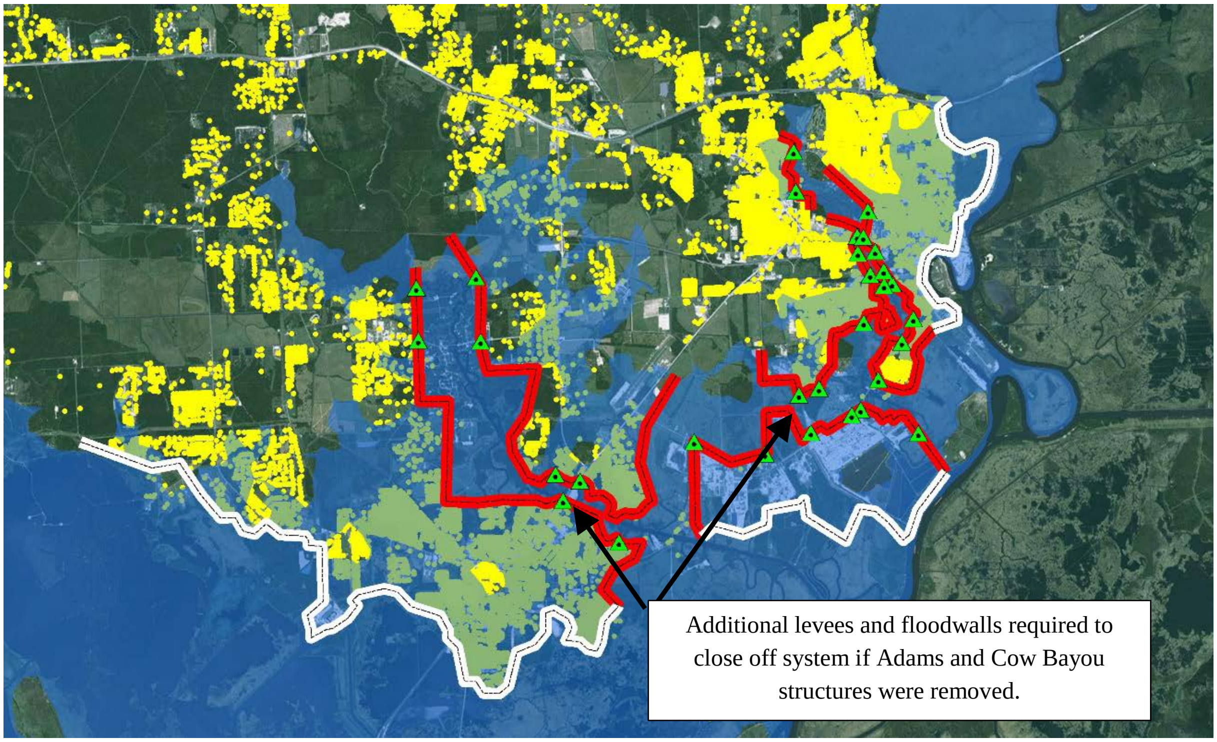

Figure 5-6: Ring Levee Review

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

Based on the information presented in Section 5.5.2, 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.

6 RECOMMENDED PLAN

6.1 PLAN COMPONENTS

As discussed in Section 5, after the TSP was verified, the team developed feasibility-level designs for the Recommended Plan. Investigations included detailed cost estimates, benefits, impacts, and implementation requirements. Below is a summary project description of the Recommended Plan. The TSP phase had broken out certain sections of the Port Arthur and Freeport HFPP as requiring rehabilitation per failure modes from the SQRA. After the TSP, the team determined that this method of analyzing the levee system was not accounting for the levee functioning as a system. Therefore a system wide approach method was used in determining the Recommended Plan, by including all areas of the levee system in the analysis. This changed the naming configuration of the alternatives from specific areas of the levee system (i.e. Old River at Dow Thumb, Freeport Dock, I-Wall Raise Near Valero, I-Wall Raise Near Tank Farm, etc.) to a system wide approach according to levee height (NF, NF + 1, NF + 2) The components of the Recommended Plan are illustrated in Figures 6-1 through 6-3. Section 6.1.1 describes the Recommended Plan in detail; additional detail of the Recommended Plan description is provided in the Engineering Appendix. An economic summary of the Recommended Plan is provided in Tables 17, 18, and 19 of Appendix C, Economics.

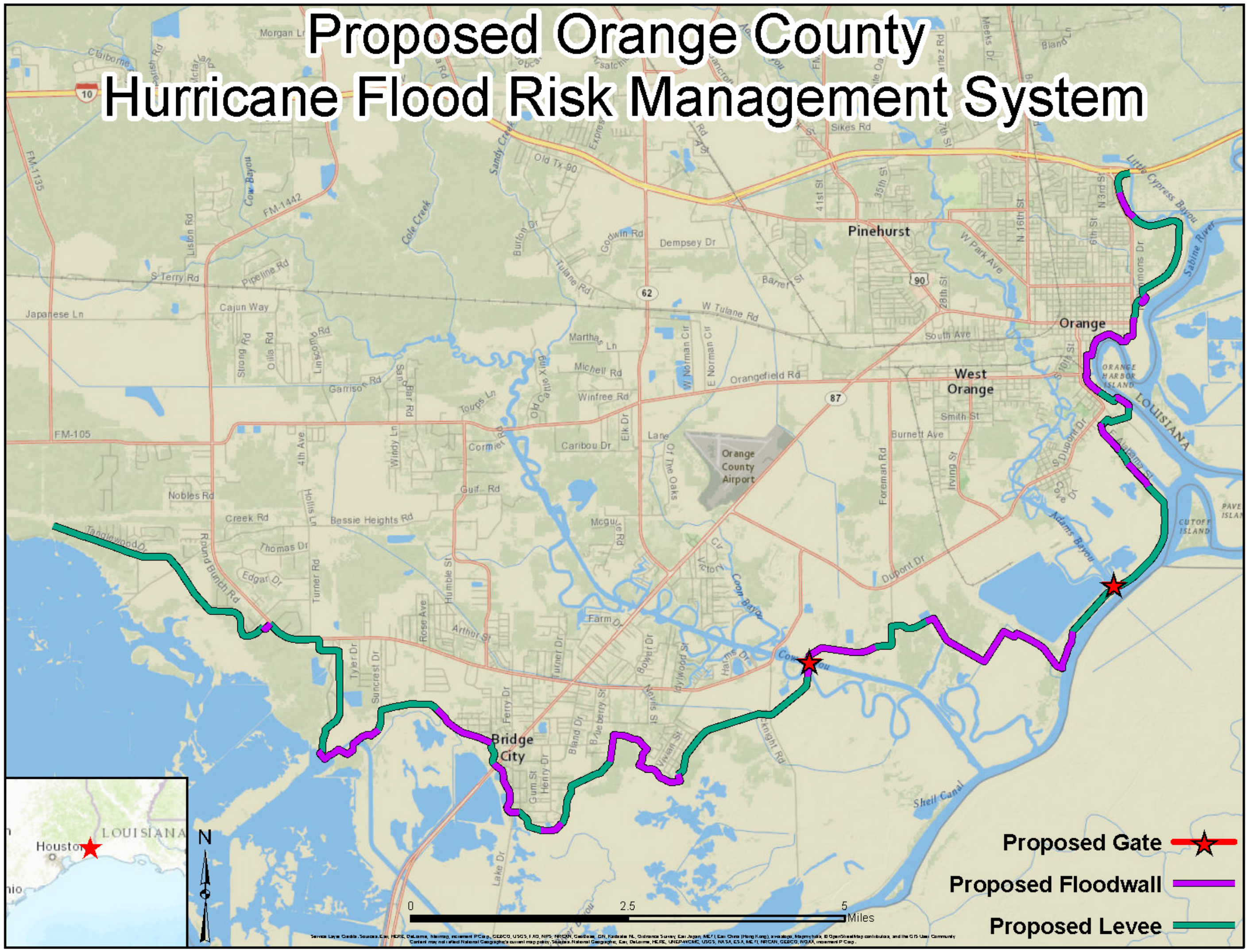

Figure 6-1: Orange-Jefferson CSRM Plan

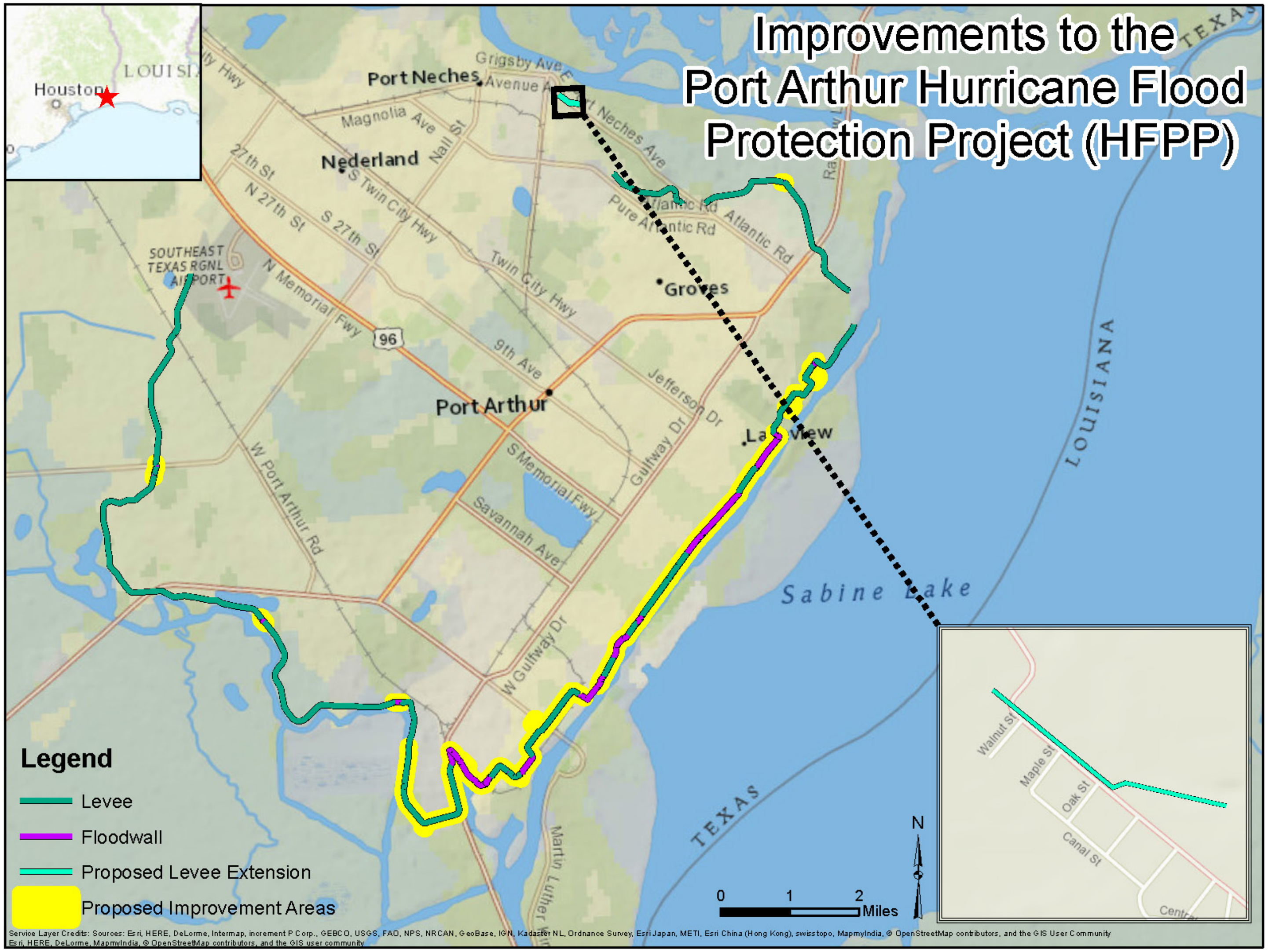

Figure 6-2: Port Arthur and Vicinity CSRM Plan

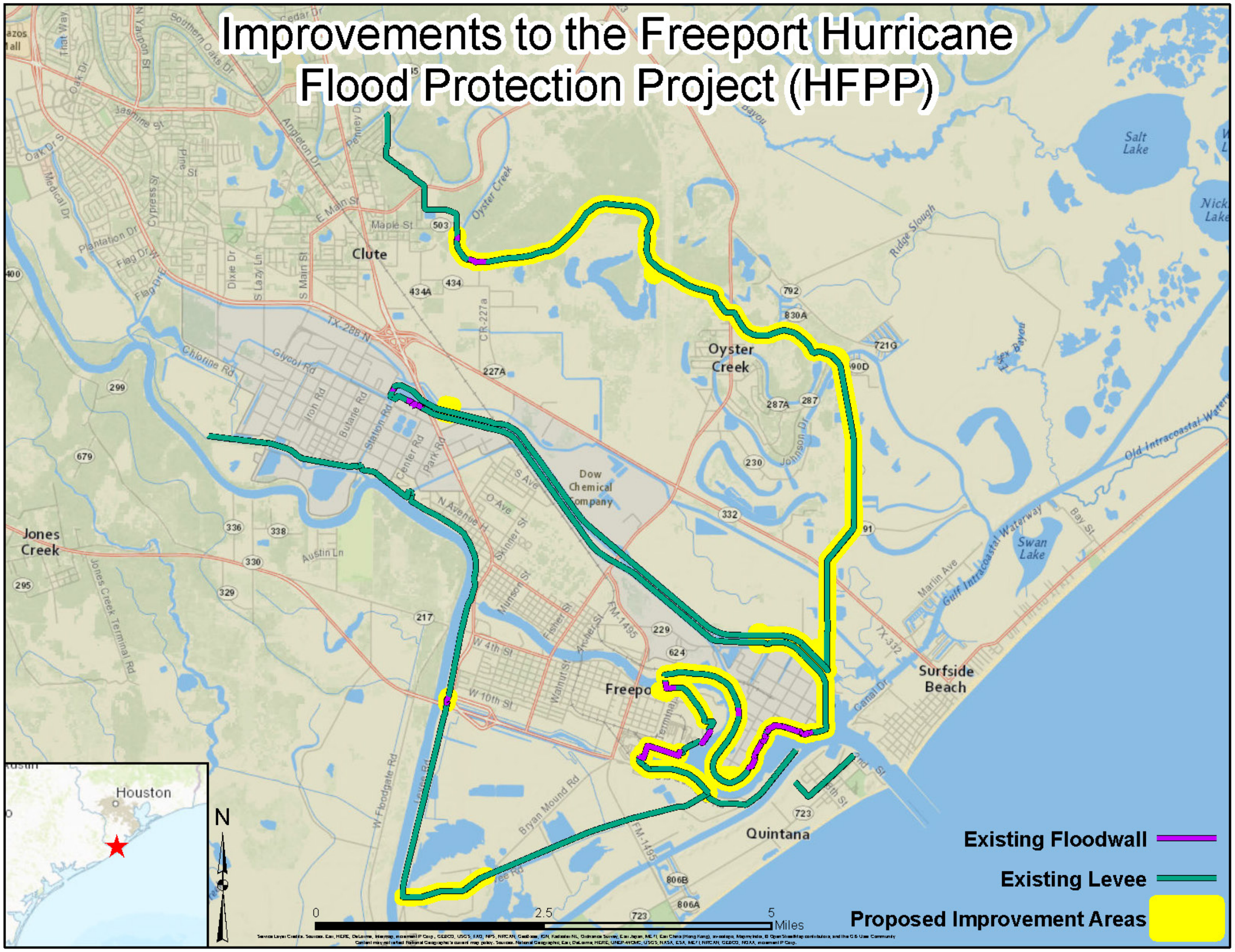

Figure 6-3: Freeport and Vicinity CSRM Plan

6.2 DESCRIPTION OF THE RECOMMENDED PLAN

6.2.1 Orange CSRM Project Area

Orange 3 New Levee (11-Foot)

The Orange 3 New Levee is a levee/floodwall flood risk reduction system that would serve to reduce the flood-damage potential from storm surge for much of the southern half of Orange County along the Sabine River and Bessie Heights Marsh. The Orange 3 system, consisting of earthen levee and floodwalls, begins at Interstate-10 at its northeast end, about 1.75 miles west of where the highway crosses the Sabine River. From there, the alignment roughly parallels the Sabine River to the south and then to the southwest to an industrial canal 1.65 miles northeast of the mouth of Cow Bayou. Along this reach, the alignment crosses Adams Bayou, which is used for navigation. There, the alignment turns sharply to the northwest, going up to a point near the south corner of the DuPont Sabine River Works plant. From this point, the alignment runs southwesterly to Bridge City, crossing Cow Bayou along the way, which is also used for navigation. The alignment then wraps around Bridge City to the south, turning northwesterly along the north side of the Bessie Heights Marsh to an end point less than a mile southwest of Farm to Market Road (FM) 1135, where it intersects FM 105 (Orangefield Road). Along this reach, the system will protect an electrical power-generating plant. In total, the length of the system will be approximately 26.7 miles. The system also assumes 10.75 miles of concrete floodwall would be need because the levee system alignment traverses several sensitive environmental habitat areas where impacts should be limited, places where the land area is insufficient for levee construction, or there are other real estate constraints. The borrow material for the levee and backfill of the floodwall is assumed to come from commercial sources.

The crossing of both Adams Bayou and Cow Bayou will require navigable gate structures incorporated into the levee alignment. The structures include a sector gate for navigation and adjacent vertical lift floodgates for allowing normal channel flow. The proposed alignment crosses several secondary roads, State Highway 87, Adams and Cow Bayous, an industrial canal, and a power plant intake canal. The features associated with the Orange 3 Reach are listed in Table 6-1. Please note that after the TSP was verified, the team developed feasibility-level designs for the Recommended Plan, the final features may vary slightly when compared from the DIFR-EIS.

Table 6-1: Orange 3 Reach – Features of Work

Feature of Work	Length (ft)
Floodwall	56,755
Levee	82,169
	Each
Pump Stations	7
Drainage Structures	56
Closure Gates (Road/Railroad Crossings)	32

Throughout the alignment water control structures and pump stations have been added to aid drainage when the system is both open and closed for storm events. The pump stations range in size from 131 to 8,190 CFS for their respective discharge capacities. Where feasible, initial smaller pump station locations were combined into larger and more efficient pump stations. Hydrologic connectivity would be maintained to the extent practicable through water control structures except during closure for hurricanes or tropical storms. When the system is closed, the pumps will operate. The risk reduction system is only authorized to address storm surge caused by hurricane and tropical storm events. It is not authorized to mitigate for or reduce impacts caused by higher day-to-day water levels brought about by increases in sea level rise. All drainage features through the levee system were sized to match the existing gravity drainage system, and would mimic the existing drainage patterns when the system is not closed. Any operational changes implemented to address changing sea level rise conditions or for any other non-project-related purpose would be considered a separate project purpose requiring separate authorization, new NEPA documentation, and/or permit approvals. In addition the NFS has an obligation relating to the operation of the project, specifically pump station capacities during storm events, to prevent encroachments that would impact the utility of the project when the pump station is operating. The NFS will be required to comply with flood plain management requirements and ensure that project features such as pump stations would not be impacted by developments in the areas behind the risk reduction system. The pump system designed to match the existing gravity drainage capacity when the system is closed. The NFS would have a responsibility to ensure that this operation of the project features is maintained.

The Orange 3 New Levee reduces the flood-damage potential from storm surge within the cities of Orange, West Orange, Pinehurst, Bridge City, and Orangefield. It also protects petrochemical plants and Entergy Texas Inc.'s Sabine (Power) Plant in Bridge City. The performed optimization efforts for the Orange 3 reach found the 11-foot still water elevation alternative to be the most economically feasible and justifiable plan. This elevation was utilized to determine the appropriate levee and floodwall heights for the features of work listed in Table 6-1. The heights were raised by a design offset and calculated from a storm index point in order for the system to have a uniform annual chance exceedance throughout its length. The heights were then rounded up to 0.5 foot increments for quantity calculations and to more easily describe the system. The heights shown on Table 6-2 are the final feasibility Recommended Elevations for the Orange 3 CSRM. Please note that after the TSP was verified, the team developed feasibility-level designs for the Recommended Plan, the final heights may vary slightly when compared from the DIFR-EIS. The risk reduction system has been designed to provide a risk reduction against a 1% probability storm based on the 2080 intermediate RSLR forecast condition within current data and modeling capabilities. The current design elevations varies across the system and utilizes the 2080 intermediate RSLR forecast condition to obtain a 1% level of risk reduction throughout the length of the system. The system should be monitored on a frequent basis to determine if there have been any changes from the initial level of risk reduction stated.

Table 6-2: Orange 3 Levee and Floodwall Elevations Recommended Elevations (NAVD88)

Geo Point ID	Levee	Floodwall
A	14.00	14.00
B	12.00	14.50
C	15.50	16.00
D	14.00	13.00
E	14.00	N/A
F	15.50	15.00
G	N/A	13.50
H	17.50	15.50
N	16.50	14.00

6.2.2 Port Arthur and Vicinity CSRM Project Area

The Port Arthur and Vicinity CSRM Project involves construction of floodwalls, raising of levees and replacement of vehicular closure structures. Several sections of floodwall and levee require raising due to a necessary increase in system capacity to further reduce the likelihood of failure of the system. The borrow material for the levee and backfill of the floodwall is assumed to come from commercial sources. For resiliency of the levee system, erosion protection is recommended to be installed around all concrete structures which are part this plan. The No-Fail + 1 alternative was chosen as the most economically justifiable and feasible plan. The Recommended Plan is described in further detail under each of the reaches for the project in Table 1-1 of the Engineering Appendix. The values presented in Table 6-3 are the features of work for each reach. Please note that after the TSP was verified, the team developed feasibility-level designs for the Recommended

Plan, the final features may vary slightly when compared from the DIFR-EIS.

Table 6-3: Port Arthur and Vicinity CSRM Project Area - Features of Work

Reach	**Floodwall (ft)**	**Levee (ft)**	**Closure Gates (Road/Railroad Crossings)**
1	690	0	3
2	10,940	9,000	0
3	7,030	8,250	10
4	9,790	8,950	12
5	1,640	3,000	1
Addition	0	1,830	0

Elevations utilized to determine the appropriate levee and floodwall heights for the features of work listed in Table 6-3, are show in Table 6-4. The heights were calculated from a storm index point in order for the system to have a uniform annual chance exceedance throughout its length. The heights were rounded up to 0.5 foot increments. The heights then had an additional 1-foot added, which is the Recommended Plan (No-Fail + 1). The existing levee elevation throughout the system was taken from recent surveys completed by the local sponsor. For purposes of this study, an average elevation was used for the lengths of levee or floodwall within each reach. The final recommended levee heights were then used against the existing surveyed elevations of the system to calculate the required raise of the existing levee and were rounded up to 0.5 foot increments. The same process was completed for the floodwall heights of the Recommended Plan. For the floodwall, if the calculated height was lower than the existing height for the same location, the existing height was used for the Recommended Plan. Additional details, such as plan views and detailed descriptions by levee reach can be found in the Engineering Appendix. Please note that after the TSP was verified, the team developed feasibility-level designs for the Recommended Plan, the final features or heights may vary slightly when compared from the DIFR-EIS. The risk reduction system has been designed to provide a risk reduction against a 1% probability storm based on the 2080 intermediate RSLR forecast condition within current data and modeling capabilities. The current design elevations varies across the system and utilizes the 2080 intermediate RSLR forecast condition to obtain a 1% level of risk reduction throughout the length of the system. The system should be monitored on a frequent basis to determine if there have been any changes from the initial level of risk reduction stated.

Table 6-4: Port Arthur Levee and Floodwall Recommended Elevations (NAVD88)

Geo Point ID	Levee	Floodwall
O	14.39	14.50
P	14.40	17.00
Q	14.93	
R	14.99	16.50

Geo Point ID	Levee	Floodwall
S	16.41	19.50
T		19.50
U	16.31	17.00
V	16.60	17.50
W	16.30	17.50
X	16.60	
Y	17.10	19.00
Z		18.00
Z1		19.50
Z2		19.50
Z3	17.20	
Z4	16.30	16.50
Z5	15.91	18.00
Z6	15.66	
Z7	15.21	15.50
Z8	14.70	16.00

6.2.3 Freeport and Vicinity CSRM Project Area

The Freeport and Vicinity CSRM Project involves construction of floodwalls, raising of levees, replacement of vehicular closure structures, and constructing a navigable gate structure in an active barge canal. Several sections of floodwall and levee require raising due to a necessary increase in system capacity to further reduce the likelihood of failure of the system. The borrow material for the levee and backfill of the floodwall is assumed to come from commercial sources. For resiliency of the levee system, erosion protection is recommended to be installed around all concrete structures which are part this plan. The No-Fail + 1 alternative was chosen as the most economically justifiable and feasible plan. The Recommended Plan is described in further detail under each of the reaches for the project in Table 1-1 of the Engineering Appendix. The values presented in Table 6-5 are the features of work for each reach. Please note that after the TSP was verified, the team developed feasibility-level designs for the Recommended Plan, the final features may vary slightly when compared from the DIFR-EIS.

Table 6-5: Freeport and Vicinity CSRM - Features of Work

Reach	**Floodwall (ft)**	**Levee (ft)**	**Closure Gates (Road/Railroad Crossings)**	**Drainage Structures (EA)**
Oyster Creek & Oyster Creek Extension	1,220	28,400	0	3
East Storm	320	17,370	0	0
DOW Barge Canal	3,190	9,150	2	1
Old River North	15,660	3,030	0	0

Reach	**Floodwall (ft)**	**Levee (ft)**	**Closure Gates (Road/Railroad Crossings)**	**Drainage Structures (EA)**
Tide Gate	530	0	0	0
Old River South	7,855	7,025	8	0
South Storm	0	4,400	0	0
East Bank Brazos River	430	0	0	0

Elevations utilized to determine the appropriate levee and floodwall heights for the features of work listed in Table 6-5, are show in Table 6-6. The heights were calculated from a storm index point in order for the system to have a uniform annual chance exceedance throughout its length. The heights were rounded up to 0.5 foot increments. The heights then had an additional 1-foot added, which is the Recommended Plan (No-Fail + 1). The existing levee elevation throughout the system was taken from recent surveys completed by the local sponsor. For purposes of this study, an average elevation was used for the lengths of levee or floodwall within each reach. The final recommended levee heights were then used against the existing surveyed elevations of the system to calculate the required raise of the existing levee and were rounded up to 0.5 foot increments for the quantity calculations. The same process was completed for the floodwall heights of the Recommended Plan. For the floodwall, if the calculated height was lower than the existing height for the same location, the existing height was used for the Recommended Plan. Additional details, such as plan views and detailed descriptions by levee reach can be found in the Engineering Appendix. Please note that after the TSP was verified, the team developed feasibility-level designs for the Recommended Plan, the final features or heights may vary slightly when compared from the DIFR-EIS. The risk reduction system has been designed to provide a risk reduction against a 1% probability storm based on the 2080 intermediate RSLR forecast condition within current data and modeling capabilities. The current design elevations varies across the system and utilizes the 2080 intermediate RSLR forecast condition to obtain a 1% level of risk reduction throughout the length of the system. The system should be monitored on a frequent basis to determine if there have been any changes from the initial level of risk reduction stated.

Table 6-6: Freeport and Vicinity CSRM Levee and Floodwall Recommended Elevations (NAVD88)

Geo Point ID	Levee	Floodwall
OC_1	20.31	
OC_2	20.40	
OC_3	20.00	
OC_4	20.15	
OC_5	20.00	
OC_6	16.30	16.50
OC_7	13.40	16.00
N_1	22.00	22.00
N_2	22.50	

Geo Point ID	Levee	Floodwall
N_3	23.50	
N_4	23.20	
N_5	23.00	
N_6	23.50	
N_7	23.16	
DBC_1	19.92	
DBC_2	19.27	
DBC_3	19.21	
DBC_4	19.18	
DBC_5	19.50	19.50
W_1	16.81	19.00
S_1	17.85	
S_2	17.40	
S_3	18.83	
S_4	17.86	
S_5	17.32	
PF_1	25.85	26.00
PF_2	19.76	20.00
PF_3W	20.62	
PF_3T	19.28	19.50
PF_4T	18.96	19.00
PF_4P	17.17	
US_1	18.89	
US_2	20.04	20.50
IH_1	19.00	19.00
LS_1	18.82	19.00

6.3 SEPARABLE ELEMENTS

A region wide systems approach for construction of Orange 3, Port Arthur and Freeport CSRM Plan is being recommended to ensure that all of the benefits stated would be achieved. However, Orange 3, Port Arthur, and Freeport CSRM Plans are able to function individually and are separable. The Economic Appendix presents the cost and benefits of each separable element. Construction and completion of a region wide risk reduction system would help to lessen the financial and social impacts that tropical storms and hurricanes can cause by reducing the risk of property damage that displaces residents, shuts down commercial and industrial services, and disrupts livelihoods. If structures avoid or have reduced damages because of a regional risk reduction system, families and businesses can rebound much more quickly after a tropical event. This is exemplified by increasing the opportunity to return residents to their homes and children to schools that have less or no damage from surge events. In addition, lost work days are reduced for workers who support the local or regional economy by reducing hurricane storm surge damage to houses, businesses and other non-residential structures; by minimizing the debris from hurricane storm damaged structures that can affect other properties; and by generally improving the opportunity and time necessary for residents, businesses and government to return to normal function after an event. Concurrent construction of all three elements would help to ensure that the regional economy would continue to operate after a storm event and the stress and hardship associated with hurricane storms would be lessened. The study area supports national needs, logistics, and persona. For example, the nation relies on the uninterrupted supply of energy and material goods from the study area. Pronounced impacts from repetitive hurricane storm surge events, threatens the productivity and sustainability of these important national interests by reducing the continuity, functionality, and export of supplies, and commerce.

6.4 FISH AND WILDLIFE MITIGATION

6.4.1 Summary of Environmental Impacts

Environmental impacts on specific resources are described in Section 7. No significant environmental impacts have been identified for the Port Arthur and Freeport and Vicinities CSRM Plans. All environmental impacts identified for the Recommended Plan are associated with the Orange 3 CSRM Plan, and these are limited to wetland impacts (Table 6-7). Direct impacts, affecting approximately 160.2 acres, would result from construction of the new levee-floodwall system, and indirect impacts on about 2,249.5 acres would be associated with functional impacts to fisheries access and sediment, nutrient and organic matter exchange on the extensive marshes in the lower Cow and Adams Bayous floodplains and limited impacts from construction of the levee and surge gates in a few locations.

Table 6-7: Direct and Indirect Impacts (Intermediate RSLC)- Recommended Plan

Wetland Type	Direct Impacts		Indirect Impacts				Total Impacts (acres)	Total AAHUs Lost
	Direct Wetland Impacts (acres)	AAHUs	Indirect Wetland Impacts (acres)	AAHUs	Functional Impacts (affected acres)	AAHUs		
Forested Wetlands								
Swamp	10.6	-7.2	1.9	-0.1	0.0	0.0	12.5	-7.3
Bottomland Hardwood	44.3	-30.3	12.7	-5.1	0.0	0.0	57.0	-35.4
Subtotal	54.9	-37.4	14.6	-5.2	0.0	0.0	69.5	-42.7
Coastal Marsh								
Fresh Marsh	24.3	-11.4	0.0	0.0	785.2	-18.8	809.5	-30.2
Intermediate Marsh	6.8	-4.0	19.2	-8.5	322.5	-4.1	348.5	-16.6
Brackish Marsh	74.2	-33.7	78.5	-35.2	1029.5	-27.6	1182.2	-96.5
Subtotal	105.3	-49.0	97.7	-43.7	2137.2	-50.5	2340.2	-143.3
Total Impacts*	**160.2**	**-86.5**	**112.3**	**-48.9**	**2137.2**	**-50.5**	**2409.7**	**-186.0**
* Totals may not add exactly due to rounding.								

In total, approximately 69.5 acres of forested wetland and 2,409.7 acres of coastal marsh would be impacted. Mitigation would be needed to compensate for a loss of 42.7 AAHUs from forested wetlands and 143.3 AAHUs from emergent marsh. However, potential exists for impacts on buried hazardous and toxic materials during construction of improvements. Additional investigation would be required during PED to identify areas of concern and strategies for minimizing impacts.

A comprehensive list of assumptions underlying our analysis of the Recommended Plan's proposed direct and indirect effects on wetlands, fish and wildlife habitat, and EFH are provided below. If changes made to the project during the PED, Construction or Operations phases undermine these assumptions, consultation with resource agencies will be required and additional mitigation could be identified.

- Impact assessment is dependent upon the exact location of the levee system features; changes in the footprint of the levee system, or identification of new access routes/work areas/system features during the PED and Construction Phases could increase project impacts.
- Fill material for levee system construction is assumed to come from approved commercial borrow sources.

- Indirect EFH fisheries access impacts assumed that the proposed surge gates in Cow and Adams Bayous would constrict flow in the waterways by no more than 50 percent.
- Construction of culverts and the Cow and Adams Bayou surge gates would follow NMFS 2008 Fisheries Friendly Design and Operation Considerations for Hurricane Flood Protection Water Control Structures (provided by the Baton Rouge field office) to the greatest extent practicable.
- Construction of mitigation areas is assumed to start concurrently with new levee system construction.
- The Operation Plan for the new Orange system would require that culverts/gates remain open during normal operations, closing for no longer than two weeks at a time during surge and maintenance events.
- Coordination with resource agencies would continue through the PED, Construction and Operations Phases to ensure appropriate consideration of project changes, implementation of mitigation, and completion of the monitoring/adaptive management plan.

6.4.2 Mitigation Plan

In accordance with the mitigation framework established by Section 906 of the Water Resources Development Act (WRDA) of 1986 (33 USC 2283), as amended by Section 2036 of WRDA 2007 and Section 1040 of the Water Resources Reform and Development Act (WRRDA) of 2014, the Council on Environmental Quality (CEQ)'s National Environmental Policy Act (NEPA) regulations (40 CFR Sections 1502.14(f), 1502.16(h), and 1508.20), and Section C-3 of Engineer Regulation (ER) 1105-2-100, USACE will ensure that project-caused adverse impacts to ecological resources are avoided or minimized to the extent practicable, and that remaining, unavoidable impacts are compensated to the extent justified.

Mitigation would be needed to compensate for a loss of 42.7 AAHUs from forested wetlands and 143.3 AAHUs from coastal wetlands. Impacts were avoided and minimized to the greatest extent practicable in several iterations of planning the footprint of the proposed new levee system alignment. The levee system right-of-way was located as close to the upland-wetland margin as possible to minimize wetland impacts, while also minimizing social effects and maximizing economic benefits. Engineering design incorporated USFWS and NMFS conservation recommendations to avoid and minimize impacts. Remaining unavoidable impacts have been fully compensated with in-kind mitigation.

Mitigation banks with service areas including the project impact areas were investigated to determine if sufficient and appropriate mitigation credits were available. None have been identified that could be utilized for S2G mitigation. Only one approved bank (the Blue Elbow

Swamp) has a service area that includes S2G impact areas and affected wetland types. However, it is a single-client bank with credits reserved for the Texas Department of Transportation (TXDOT). Since mitigation banks are not available to compensate for all or even a portion of project impacts, areas in the floodplains of the Neches and Sabine Rivers within and adjacent to the study area were reviewed to identify potential in-kind mitigation sites.

A wide array of potential mitigation measures, described more fully in Appendix O, were evaluated to select the final array of mitigation alternatives. Selection of potential mitigation sites and modeling of benefits were conducted in coordination with Federal and state resource agencies. Mitigation measures that were initially considered included various types of hydrologic restoration (canal backfilling; removal of berms, oil field pads or roads that block tidal flows; improving drainage), marsh restoration, forested wetland restoration, and preservation in perpetuity. These measures are presented in an attachment to Appendix O, along with the screening decisions. Reasons for exclusion from the evaluation array varied but generally were based on small benefits relative to amount of compensation needed, lack of need for the restoration, incompatibility with existing land use, contamination concerns, or combination/incorporation with other mitigation measures.

Areas evaluated as potential mitigation areas excluded areas already identified for beneficial use or mitigation in conjunction with other projects. Specifically, authorized improvements to the SNWW navigation project include the restoration of large areas within both Bessie Heights and Old River Cove marshes with the beneficial use of dredged material. In addition, areas in the process of being restored by TPWD have also been excluded. Any mitigation sites selected for this project augment, and do not replace, these other proposals.

Three measures (marsh restoration, preservation, and forested wetland restoration) were used to build the seventeen mitigation alternatives that were advanced for screening in the evaluation array. WVA modeling was conducted to quantify benefits (AAHUs) of mitigation measures. Feasibility-level costs of selected mitigation measures were developed, and the IWR Planning Suite software was used to identify a best buy mitigation plan for each affected wetland type. This certified software conducts a cost effectiveness-incremental cost analysis and identifies Best Buy mitigation plans that fully compensate for all impacts. The analysis was structured to ensure that the Best Buy Plans would provide sufficient in-kind mitigation for each wetland type. To achieve this, separate planning sets were developed for swamp, BH, and each of the marsh types (fresh, intermediate and brackish).

Preliminary costs were developed to support mitigation plan selection. Costs include real estate, construction and monitoring/adaptive management costs. These costs were annualized using the

IWR-Plan Annualizer. Construction costs include construction of containment dikes, pumping dredged material into open water areas, dewatering, marsh plantings and containment dike removal.

The result of the incremental analysis is illustrated on Table 6-8. The IWR Planning Suite identified multiple best buy plans for each of the wetland types (8 each for Swamp and BH; 3 each for fresh, intermediate and brackish marsh). Column 3 “Best Buy Plan #” identifies the plan number from the Planning Suit’s “Incremental Cost of Best Buy Plans” table. Plan 1 is always the No-Action Plan, with no cost and no output. For all wetland types, the Best Buy Plan with the lowest incremental cost (Plan 2) was selected for inclusion in the Mitigation Plan. The fourth column “Best Buy Plans” lists all of the wetland alternative codes in that planning set for the indicated Best Buy Plan, with a “0” following those that were not included in the Best Buy Plan, and a “1” after those codes which are included. The codes with the number “1” indicator are shown in bold. Each Plan 2 provided compensation greater than the target for that specific wetland type. When considered together, the Best Buy plans for all of the affected wetland types provide 262.9 AAHUs of compensation for a total mitigation target of -186.0 AAHUs.

Table 6-8. Mitigation Best Buy Plans

Wetland Type	Mitigation Target	Best Buy Plan #	Best Buy Plan(s)	Best Buy Alternatives	AAHUs	Average Annual Cost ($1,000)
Swamp	-7.3	2	**S111**S120S140S150H170H220H240	S11	13.2	$ 4.4
Bottomland Hardwood	-35.4	2	BH110BH120BH140BH150BH260**BH1611**	BH161, Scale 1	49.3	$ 2.5
Fresh Marsh	-30.2	2	F420**F521**	F52	33.4	$ 82.9
Intermediate Marsh	-16.6	2	**I311**I320I1430	I31	60.4	$ 243.1
Brackish Marsh	-96.5	3	B270**B281B291**	B28 and B29	100.4	$ 310.1
Totals	-186.0				262.9	$ 643.0
*S11 provides bottomland hardwood (BH) benefits of 6.2 AAHUs at no additional cost because BH are intermingled with swamp.						

While this combination of Best Buy plans is the most cost effective plan, it provides about 40 percent more compensation than is required. This excess is due to two factors. First, the mitigation plan is made up of six separate mitigation areas, which are needed to provide in-kind mitigation for five different habitat types. The mitigation for each habitat type needs to exceed the mitigation target for that type in order to fully compensate for each kind of loss. Most of the areas provide a small amount of excess benefits, but Area 31 provides an excess of 43.8 AAHUs or a little over half of the total excess benefits. This measure is the most cost effective plan because it utilizes natural features (uplands, islands and existing marsh) and existing levees to contain the hydraulically-pumped material that will be used for marsh restoration. Costs for constructing containment levees and impacts to existing wetlands associated with containment construction are thus minimized with this configuration.

6.4.2.1 Description of the Mitigation Plan

A detailed description of the mitigation plan is presented in Appendix O. The description provided below is a brief summary of the information presented there. Appendix Q presents sensitivity analyses of the WVA marsh models using a sensitivity spreadsheet prepared by the ERDC Environmental Lab (USACE, 2013). These sensitivity analyses provide additional information to assist in the investigation of several unresolved issues related to the suitability graphs for Variables 1 and, 2, and the aggregation method used to combine the marsh habitat units and open water habitat units for each sub-model.

The mitigation plan for forested wetlands consists of preservation in perpetuity of approximately 447 acres of swamp and bottomland hardwoods (BH) in Mitigation Area 11 in the bottomlands of the Sabine River and about 112.5 acres of BH forest in Mitigation Area 161 on the upland/wetlands margin of the Neches River in the Bessie Heights area (Figures 6-4 and 6-5). These lands would be acquired during the construction phase by the NFS for project implementation. The NFS would manage the property and grant USACE right of entry for monitoring to verify preservation through the 50 year period of analysis.

"Preservation only" was evaluated as potential mitigation for forested wetlands because the extensive interagency evaluation of restoration measures found very limited opportunities for forested wetland restoration in the study area. The selected forested wetland Best Buy plans are the best performing measures under the CE/ICA analysis and provide a high ratio of preservation. Hydrologic restoration of three swamp areas in the Blue Elbow/Tony Houseman WMA were evaluated, and one Chinese tallow control measure was evaluated for bottomland hardwood. The CE/ICA analysis determined that these forested wetland restoration plans were the lowest ranking of all plans, with significantly higher incremental costs per output than the restoration only plans. In addition, the hydrologic swamp restoration measures may not be implementable because TxDOT approval is required to restore these areas, which are co-managed with USFWS as a single user mitigation bank.

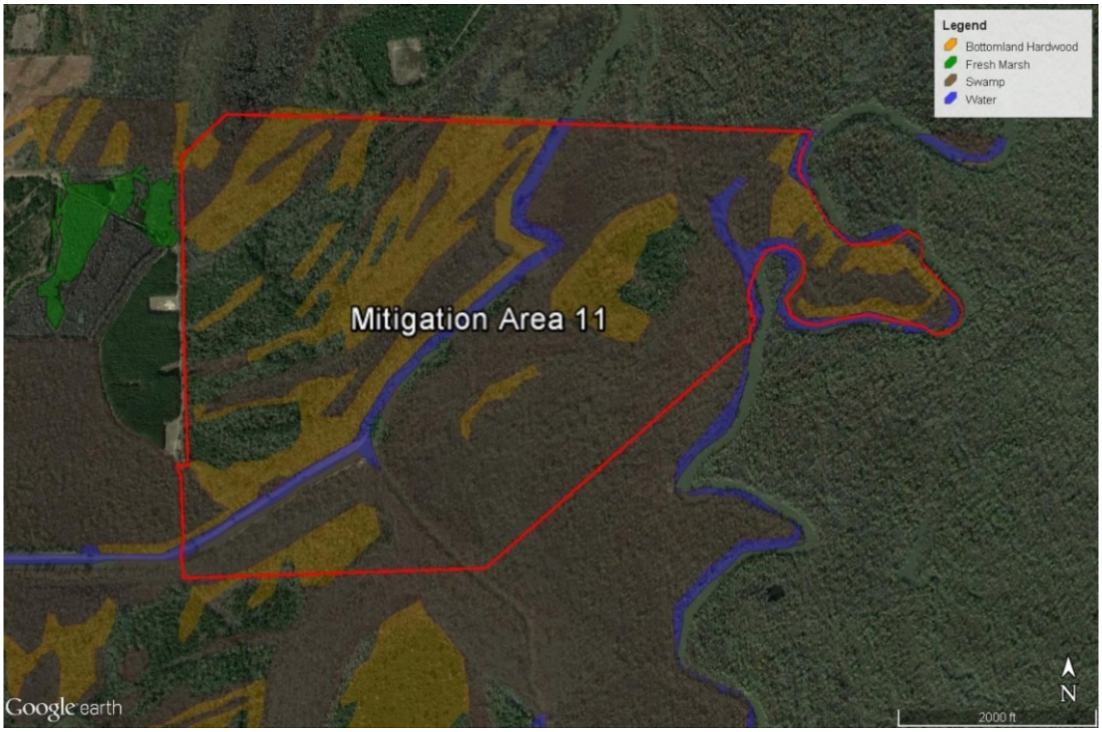

Figure 6-4. Swamp and Bottomland Hardwood Mitigation Area 11

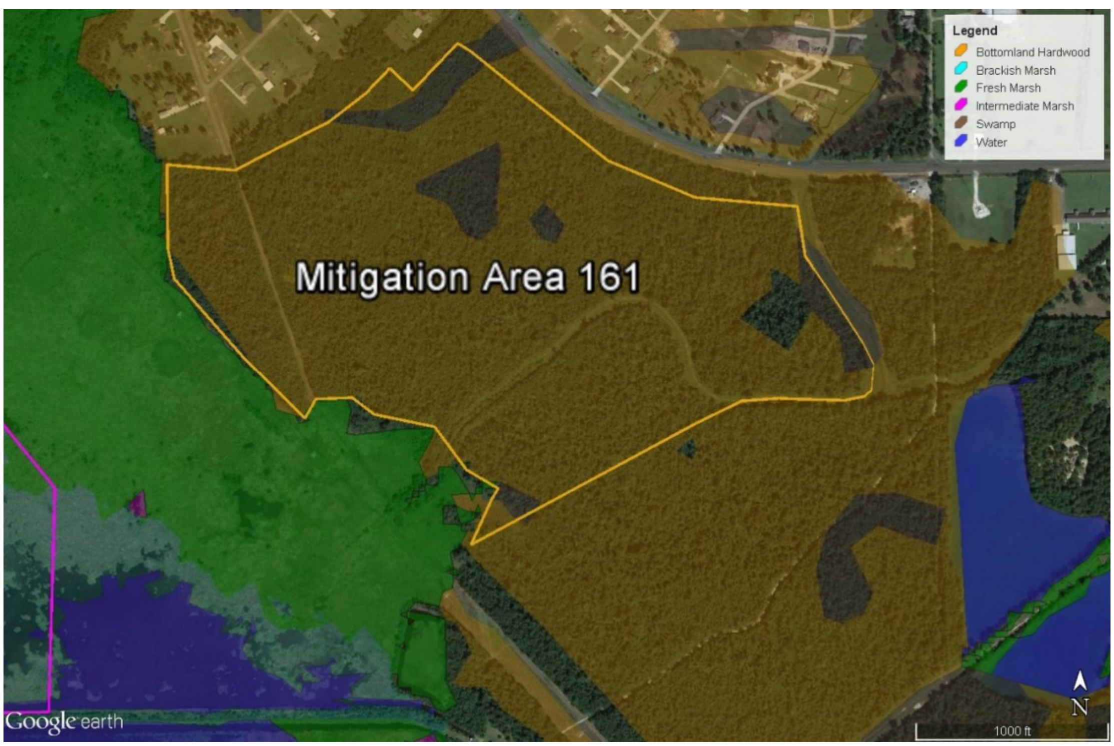

Figure 6-5. Bottomland Hardwood Mitigation Area 161

The mitigation plan would restore approximately 63 acres of fresh marsh and associated shallow ponds and sinuous channels in Mitigation Area 52, 151 acres of intermediate marsh and associated waters in Mitigation Area 31, and 239 acres of brackish marsh and associated waters in Mitigation Areas 28 and 29 (Figures 6-6, 6-7 and 6-8). Mitigation Areas 28, 29 and 31 are owned by TPWD. Mitigation Area 52 is privately owned; acquisition and preservation of this area would be accomplished as described for Mitigation Areas 11 and 161.

Shoaled sediments from maintenance dredging of the adjacent deep-draft navigation channels of the Sabine-Neches Waterway (SNWW) would be used to restore marsh in areas of open water within the outlined areas shown on Figures 1-3 through 1-5. Marsh would be constructed to target elevations determined during the PED phase in coordination with the resource agencies, utilizing comparisons to nearby reference marshes to establish the optimum post-settlement elevation range. At this time, it is projected that a range of elevations between 1.2 and 1.5 feet (NAVD88) would be achieved for emergent marsh and 0 to – 2.0 feet MLLW for restored ponds and channels within the marsh.

The construction estimate assumes that shoaled material from SNWW's Sabine-Neches Canal B, which extends across the north end of Sabine Lake from the mouth of the Neches River to the mouth of the Sabine River, would be used to construct mitigation areas 28 and 29. This is the closest segment of the SNWW to the Old River mitigation sites. This channel is not regularly dredged, so cost estimates included the full cost of maintenance dredging to hydraulically dredge the material and pump it into targeted open water areas. Maintenance material from the SNWW's Neches River Channel might be used instead of, or in addition to, the Sabine-Neches Canal B material for these areas. Material from regularly scheduled maintenance dredging of nearby reaches of the Neches River Channel is proposed for construction of mitigation areas 31 and 52. Only the incremental cost of additional hydraulic pipeline, pumping and pipe movement needed to create the marsh is included in the cost estimates for these alternatives.

Shoaled sediments in the Sabine region are fine-textured (mean percent clay is 76 percent) and generally of good quality, as evidenced by testing of water and sediments in conjunction with maintenance dredging of existing navigation channels and proposed modifications for the SNWW (USACE, 2011; SOL, 2012). SNWW sediments are routinely used for beneficial use projects, both on private and TPWD properties in the region. A routine water and sediment testing contract is planned in the near future to support USACE maintenance dredging of the Neches River Channel; sediment testing for dioxin has been added due to recent information confirming the historic presence of paper mills in the region.

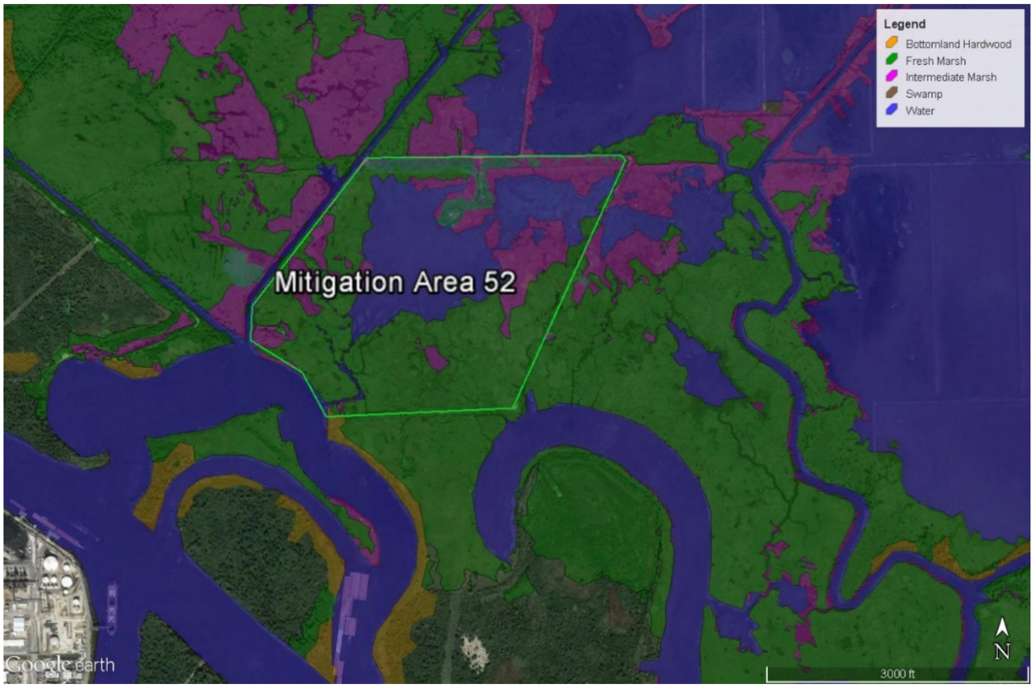

Figure 6-6. Fresh Marsh Mitigation Area 52

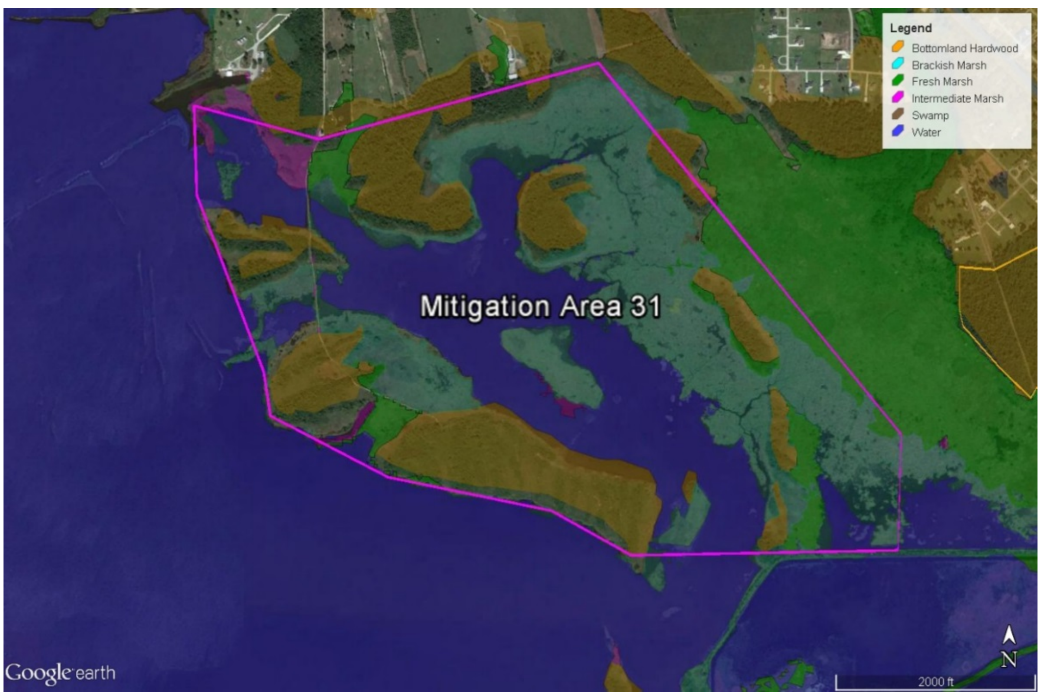

Figure 6-7. Intermediate Marsh Mitigation Area

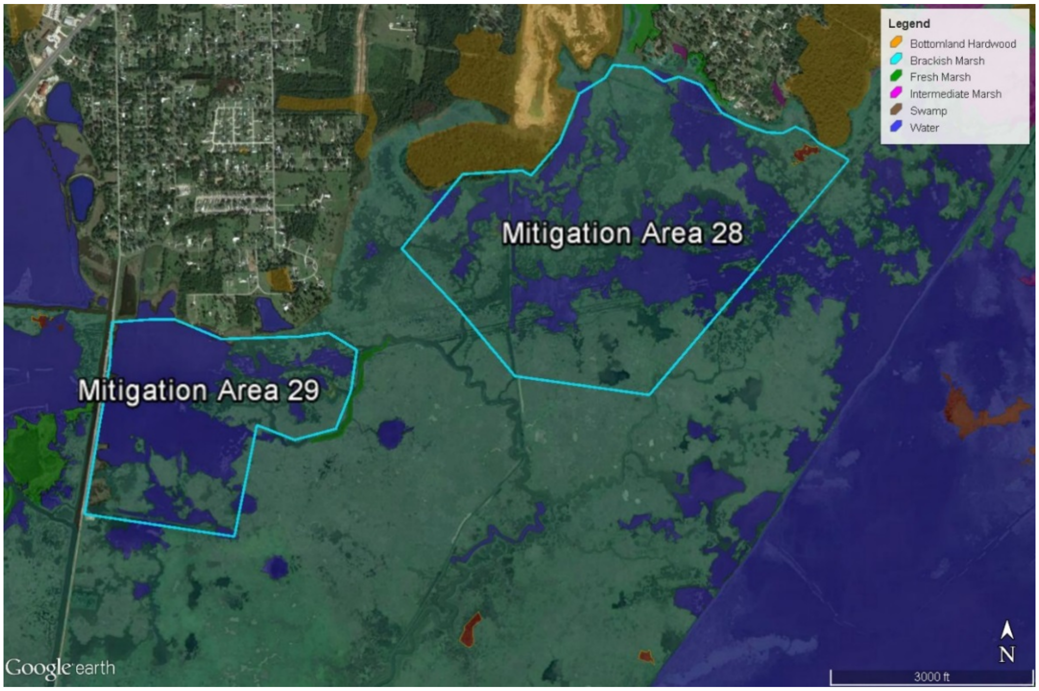

Figure 6-8. Brackish Marsh Mitigation Areas

Based upon the high percentages of fines in the SNWW sediments (55 – 94% from stations SNR-13-1 through SNR-13-13), binding of chemical constituents to sediment is expected to be significant and irreversible, resulting in low to no desorption from the sediments into surface water and elutriate during placement into mitigation features. The surface water and elutriate data support this, showing a high degree of consistency over the samples analyzed with virtually 100 percent of the results being below the reporting limit. With these findings, USACE believes that the material is suitable for like-to-like placement within the SNWW system.

Recent sediment and water testing in the Neches River in conjunction with a Galveston District regulatory action identified one positive result for dioxin in the elutriate of one sample (EPA, personal communication, 2016). This result is suspect, since dioxins are polar, highly chlorinated organic compounds with low water solubility and a high binding affinity. Given these characteristics, dioxin's affinity for binding with fine sediments over water, and the dominance of fine textured sediments in this waterway, this single positive elutriate result for dioxins could well be the result of a laboratory handling artifact where elutriate sampling were not filtered. Such a laboratory procedure could result in a false positive. However, given this anomalous dioxin elutriate result, during PED the USACE would evaluate the results of O&M maintenance material sediment testing, and if warranted based upon the results of this testing and evaluation, conduct additional sediment testing prior to construction to confirm the suitability of SNWW sediments for use in marsh mitigation features. The risk of identifying insufficient quantities of suitable sediment for the mitigation features is considered to be low based on the large quantity of shoaled sediments available in adjacent navigation channels, routine O&M water and sediment testing results, and the acceptability of this material for several recent Neches River beneficial use projects.

6.4.2.2 Monitoring/Adaptive Management Plan

A detailed description of the monitoring/adaptive management plan is presented in Appendix P. The description provided below is a brief summary of the information presented there. All of the mitigation areas would require periodic inspection as part of normal operations and maintenance (O&M), in accordance with ER 1105-2-100, Section C-3(e)(10) and Section 2(d) of implementation guidance for WRDA 2007 Section 2036(a) (USACE, 2006). Monitoring to determine the success of mitigation measures is primarily the responsibility of the NFS for project implementation. The monitoring cost has been included in the O&M cost. Specific methods for the surveys and data collection described below would be developed in coordination with resource agencies during the PED phase.

An effective monitoring program is required to determine if the mitigation outcomes are consistent with performance standards. Mitigation success criteria were developed as the basis of determining ecological success and to determine if adaptive management actions are required. Upon completion of the mitigation area acquisition and construction, monitoring for ecological success would be initiated and would continue until ecological success is achieved, as defined by the mitigation success criteria. The objectives, performance standards and success criteria are presented in detail in Appendix P.

If one or more of the monitoring reports detailed in Appendix P indicates that mitigation success is threatened, as determined by USACE and the NFS in coordination with the resource agencies, significant corrective actions would be necessary as described in the Adaptive Management Plan (Section 3.0 of Appendix P). The need for such actions could trigger the need for additional monitoring, including the need to extend monitoring beyond the times indicated. The NFS would be responsible for conducting this additional monitoring, preparing monitoring reports, and conducting required corrective actions. Necessary corrective actions would be determined by USACE in coordination with the NFS and the resource agencies.

6.4.2.3 Resource Agency Views on the Best Buy Mitigation Plan

The Best Buy Mitigation Plan and Monitoring and Adaptive Management Plan were provided to the resource agencies for review and comment prior to release of the FIFR-EIS. Resource agency views described below were provided during a meeting, and in subsequent emails and correspondence. The proposed Mitigation Plan fulfills recommendations by USFWS (August, 2016), and letters from EPA (Oct 30, 2015), NMFS (October 26, 2015), TCEQ (October 21, 2015) and TPWD (October 26, 2015).

- The final USFWS CAR (August 9, 2016) noted that the proposed mitigation plan was discussed with resource agencies during a meeting on June 15, 2016. The CAR states that the USFWS accepts the proposed mitigation plan and the monitoring/adaptive management plan, and recommends continued coordination with all of the resource agencies during PED and the Construction phases.
- In their letter concluding EFH consultation (August 10, 2016), NMFS accepted USACE responses to their Conservation Recommendations, including the proposed mitigation plan and its compensation for direct and indirect EFH impacts.
- EPA in their Section 404 CWA comments (provided as an attachment to their Oct 30, 2015 comments on the DIFR-EIS) indicated that “preservation only” mitigation plans are their “lowest priority, and thus least desirable option.” In subsequent meetings, EPA also expressed concern about the suitability of shoaled sediments to be used in marsh mitigation features. USACE has determined that shoaled sediments in the SNWW are acceptable for marsh mitigation and are already being used beneficially for other marsh restoration projects in the area. More information regarding selection of the ‘preservation only” measures and concerns regarding sediment suitability are provided in Section 6.4.1.2.
- TPWD (October 2016 letter) has agreed that the feasibility-level impact analysis is sufficient at this time, pending additional study and consultation during the PED phase as planned by USACE. Further H&H analysis would be conducted at that time to confirm assumptions related to potential alterations of sheet flow from uplands to coastal marshes. Final approval or concurrence by TPWD cannot occur until requirements of Chapter 26 of the Parks and Wildlife Code are met, and that cannot occur until after the FEIS is complete and the project is authorized. At this time, no significant obstacles to this approval have been identified. TPWD is willing to accept locating mitigation areas on lands in the Lower Neches WMA and has requested that USACE consider hydrologic or invasive species restoration measures in the Blue Elbow/Tony Houseman WMA as mitigation for the project’s impacts to cypress-tupelo swamp. TWPD would like USACE to consider the value of restoration in the WVA because it functions as one of the greatest examples of the demonstration of, and education about, wildlife habitat in Texas. More information about the value of the Blue Elbow/Tony Houseman WMA is provided in the TPWD letter (Appendix G). USACE has informed TPWD that restoration measures may not be implementable because TxDOT approval is required to restore these areas, which are co-managed with USFWS as a single user mitigation bank. TPWD would consider managing any and possibly all of the private properties acquired for mitigation purposes, as long as the properties are readily accessible to TPWD staff and the public, and practically

manageable. TPWD would also be willing to divest the remainders of their property which would be isolated by levee construction.

- Several other agencies (notably NRCS, TCEQ, and TxDOT) participated in interagency meetings in which the mitigation plan was developed and reviewed. No reservations or adverse comments were expressed about the plan in these meetings.

6.4.3 Historic Properties Mitigation

Development of a mitigation plan will be deferred to the Preconstruction Engineering and Design (PED) phase when surveys and site assessments will be completed. The mitigation of historic properties may be necessary following an evaluation of impacts to determine if any of the four currently listed historic properties would be indirectly impacted. The eight archeological sites within the study area also would need to be evaluated as to their horizontal and vertical extent and eligibility for inclusion in the National Register of Historic Places (NRHP). The two cemeteries within the study may also be directly impacted and would need to be delineated and evaluated. There is also the potential for identifying cultural resources during survey investigations of high probability areas. Based on the current level of data, the mitigation of impacted historic properties might involve the construction of measures to reduce impacts on the setting of historic buildings or districts, as well as Historic American Building Survey documentation. If impacts are identified, archeological historic properties would require data recovery excavations or avoidance and cemeteries would need disinterment and interment of burials to a new location. The relocation of burials from impacted cemeteries might also involve purchasing land if other arrangements cannot be made.

6.5 COST ESTIMATE

A Class 4 parametric cost, using historical and unit costs, was applied to develop the cost estimate for screening the final array within the alternative reaches in the project areas. A Class 3 cost estimate using a Microcomputer Aided Cost Estimating System (MCACES) was developed for the Recommended Plan. The estimate was divided into 3 construction contracts mirroring the three distinct geographical locations: Orange, Port Arthur, and Freeport, Texas. The engineering design work was premised on a feasibility level of detail and analysis, consistent with the SMART planning process that is necessary to substantiate the Recommended Plan baseline cost estimate. Another key concept is to utilize existing information where applicable. Quantities and design features were developed by the Galveston District (SWG) Engineering Branch. This estimate was prepared using the latest Unit Price Books and labor rates for fiscal year 2016 (October 2015). The estimate was prepared in accordance with ER 1110-2-1302, dated 30 June 2016. The costs were escalated in accordance with the above Engineering Regulation and EM 1110-2-1304, dated 31 March 2016. All data was input into the Total Project Cost Summary Sheet (TPCS). The TPCS also incorporates a formal Cost Risk Analyses was performed with the cooperation of Cost Engineering

Directory of Expertise (DX) of the Walla Walla District. The risks were quantified and a cost risk model developed to determine a contingency at 80% confidence level (CL). The final results of the TPCS broken up by the three main project areas are shown on Table 6-9.

Table 6-9. TPCS Overview

Project Area	Total Project First Cost (**Constant Dollar Basis**)	Total Project Cost (**Fully Funded**)
Orange CSRM	$1,926,224,000	$2,304,741,000
Port Arthur and Vicinity CSRM	$729,069,000	$832,191,000
Freeport and Vicinity CSRM	$593,313,000	$677,193,000
Total	$3,248,607,000	$3,814,126,000

6.6 PROJECT SCHEDULE AND INTEREST DURING CONSTRUCTION

A project schedule was developed for all project components assuming an adequate funding stream. Also as described in section 6.3, A region wide systems approach for construction of Orange 3, Port Arthur and Freeport CSRM Plan, is being recommended to ensure that all of the benefits stated would be achieved. The project schedule included Preconstruction Engineering and Design (PED) and followed normal construction practices under USACE regulations and standards. Lands, easements, right-of-ways, relocations and borrow/disposal areas (LERRDs) were an NFS obligation and were assumed to be provided consistent with a normal construction processes. Port Arthur and Vicinity CSRM and Freeport and Vicinity CSRM project assumed a 72 month construction period and the Orange CSRM project area assumed a 120 month construction period. Interest during construction over these periods are reflected in the fully funded cost shown on Table 6-6.

6.7 DESIGN AND CONSTRUCTION CONSIDERATIONS

Significant consideration was given to the existing infrastructure that is in extremely close prominently to the work areas. Construction activities would be closely monitored to ensure that there is not any damage to industrial facilities or the existing project. Coordination with numerous different stakeholders along with the project local sponsors will be required.

6.8 DEFERRED MAINTENANCE CONSIDERATIONS

Currently the existing Freeport system is “unacceptable” in the Flood Control and Coastal Emergency Act (PL 84-99) program and not certifiable for FEMA accreditation under the National Flood Insurance Program (NFIP) Code of Federal Regulations (44 CFR. Section 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 44 CFR. Section 65.10 accreditation. The local sponsor submitted a System Wide Improvement Framework (SWIF) letter of intent (LOI) to the USACE in November 2012, and this letter of intent was accepted and approved by USACE on January 13, 2013. As part of the formulation process the final recommendation assumed all of the SWIF items, shown on Table 6-10, would be addressed and would not impact the implementation of the final recommendation.

Table 6-10. Deficiency Tabulation from the Freeport and Vicinity Hurricane Flood Protection System (HFPS) System Wide Improvement Framework (SWIF)

Deficiency	Description
Potential Shallow slope stability due to flood side seepage	North and South Barge Canal Levees. These levees were originally dredge spoil from construction of the Barge Canal and subsequently now function as levees. They contain various quantities and quality of sand and clay.
Inadequate Factor of Safety Deep Slope Stability	Old River North Deficiency is deep (circular) slope stability. This reach had marginal factor of safety in the HFPS upgrade post-Carla in 1965. Subsequent construction of 45 ft navigation channel at Port Freeport in 1985 had a negative impact on the slope stability which the DM showed was to be solved during construction by establishing a 95 ft bench(berm) seaward of the toe of the levee. Current soundings do not show evidence of that bench. A new 55 ft navigation channel project for Port Freeport has finished a feasibility study and would exacerbate the stability issue on this reach of the levee, thus, this issue will be evaluated and resolved by USACE as a part of the PED/GRR of the 55 ft. project.
Horizontal pipeline encroachment (4)	East Bank of Brazos River, Old River South, Old River North, North and South Barge Canal (approx. 100 pipelines)
Abandoned Pipelines	178 pipelines system wide (final number subject to increase)
Abandoned Structures	(1) Complex Pump structure at Barge Canal Turning Basin, (1) Old River North (Shell dock); Marine Dock A-5 Old River North, Dow Dock A-7 on South Barge Canal Levee
Potential under seepage	North and South Barge Canal Levees. Soil borings confirmed a sand seam approx. 30+ ft beneath a large portion of these levees and the adjacent Waste Water

Deficiency	Description
	and Fresh Water canals that parallel the levees on the South and North side, respectively.
Potential piping along pipelines in levee, cover unknown	Approx. 350 pipelines in North and South Barge Canal Levees, pipelines in East Bank of Brazos River Levees 1 and 2; Oyster Creek Levees
Docks – Dock design without dynamic loading.	(3) Old River South, Berth 5 (1) Old River North - Dock A-5 (also noted under Abandoned Structures). An independent preliminary dynamic analysis of Wave loading impact of realigned line of protection cause uncertainty of performance.
I-Walls Unknown condition.	Plant B Turning Basin; (1) Old River North - A 611; (3) Old River South. Visual inspection created an uncertainty in performance during design storm.
Potential Structural deficiency	Port Freeport Berth 5 (also listed under Docks), A 801 Sea Water Intake, Old River North,
Poorly maintained sea water intake structure	(1) Old River North A 801 structure, also noted under potential structural deficiency.
Damage to Closure elements	(1) East Bank of the Brazos River 2; (1) Barge Canal Turning Basin
Levee instability due to too steep protected side	(1) Old River South – Phillips Docks; (2) Old River North – at Dow Pump Station; Plant A Shell Dock;
Vertical penetrations below the standard project hurricane surge elevation	All Levees
Interior Drainage	Delineate the ponding areas behind all Levees

6.9 VALUE ENGINEERING (VE)

A VE study was conducted on the Sabine Pass to Galveston Bay Coastal Storm Risk Management Planning Study during the Alternative Formulation and Analysis phase of the SMART Feasibility Study process prior to determining the Tentatively Selected Plan (TSP) that was carried forward into project feasibility development. The VE study validated the final array of planning alternatives and reviewed their preliminary development to assure project value considerations were integrated into the process. Additional details, can be found in the Value Engineering Appendix.

6.10 SEA LEVEL AND CLIMATE CHANGE

In recognition of the uncertainty presented by sea level rise and climate change and the potential for directly proportionate impact in the design assumptions due to the coastal setting of the project, several measures have been incorporated at this stage of the project. Consistent ER 1100-2-8162 and ETL 1100-2-1, all proposed floodwall sections will be constructed to the 50-year intermediate RSLC and will be designed for the greatest hydraulic loading out of the 50-year intermediate, the 50-year high and the 100-year intermediate. These load cases will ensure that the wall will meet all design criteria for the 50 year intermediate and still survive and not suffer a brittle failure under hydraulic loading from the 50-year high or the 100-year intermediate RSLC. All levee sections will be designed to the 50-year intermediate RSLC, with the assumption that they can be more easily adapted to future SLC than the floodwall. The recommended plan for the floodwall will allow for future increases in wall height due to its current robust structural design in the floodwall base and stem.

Drainage features will also be designed with similar considerations to those implemented on the floodwalls, allowing them to withstand the additional loads that should there be a future need to modify the project to address a changing environment. Proposed pump stations will be provided with future expansion considerations in order to be able to handle potential increments in their capacity requirements while minimizing impacts to the structure or the need for an additional one. This recommended approach allows the entire system to be adaptable to the 50-year high or the 100-year intermediate RSLC, which are the proposed performance limits of the systems.

The limits of 50-year high or the 100-year intermediate RSLC were recognized due to the constraints of high ground tie in, levee footprint impacting ultimate levee height, and adaptability constraints on closure structures, navigation gates, and pump stations. The adaptability concept for the RSLC scenarios above the 50-year intermediate will allow for limited overtopping of waves and minor still water overtopping that would then be mitigated for using interior drainage features. This approach also minimizes the initial cost of the floodwall while still allowing for adaptation. The recommended plan for the floodwall will allow for future increases in wall height due to its current robust structural design in the floodwall base and stem.

6.11 REAL ESTATE CONSIDERATIONS

The Non-Federal Sponsors will be responsible for acquiring and furnishing all lands, easements, rights-of-way, relocations (i.e., P.L. 91-646 relocations and utility/facility relocations), borrow material, and dredged or excavated material disposal areas (LERRD) for the project areas, as required. All lands needed for this project will be acquired in fee, with the exception of the land needed for the flood risk reduction levee easements, staging areas, perpetual road easements, and borrow area easements. A Real Estate Plan was developed to present the Real Estate requirements for the Recommended Plan. It is estimated that up to 252 ownerships could be impacted by the Recommended Plan. Additional details, the chart of accounts can be found in the Real Estate Appendix.

6.11.1 Lands, Easements, and Rights-of-Way

The following lists the Lands, Easements, and Rights-of-Way requirements for the Recommended Plan. For the Orange 3 New Levee, current plans indicate 15 miles of new levee (100 to 150 feet wide) and 11 miles of new floodwall (78 feet wide) would be constructed. In support of the construction activities, the following estimates were used:

- 130 acres of perpetual easement for operations and maintenance; and
- Temporary work area easement will be used for staging for three years (20 acres).

For the Port Arthur and Vicinity CSRM, certain portions of the existing 29.04-mile system of levees and floodwalls and/or closure system would be improved or replaced. There will also be a new levee section on the northeastern end of the system measuring 1,830 LF in which a perpetual easements will be needed. All work would be achieved within the existing rights-of-way. In support, the following estimates were used:

- Temporary work area easement will be used for staging areas for 3 years (33 acres)

For the Freeport and Vicinity CSRM, certain portions of the existing 43.12-mile system of levees and floodwalls and/or closure system would be improved or replaced. All work would be achieved within the existing rights-of-way. In support, the following estimates were used:

- Temporary work area easement will be used for staging areas for 3 years (20 acres).

6.11.2 Facility Removals/Utility Relocations

Multiple pipelines would be impacted by this project. An estimate of the number and location of these pipelines was developed and utilized in developing the Orange 3 alternative. Plan formulation costs were based on cost estimates prepared by engineering consultants for a very similar plan in the same general location (Hurricane Flood Protection System, Orange County, Texas (2012), a Flood Protection Planning Study prepared for the Orange County Economic Development Corporation by Carroll & Blackman, Inc., Costello, Inc., and LJA Engineers, Inc.). This cost included relocation costs for pipelines that were identified in the project area using a state database. Cost risks already identified in the risk register relate to uncertainties in the state database. Plans and costs for relocations were developed in greater detail for the Recommended Plan.

6.12 OPERATION AND MAINTENANCE, REPAIR, REHABILITATION AND REPLACEMENT (OMRR&R)

OMRR&R of these facilities would be extensive. The Recommended Plan is a complex system constructed in a marine environment. OMRR&R requirements would include, but not be limited to, biannual exercising of the systems gates and closure structures, grass mowing, painting, pump station O&M, drainage and navigation structure operation, and maintenance and alteration approvals under Section 408. The purpose of OMRR&R is to sustain the constructed project and to maintain the stated level of benefits at the completion of construction. Under 33 U.S. Code 408 (commonly referred to as Section 408), the Secretary of the Army, on the recommendations of the Chief of Engineers, may grant permission for the alteration of a USACE civil works project if it is determined that the alteration will not be injurious to the public interest and will not impair the usefulness of the project. The local sponsors would also be required to coordinate with stakeholders for OMRR&R concerns and evacuation/emergency action planning. The total estimated annual OMRR&R cost is $5,468,000 based on the current Federal Fiscal year discount rate. A majority of the annual OMRR&R costs are based upon sustaining the new levee system under Orange 3. The NFS is not obligated to address loss of risk reduction due to RSLR through future levee lifts or structure modification, but they will still be required to repair, rehabilitation or provide replacement of components to maintain the original project benefits. As part of PED, a OMRR&R manual will be developed to outline the expected OMRR&R requirements. After the District Engineer provides notice of construction completion for the project, or functional portion of the project, the NFS will commence OMRR&R responsibilities associated with the project.

6.13 ECONOMIC ANALYSIS FOR RECOMMENDED PLAN

6.13.1 Summary of Accounts

6.13.1.1 National Economic Development (NED)

Estimated net benefits for the Recommended Plans Separable Elements are listed below by project area. Overall, the estimated Equivalent Annual Net Benefits of the TSP is $300,043,000.

- Orange 3 CSRM - Equivalent Annual Net Benefits = $15,634,000
- Port Arthur and Vicinity CSRM - Equivalent Annual Net Benefits = $106,318,000
- Freeport and Vicinity CSRM - Equivalent Annual Net Benefits = $178,091,000

The Table 6-11 displays the total economic performance of Recommended Plan.

Table 6-11. Economic Performance of Recommended Plan Overview

(FY 2017 Price Level/2.875 percent interest rate)	Recommended Plan
INVESTMENT	
Estimated First Cost	**$3,248,606,000**
Annual Interest Rate	2.875%
Project Life (years)	50
Construction Period (months)	120
Interest During Construction	$368,075,000
Investment Cost	$3,616,681,000
Interest	$103,980,000
Amortization	$33,267,000
OMRR&R ($/year)	$5,467,000
TOTAL ANNUAL COSTS	**$142,713,000**
Without Project EAD	$648,349,000
Residual EAD	$205,594,000
Storm Reduction Benefits	$442,756,000
TOTAL BENEFITS	**$442,756,000**
NET BENEFITS	**$300,043,000**
BENEFIT-COST RATIO	**3.1**

6.13.1.2 Environmental Quality (EQ)

Potential impacts of the Recommended Plan on human and environmental resources have been identified and presented in this document. All factors that were be relevant to the Recommended Plan were considered, including direct and indirect impacts on wetlands, effects on essential fish habitat and listed species, air quality, water and sediment quality, hazardous materials, historic properties, socioeconomic, and environmental justice impacts. Environmental impacts on wetlands are the primary environmental effect. All potential effects are evaluated in Section 7.0.

6.13.1.3 Regional Economic Development Benefits (RED)

The proposed Recommended Plan reduces probabilities of direct damages, but also decreases the occurrence of secondary impacts, such as potential disruptions to refining capacities, which could lead to higher fuel prices.

6.13.1.4 Other Social Effects (OSE)

Based on the qualitative evaluation performed on the Orange 3 CSRM, Port Arthur and Vicinity CSRM, and the Freeport and Vicinity CSRM, the expectation for each project area would be that all plans would positively impact life-safety risk. A quantitative model was not used to determine performance of plans against life-safety risk reduction, but it is expected that the Recommended Plan would have a positive impact and no increase in risk.

6.14 RISK AND UNCERTAINTY

6.14.1 Engineering Data and Models

This section summarizes risk and uncertainty included in some key models and methods applied in this study and documented in the report appendices in more detail.

6.14.1.1 Hydrology and Hydraulics

The hydrologic, hydraulic, and coastal information presented in this report relied heavily on available data gathered from many local, state, and national sources. Some of the information was preliminary, such as the HEC-RAS models for the Neches River, Cow Bayou, and Adams Bayou. The models had been through quality control and assessment by the entities they were acquired from, and additional Quality Assurance/Quality Control was performed by USACE. These models have relatively low risk and uncertainty but should be reevaluated again during PED. Additionally, the watersheds and waterways may change by the time PED begins and this should be addressed at that time.

For most interior drainage areas, hydrologic calculations were performed using the rational and regression methods. These are common methods of estimating rainfall runoff and discharges at outfalls, and their use is permitted by USACE. To reduce uncertainty, two separate rational method calculation formulations and two separate regression formulations were used. The results produced very similar results; typically, the difference was in the 5-10 percent range. More detailed modeling (utilizing HEC-HMS and HEC-RAS), which was not completed during the feasibility, will be performed during PED.

Relative Sea Level Change

The project must consider possible trends that affect the area. One trend that would likely impact the area is RSLC. The degree of uncertainty and values vary considerably amongst the worldwide scientific community, and this issue will likely be debated and methods will likely be improved over time. This study uses current USACE sea level change guidance as required for USACE studies. To account for the unknowns in sea level change, USACE requires evaluation of high, medium, and low scenarios of sea level change projections.

Recommendations to address RSLC scenarios are described in detail in the engineering appendix and summarized here. The entrance channel jetties at both Freeport and Sabine Neches Waterway are high enough that there is no concern of being impacted by RSLC estimates. Levees should be constructed in an adaptable or anticipatory manner for estimated sea level rise if possible. Outfall calculations account for the predicted rise in sea level by increasing size and capacity.

This project utilizes the highest estimated sea level change value following required USACE guidance. Using the “high” estimates in the guidance reduces the risk that sea level change is underestimated or that future estimates may impact the project. Uncertainty is considered by evaluating a range of possible sea level change possibilities from “low” to “high.” It is recommended that RSLC be reevaluated during PED because the understanding of sea level change and USACE guidance may change between the completion of this report and initiation of PED.

Hydrodynamics and Storm Surge

Typical Conditions. Typical conditions were assessed using previous modeling efforts, analysis of existing data, and limited salinity transport modeling. Uncertainties in collected data are transferred to the analyses presented here. ERDC-CHL utilized a Desktop Off-Channel Wetland Salinity Mitigation Model (DOWSMM) to perform an analysis to quantitatively assess the impacts of the proposed gates. DOWSMM modeling is based on previous modeling efforts without site-specific calibration or validation data.

Storm Conditions. Baseline storm surges used for the analysis were composed of the suite of storm surges produced from the Federal Emergency Management Agency (FEMA) Texas Joint Storm Surge Study (JSS). The FEMA Texas JSS used the Advanced Circulation (ADCIRC) model together with the ERDC Steady State Wave model (STWAVE) to perform storm surge and wave simulations. Statistics based on the JSS model runs were updated using the most recent Joint Probability Method-Optimal Sampling (JPM-OS) code.

In the Freeport region, without project storm model results were applied for both with- and without-project conditions. This approach includes uncertainty associated with still water level overtopping and potential adjacent impacts.

Storms at Orange County and Port Arthur were modeled for without-project conditions in the same manner as Freeport. One new with project alignment was modeled as a vertical wall in this region. This approach provides information about adjacent impacts but does not include calculation of still water level overtopping. It also does not include detailed analysis of the separable elements, since all elements were included in the sole with-project model run.

6.14.1.2 Other Engineering Risk and Uncertainty

Risk and uncertainty for the existing systems stems from the use of existing information for the initial assumptions of the feasibility-design. This risk varies from small for I-wall reconstruction/resiliency features in areas where significant information is available, to large risk in areas of levee raising where minimal existing information was available. As described in section 6.4.3 a formal Cost Risk Analyses was performed and risks and uncertainty were quantified and incorporated to the final results of the TPCS.

Other risks and uncertainties associated with the engineering data and modeling are in the assumptions that were made based on the following:

- The accuracy of available information and data collected.
- Assessment of existing physical conditions based primarily on photo imagery and LiDAR data, no on-the-ground physical survey data.
- The preliminary levee system alignments assumed for the Orange CSRM project. Alignments might adjust during feasibility-level design.
- Assessment of the foundation conditions/soil properties for the Orange CSRM project area based on very limited geotechnical investigations.
- Generic conceptual design templates for the levee embankment and floodwall uniformly applied across the new Orange CSRM alignment. Future designs will be tailored to the local conditions and will therefore vary.
- The closure structures with navigable opening and pump stations are conceptual in nature based on similar structures and pump stations that were constructed for the New Orleans Hurricane and Storm Damage Risk Reduction System. These have not been conceptually designed for the CSRM projects.

6.14.2 Economic and Life Safety Risks

The Hydrologic Engineering Center Flood Damage Analysis (HEC-FDA) Version 1.4.0 certified model was used to calculate the damages for the without project existing and future conditions. Measurable damage categories from HEC-FDA including residential and non-residential structures and automobiles are accounted for in the residual damages. Uncertainty related to economics can come from several sources. One source is the structure elevation, which has two components: the topographic ground elevation that a structure sits on, and the structure's estimated first floor elevation. Another source is the value of the structure and its contents. The final source of uncertainty is in the inundation depth/percent damage relationship (usually known as depth damage functions) used to estimate damages to a structure for a given level of flooding. Parameter settings in HEC-FDA account for these uncertainties. Residential, Commercial, and Industrial

Damages: The recommended plan would greatly reduce the equivalent annual storm surge damages in areas behind the new levee system and in areas where the existing systems would be upgraded. However, damages can still occur from project exceedance events, rainfall events, and hurricane winds and windblown debris, particularly in upland areas where drainage features are restricted by railway and roadway features. The recommended risk reduction system is only authorized to address storm surge caused by hurricane and tropical storm events. The levee system is not authorized to be closed under non-hurricane and tropical storm events. Some damages will still occur from rainfall events and from storm surge that exceeds the crest of the system.

The system is expected to withstand storm surges up to the 1% probability storm level, but the level of risk reduction afforded by the recommended plan will depend on the rate at which relative sea level change occurs. The damage analysis incorporates a rate of relative sea level rise equivalent to the intermediate curve prescribed by USACE guidance. The levee system will reduce hurricane and tropical storm surge damages by 68 percent to the existing structures behind the levee system over a 50 year period base on the intermediate RSLR conditions.

Table 6-12 shows the equivalent average annual remaining damages provided by the HEC-FDA model.

Table 6-12. Equivalent Annual Residual Damages - By Components of Recommended Plan

Component	Total Equivalent Annual Residual Damages[1] (FY 2017 Price Level)
Orange 3 CSRM	$59,228,000
Port Arthur and Vicinity CSRM	$104,674,000
Freeport and Vicinity CSRM	$41,692,000

Risk to Life and Safety: Life-safety risks are reduced through effective warnings and evacuation procedures. Warnings are expected to be issued and heeded well before hurricane landfall, thereby removing the residents from harm's way. The erratic nature and unpredictability of hurricane path and intensity requires early and safe evacuation. This policy should be continued both with and without the storm damage reduction project. Additional information on the uncertainties is contained in Appendix C, Economic Analysis, in the Risk Performance of Proposed Action section.

6.14.3 Environmental Data and Analyses

The most current available data were used for environmental analyses of the study area, augmented by brief field visits to the study areas and reviews of habitat classification using the most recent aerial photographs. Ecological modeling was required to quantify impacts or mitigation. Uncertainty is inherent in ecosystems, and therefore unavoidable when evaluating ecological processes and impacts. There is often a lack of extensive data sets for all parameters under study, and many of the physical and biological processes are not completely understood. Ecological analyses for the study utilized input from several engineering models referenced in the table above.

Impact assessments for the Orange CSRM Plan are based in part on assumptions regarding the operating plans that will be developed during PED. Resource agencies have requested to participate in the preparation of this plan to ensure that the system is operated to maintain tidal access to wetlands inside and outside of the levee system. Because of uncertainty associated with project performance, the O&M monitoring should include evaluation of the performance of the culvert system in maintaining tidal flows. Impact assessments are also based upon assumptions regarding the amount of constriction (and thus fisheries access impacts) to Adams and Cow Bayous created by placement of the surge gate structures within the bayou floodways. Impact assumptions should be reviewed when engineering design is sufficiently complete to determine if impacts have been captured appropriately.

There is risk that changes to the alignment may be needed to address unexpected HTRW discoveries during construction. Although no unresolved current or recent hazardous material releases were found near any of the CSRM Plan alignments, most of the refineries and chemical plants have had violations in the past. The HTRW facilities along the construction right-of-way should be more thoroughly investigated with visual inspections and interviews with facility managers to confirm the potential HTRW risks along the levee alignment prior to construction or more detailed design. If significant changes in the alignment are needed, environmental impacts will be reevaluated, and additional NEPA review may be needed.

6.15 CONSISTENCY WITH OTHER STATE AND FEDERAL LAWS

This FIFR-EIS has been prepared to satisfy the requirements of all applicable environmental laws and regulations and has been prepared using the Council on Environmental Quality (CEQ) NEPA regulations (40 CFR Part 1500–1508) and the USACE's regulation ER 200-2-2 - Environmental Quality: Policy and Procedures for Implementing NEPA, 33 CFR 230. In implementing the Recommended Plan, USACE would follow provisions of all applicable laws, regulations, and policies related to the proposed actions. The following sections present brief summaries of Federal environmental laws, regulations, and coordination requirements applicable to this FEIS-EIS.

6.15.1 Clean Air Act

Temporary air emission impacts resulting from construction of the Recommended Plan in the Sabine and Brazoria Regions have been calculated; the analysis is presented in Appendix I. The Sabine Region is currently designated as in attainment or unclassifiable with National Ambient Air Quality Standards (NAAQS); therefore, a General Conformity Determination is not required. Brazoria County is contained within the Houston-Galveston-Brazoria (HGB) Air Quality Control Region (AQCR); this region meets all of the NAAQS, except for ozone. The HGB area is currently classified as being in severe nonattainment for the 8-Hr ozone (1997) standard and marginal nonattainment for the 8-Hr ozone (2008) standard. Direct and indirect emissions would result from temporary construction activities. Construction of the Recommended Plan in this area would result in emissions below the *de minimis* threshold for nonattainment pollutants and thus a conformity determination is not required. In order to reduce impacts associated with emissions of particulate matter and other pollutants, the control measures specified in Section 7.8.2.1 would be included in construction contracts, as applicable and practicable.

Air emissions from the operation of internal combustion engines that produce exhaust result in Greenhouse Gas (GHG) emissions that could contribute to global climate change. The CEQ published “Draft NEPA Guidance on Consideration of the Effects of Climate Change and Greenhouse Gas Emissions", December 18, 2014. The Draft Guidance suggests that the impacts of projects directly emitting GHG in excess of 25,000 metric tons or more of carbon dioxide (CO2)-equivalent (CO2e) GHG emissions per year be considered in a qualitative and quantitative manner in NEPA reporting; however, there are no implementing regulations to direct development of these analyses for Federal projects. GHG emissions are expected to be well below the significance threshold. In order to reduce GHG emissions, emission reduction methods described in Section 7.8.2.2 would be implemented.

6.15.2 Clean Water Act

Section 404 of the CWA regulates dredge-and/or-fill activities in waters of the U.S. In Texas, Section 401 of the CWA (State Water Quality Certification Program) is regulated by the TCEQ. USACE requested and has received Section 401 State Water Quality Certification for the Recommended Plan from TCEQ. Based on the alternatives and environmental consequences analysis presented in this FIFR-EIS, TCEQ has concurred that there is a reasonable assurance that construction of the Recommended Plan would not violate water quality standards and is the least environmentally damaging practicable alternative that meets the project purpose. No impacts to special aquatic sites are anticipated in conjunction with the Port Arthur and Vicinity or Freeport and Vicinity CSRM Plans. However, two types of special aquatic sites (“wetlands” and “sanctuaries and refuges”) would be impacted by construction of the Orange 3 CSRM Plan. The alignment of the Orange 3 CSRM Plan has been carefully situated to avoid and minimize impacts to these special aquatic sites and the aquatic ecosystem to the greatest extent practicable. Unavoidable, significant impacts would be fully mitigated by the proposed Orange CSMR mitigation plan. The CWA Section 404(b)(1) Evaluation (presented in Appendix H) concludes that the discharge of fill material in conjunction with construction of the Orange CSRM plan complies with Section 404(b)(1) Guidelines.

6.15.3 Endangered Species Act

A Biological Assessment (BA) was prepared and coordinated with USFWS and NMFS describing the study area, Federally listed threatened and endangered species of potential occurrence in the study area as identified by the NMFS and USFWS, and potential impacts of the TSP on these protected species (Appendix J). The Recommended Plan results in fewer wetland impacts than the TSP, and no changes to the USACE "no effect" determination. ESA coordination correspondence is provided in Appendix G. USACE has determined that the Recommended Plan would have no effect on the following listed animal species: piping plover, red knot, whooping crane, West Indian manatee, four whale species (fin, humpback, sei, and sperm), four sea turtle species (green, Kemp's ridley, loggerhead and hawksbill), and four coral species (lobed star, mountainous star, boulder star and elkhorn). The Recommended Plan would also have no effect on the following candidate species: Sprague's pipit, and two freshwater mussel species (smooth pimpleback and Texas fawnsfoot). There is no designated critical habitat in the project areas. The USFWS concurred with the USACE "no effect" determinations.

6.15.4 Magnuson-Stevens Fishery Conservation and Management Act

The Magnuson-Stevens Fishery Conservation and Management Act (PL 94-265), as amended, establishes procedures for identifying EFH and required interagency coordination to further the conservation of Federally managed fisheries. Its implementing regulations specify that any Federal agency that authorizes, funds, or undertakes, or proposes to authorize, fund, or undertake, an activity that could adversely affect EFH is subject to the consultation provisions of the Act and identifies consultation requirements. EFH consists of those habitats necessary for spawning, breeding, feeding, or growth to maturity of species managed by Regional Fishery Management Councils in a series of Fishery Management Plans.

Submittal of the DIFR-EIS and its assessment of S2G impacts on EFH to NMFS initiated EFH consultation. Direct and indirect impacts associated with construction of the Orange-Jefferson CSRM Plan would result in the loss of about 203.0 acres of estuarine emergent marsh over the period of analysis. Marsh acres include water within the marsh and small drainages; some SAV in the estuarine marsh areas would also be lost. The Cow and Adam Bayous surge gate structures would constrict flows in these bayous while in their normal open condition, resulting in functional fisheries access impacts on a total of about 2,137 acres of estuarine emergent marsh in the bayou floodplains upstream of the gated structures. Direct and indirect impacts would be fully compensated with the restoration of approximately 453 acres of estuarine emergent marsh and shallow water as described in the mitigation plan. NMFS has determined that USACE has satisfactorily addressed NMFS EFH Conservation Recommendations and no further EFH consultation is required. A summary of the Conservation Recommendations and the USACE response is provided below. The full record of USACE EFH consultation with NMFS is presented in Appendix G.

NMFS provided six Conservation Recommendations (CR) by letter dated October 26, 2015. USACE fully concurs with the CR with the exception of two (Recommendations 2 and 5), as explained further below. NMFS recommended that USACE: 1) develop a complete mitigation plan in consultation with the NMFS Habitat Conservation Division (HCD), 2) complete mitigation within 18 months of the start of construction of the Orange CSRM system, 3) conduct additional modeling and environmental analysis if the Adams and Cow Bayous surge gates constrict bayou cross sections by more than 50 percent; 4) develop an Operations Plan in consultation with resource agencies that ensures that surge gates and culverts remain open except during surge events; 5) reassess functional fisheries access impacts if closures exceed assumptions; and 6) use construction fill material from approved, upland borrow sources.

USACE cannot comply with CR 2. Due the scale of the marsh mitigation features and beneficial use of dredged material from the adjacent Sabine-Neches Waterway (SNWW), it would not be possible to establish tidal elevations and plant wetland vegetation within 18 months of the initiation of levee construction. Construction of the mitigation areas would begin as soon as possible after levee system construction is initiated, and would be complete within 8 years.

USACE provided clarification of the estimated surge gates and culverts closure times in regard to CR 5. At this time, it is assumed that the return interval for storm surges high enough to threaten the project area would be 10 to 15 years. Gates or water control structures would need to be closed for large storm events, even if the storms occur more frequently than this predicted return period. The operating plan for the gates has not yet been developed, but an estimated closure time (one week for each storm event closure or up to two weeks for periodic maintenance) would result in only minor and temporary impacts to fisheries access. The details and schedule of these closures would be determined during preparation of the Operation Plan in consultation with NMFS HCD and the other state and federal resource agencies.

6.15.5 Coastal Zone Management Act

Under the Texas Coastal Management Program (TCMP), enacted under the Coastal Zone Management Act in 1972, the GLO reviews Federal activities to determine whether they are consistent with the policies of the TCMP. USACE prepared a Consistency Determination that evaluated the TSP for consistency with the TCMP and concluded that it was fully consistent to the maximum extent practicable with the enforceable policies of the Texas program. GLO confirmed the USACE consistency determination and recommended no conditions. The Recommended Plan results in fewer wetland impacts than the TSP, and no changes to the USACE consistency determination. TCMP coordination correspondence is provided in Appendix M.

6.15.6 Fish and Wildlife Coordination Act

The Fish and Wildlife Coordination Act (FWCA) provides for consultation with the USFWS and, in Texas, with TPWD whenever the waters or channel of a body of water are modified by a department or agency of the U.S. USFWS and TPWD have actively participated in the extensive resource agency meetings conducted to evaluate impacts and develop mitigation measures for the Recommended Plan.

The CAR's 30 Final Recommendations and USACE responses are summarized in the Table 6-13. The recommendations were followed in developing the Recommended Plan, engineering design considerations and the Mitigation Plan. Readers should refer to Appendix K to see the complete CAR document; CAR recommendations have been integrated in the description of the Recommended Plan throughout the report.

Table 6-13. USFWS Final CAR Recommendations

USFWS Final CAR Recommendations	USACE Response
1. Situate flood risk reduction features to minimize wetland and bottomland hardwood impacts. Fully compensate for any unavoidable losses caused by project features.	Concur.
2. Minimize enclosure of wetlands with levee alignments. Maintain hydrologic connections with unavoidable enclosures or establish non-development easements in those areas.	Concur.
3. Avoid adverse impacts to bald eagle nesting locations and wading bird colonies through careful design risk reduction features and timing of construction.	Concur.
4. Conduct forest clearing associated with project features during the fall or winter to minimize impacts to nesting migratory birds, when practicable.	Concur.

USFWS Final CAR Recommendations	USACE Response
5. Develop a complete mitigation plan to compensate for direct and indirect habitat impacts in consultation with the Service and other state and federal natural resource agencies during final feasibility planning, and implement mitigation construction concurrently with project construction.	Concur. See mitigation plan presented in FIFR-EIS.
6. Include language in the project's first Project Cooperation Agreement (or similar document) specifying the responsibility of the local-cost sharer to provide operational and construction monitoring, and maintenance funds for mitigation features.	Concur.
7. Coordinate PED planning of project features with the Service and other Federal/State resource agencies and provide 30 days for review.	Concur.
8. Avoid impacts to state and federal lands. If not feasible, coordinate with affected agencies until construction of that feature is complete and prior to any subsequent maintenance.	Concur.
9. If mitigation lands are purchased for inclusion within a National Wildlife Refuge (NWR), those lands must meet certain requirements; a general summary of some of the requirements is provided in Appendix A.	Concur.
10. If applicable, a General Plan should be developed by the Corps, through coordination with the Service, and the natural resource agencies in accordance with Section 3(b) of the FWCA for mitigation lands.	Concur.
11. Initiate consultation pursuant to Section 7 of the Endangered Species Act if the proposed project features change, the status of species change, or the project is not implemented within three years of the date of our Endangered Species Act coordination.	Concur.
12. Incorporate larger, numerous openings within a diversity of locations in a risk reduction levee aimed at maintaining estuarine dependent fishery migration.	Concur.
13. Flood protection water control structures in any watercourse should maintain pre-project width and depth to the maximum extent practicable, especially structures located in tidal passes.	Concur.
14. To the extent possible, water control structure sited in canals, bayous, or navigation channels that do not maintain the pre-project cross section should be designed and operated with multiple openings within the structure.	Concur.
15. Should final surge gate structure designs reduce the cross section of Adams or Cow Bayous more than 50 percent, additional modeling and environmental analysis will be performed to characterize potential hydrologic and fish passage impacts and determine additional mitigation requirements.	Concur.

USFWS Final CAR Recommendations	USACE Response
16. Flood risk reduction surge gates, sluice gates, culverts, and any other water control structures should remain completely open except during storm events or regularly scheduled maintenance or inspections. O&M and management plans for structures should be developed in coordination with the Service and other resource agencies.	Concur.
17. The O&M plan should include a schedule of maintenance events for each gate and culvert and proposed closure times for said maintenance activities. A worst case closure scenario is estimated to be 5-7 days every 10-15 years based on predicted storm surge return intervals high enough to threaten areas targeted for risk reduction. However, in years where more than one storm event occurs, we expect the gates to remain closed (5-7 days) for each storm event. Periodic maintenance of the gates and culverts (not included in the worst case scenario) may result in additional closures estimated of not more than two weeks for each instance. Any proposed operational deviation from the estimated frequency or duration of structure closures must be assessed in coordination with the Service and other resource agencies at which time additional mitigation would be required to offset such operational impacts.	Concur.
18. The number and siting of openings in flood risk reduction levees should be optimized to minimize the migratory distance from the opening to enclosed wetland habitats.	Concur.
19. Flood risk reduction structures within a waterway should include shoreline baffles and or ramps (e.g., rock rubble, articulated concrete mat) that slope up to the structure invert to enhance organism passage. Coordinate structure design with the resource agencies.	Concur.
20. To the maximum extent practicable, structures should be designed and/or selected and installed such that average flow velocities during peak flood or ebb tides do not exceed 2.6 feet per second. However, this may not necessarily be applicable to tidal passes or other similar major exchange points.	Concur.
21. To the maximum extent practicable, sluice gates or culverts (round or box) should be designed, selected, and installed such that the invert elevation is equal to the existing water depth and flows are sufficient to prevent siltation.	Concur.
22. Temporary culverts or sluice gates should be installed in construction access roads unless otherwise recommended by the natural resource agencies. Culvert spacing should be optimized on a case-by-case basis in consultation with resource agencies. At a minimum, there should be one, 24-inch culvert or sluice gate placed every 500 feet and one at natural stream crossings.	Concur.

USFWS Final CAR Recommendations	USACE Response
23. Water control structures should be designed to allow rapid opening in the absence of an off-site power source after a storm passes and water levels return to normal.	Concur.
24. Levee alignment and water control structure alternatives should be selected to avoid the need for fishery organisms to pass through multiple structures (i.e., structures behind structures) to access an area.	Concur.
25. Operational plans for water control structures should be developed to maximize the cross-sectional area open for as long as possible.	Concur.
26. Any proposed change in mitigation features or plans should be coordinated in advance with the Service, NMFS, EPA, TPWD, TCRQ, and TGLO.	Concur.
27. A report documenting the status of mitigation implementation and maintenance should be prepared every three years by the managing agency and provided to the Corps, the Service, NMFS, EPA, TPWD, TCEQ, and TGLO.	Concur.
28. Fill material used during the construction of the levees or its associated features should come from an approved upland borrow source that has undergone contaminant testing criteria approved by the EPA.	Concur.
29. The Corps shall fully compensate for any unavoidable losses of wetland habitat (including forested wetlands) or non-wet bottom hardwoods caused by project features as dictated by the Wetland Value Assessment modeling.	Concur.
30. Acquisition, habitat development, maintenance, and management of mitigation lands should be allocated as a first-cost expense of the project to ensure mitigation obligations are met on behalf of the public interest.	Non-Concur. See response in this section.

USACE fully concurs with the USFWS Final Recommendations with one exception. The allocation of mitigation construction, monitoring and maintenance costs are governed by WRDA 1986 and USACE guidance. First costs, which include all costs of acquisition, habitat construction and construction monitoring, are apportioned between the Federal government and the non-Federal sponsor as stipulated by law and USACE policy. Periodic inspections would be conducted as part of normal Operations and Maintenance. Monitoring to determine the success of mitigation measures is primarily the responsibility of the non-Federal sponsor, as specified in the Project Partnership Agreement.

6.15.7 Marine Mammal Protection Act of 1972

The Marine Mammal Protection Act was passed in 1972 and amended through 1997. It is intended to conserve and protect marine mammals and establish the Marine Mammal Commission, the International Dolphin Conservation Program, and a Marine Mammal Health and Stranding Response Program. The Recommended Plan would have no effect on marine mammals.

6.15.8 National Historic Preservation Act

Compliance with the National Historic Preservation Act of 1966, as amended (54 U.S.C. § 306108), requires the consideration of effects of the undertaking on all historic properties in the project area and development of mitigation measures for those adversely affected properties in coordination with the SHPO and the Advisory Council on Historic Preservation. It has been determined that there is a potential for new construction, improvements to existing facilities, and maintenance of existing facilities to cause effects on historic properties. Therefore, in accordance with 36 CFR 800.14, USACE has executed a Programmatic Agreement among USACE, the Texas SHPO, and non-Federal implementation sponsors to address the identification and discovery of cultural resources that may occur during the construction and maintenance of proposed or existing facilities. USACE invited the ACHP and Native American tribes to participate as signatories to the Programmatic Agreement, but both groups declined the invitation. The executed Programmatic Agreement is provided in Appendix L.

6.15.9 Federal Water Project Recreation Act

This 1995 Act requires consideration of opportunities for outdoor recreation and fish and wildlife enhancement in planning water-resource projects. The Recommended Plan is not expected to have any long-term effects on outdoor recreation opportunities in the area.

6.15.10 Farmland Protection Policy Act of 1981 and the CEQ Memorandum Prime and Unique Farmlands

In 1980, the CEQ issued an Environmental Statement Memorandum “Prime and Unique Agricultural Lands” as a supplement to the NEPA procedures. Additionally, the Farmland Protection Policy Act, passed in 1981, requires Federal agencies to evaluate the impacts of Federally funded projects that may convert farmlands to nonagricultural uses and to consider alternative actions that would reduce adverse effects of the conversion. The TSP would have directly impacted approximately 178 acres of prime or otherwise important farmlands. Elimination of levee system reaches and reductions in the width of the construction and permanent rights-of-way for the Orange 3 CSRM Plan reduced these impacts significantly. The Orange 3 CSRM element of the Recommended Plan would permanently convert approximately 36 acres of prime farmland, as defined by the NRCS Web Soil Survey (USDA 2015), into a CSRM levee system. Approximately 61 additional acres would be temporarily unavailable for agriculture while in use as construction staging areas. No prime and unique farmlands would be impacted by construction of the Port Arthur and Vicinity or Freeport and Vicinity CSRM Plans.

Orange 3 CSRM Plan impacts on prime and important farmlands have been minimized to the greatest extent possible by locating the alignment at the upland/floodplain transition. Existing drainage patterns would be maintained, and surrounding land uses would remain compatible with agriculture in so much as they are today. The NRCS evaluated the impacts of the TSP and concluded that the sites would receive a total score of less than 160, and therefore need not be given further consideration for protection. The NRCS impact evaluation is consistent with impacts of the Recommended Plan, which results in fewer prime farmland impacts. NRCS coordination correspondence is provided in Appendix G.

6.15.11 Executive Order 11988, Floodplain Management

This Executive Order (EO) directs Federal agencies to evaluate the potential effects of proposed actions on floodplains. Such actions should not be undertaken that directly or indirectly induce growth in the floodplain unless there is no practicable alternative. The Water Resources Council Floodplain Management Guidelines for implementation of EO 11988, as referenced in USACE ER 1165-2-26, require an eight-step process that agencies should carry out as part of their decision making on projects that have potential impacts on or within the floodplain. The eight step assessment, presented later in this report, concludes that all practicable alternatives have been considered in developing the Recommended Plan, and that the main Federal objective of reducing coastal flood risk cannot be achieved by alternatives outside the floodplain. The Recommended Plan does not support direct or indirect floodplain development within the base floodplain. USACE and the study's NFS have lead public outreach efforts to local communities starting with the NEPA scoping meeting, and will continue throughout the study process.

6.15.12 Executive Order 11990, Protection of Wetlands

This EO directs Federal agencies to avoid undertaking or assisting in new construction located in wetlands, unless no practicable alternative is available. Construction of the Orange CSRM Plan would result in the conversion of about 160 acres of wetlands to a levee system. All practicable measures have been taken to minimize the loss of wetlands. Alternatives to avoid the loss of wetlands were evaluated, and the levee alignment was carefully located to minimize the loss. The alignment was reviewed during the final feasibility phase and impacts were reduced significantly from those presented in the DIFR-EIS. The DIFR-EIS afforded the public an opportunity for review prior to completion of the FIFR-EIS and the selection of a Recommended Plan. Based on these actions and considerations, it has been determined that the Recommended Plan is the only practicable alternative. These impacts will be fully compensated by the mitigation plan so that there will be no net loss of wetlands.

6.15.13 Coastal Barrier Improvement Act of 1990

This Act is intended to protect fish and wildlife resources and habitat, prevent loss of human life, and preclude the expenditure of Federal funds that may induce development on coastal barrier islands and adjacent nearshore areas. The Coastal Barrier Improvement Act of 1990 was enacted to reauthorize the Coastal Barrier Resources Act (CBRA) of 1982. The Gulf shoreline area south and west of the existing Freeport HFP is designated as unit T05. Improvements to the existing levee system would be made within the existing levee right-of-way, which is not included in the CBRA unit. CBRA units in the Sabine Region are more than 10 miles south of the project area. No construction would occur within any of the CBRA zone units in the general area of the Recommended Plan in the Sabine and Brazoria regions.

6.15.14 Executive Order 12898, Environmental Justice

This EO directs Federal agencies to determine whether the Preferred Alternative would have a disproportionate adverse impact on minority or low-income population groups within the project area. Based on a demographic analysis of the study area presented in Appendix R and findings of an environmental justice review, the Recommended Plan would not have a disproportionately high and adverse impact on any low-income or minority population.

6.15.15 Executive Order 13186, Responsibilities of Federal Agencies to Protect Migratory Birds and the Migratory Bird Treaty Act

The Migratory Birds and the Migratory Bird Treaty Act (MBTA) of 1918 (as amended) extends Federal protection to migratory bird species. Among other activities, nonregulated “take” of migratory birds is prohibited under this Act in a manner similar to the ESA prohibition of “take” of threatened and endangered species. Additionally, EO 13186 “Responsibilities of Federal Agencies to Protect Migratory Birds” requires Federal agencies to assess and consider potential effects of their actions on migratory birds (including, but not limited to, cranes, ducks, geese, shorebirds, hawks, and songbirds). The effect of the Recommended Plan on migratory bird species has been assessed, and no impacts are expected on migratory birds or their habitat in the project area. Construction contracts would include instructions to avoid impacts on migratory birds and their nests from construction-related activities.

6.15.16 Executive Order 13045, Protection of Children from Environmental and Safety Risks

This EO requires Federal agencies to make it a high priority to identify and assess environmental health and safety risks that may disproportionately affect children and to ensure that policies, programs, activities, and standards address these risks. This report has evaluated the potential for the Recommended Plan to increase these risks to children, and it has been determined that children in the project areas would not likely experience any adverse effects from the proposed project.

6.15.17 Hazardous Wildlife Attractants On or Near Airports

In accordance with FAA AC 150/5200-33 and the Memorandum of Agreement among the FAA, the USACE, and other Federal agencies (July 2003), the Recommended Plan was evaluated to determine if proposed land uses could increase wildlife hazards to aircraft using public use airports in the study area. Only one element of the Recommended Plan (the Orange 3 CSRM Plan) included features which could be considered wildlife attractants. Potential attractants (three marsh mitigation features) were found to be located beyond the 5-mile perimeter of the Southeast Texas Regional Airport in Beaumont, Texas. No change in land use is proposed in conjunction with construction of two mitigation measures within the five-mile perimeter of the Orange County Airport. USACE provided this information to the FAA concluding that construction of the Recommended Plan would not constitute a change in land-use incompatible with airport operations. At the request of FAA, the TXDOT Aviation Division reviewed the impact analysis and concurred that the Recommended Plan is compatible with operation of the Orange County and Southeast Texas Regional airports. FAA made this request because evaluation of potential environmental impacts to these airports is the responsibility of TXDOT under terms of the FAA State Block Grant Program.

6.15.18 Consultation with Federally-recognized Indian Tribes

In accordance with the USACE Tribal Policy Principles, Presidential Memorandum (April 29, 1994) Government to Government Relations with Native American Tribal Governments, Executive Order 13175 (Consultation and Coordination with Indian Tribal Governments (November 06, 2000), and President Obama's Memorandum of November 5, 2009 – Tribal Consultation, USACE has contacted and coordinated with Federally-recognized Indian Tribes which have demonstrated an interest in the study to obtain their views and assess the impact of the proposed CSRM plans on tribal lands, resources and concerns. The Alabama Coushatta Tribe of Texas, the Comanche Nation of Oklahoma, the Coushatta Tribe of Louisiana, the Kiowa Indian Tribe of Oklahoma, the Mescalero Apache Tribe, and the Tonkawa Tribe of Oklahoma were contacted by letter in November, 2014, to inform them of the upcoming S2G study, invite them to participate as cooperating agencies, coordinate the study schedule, and initiate consultation regarding any concerns the tribes may have regarding potential project impacts to sites, areas or resources of religious, cultural or other tribal interest. No responses were received from the tribes and no concerns or potential impacts were identified. The DIFR-EIS was provided to the same tribes in September 2015, and the tribes were notified that USACE intended to execute a Programmatic Agreement to govern the scope of cultural resource investigations, to be determined in concert with the Texas SHPO and Indian tribes. No comments on the DIFR-EIS or the Draft Programmatic Agreement were received from the tribes. The FIFR-EIS will be provided to the tribes during State and Agency Review.

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7 ENVIRONMENTAL CONSEQUENCES*

Environmental consequences of the No Action Alternative and Recommended Plan are compared below. Impacts described below apply to all of the optimization heights of the alternatives in the Final Array. The right-of-way was sized to include lands needed to construct a levee or floodwall suitable for at least the Intermediate RSLC scenario plus additional lands needed for construction. A comparison of all factors compared in evaluating the Final Array of Alternatives, including environmental effects, is presented in Section 5.4 of this report.

7.1 PROTECTED LANDS

7.1.1 Orange 3 CSRM Plan

No Action Alternative. State-managed lands in the vicinity would continue to be conserved and managed for the benefit of fish of wildlife resources through the period of analysis. The Tony Houseman WMA is located at northeast end of the Orange CSRM Plan, north and south of Interstate 10. The Lower Neches River WMA includes three separate properties along the central section of the CSRM Plan in Orange County.

Recommended Plan. Impacts to TPWD property were avoided and minimized to the greatest extent practicable by modifying the new levee system’s alignment location. Remaining unavoidable impacts of the Orange 3 CSRM plan would consist of approximately 80.1 total acres; 1.7 and 78.4 acres, respectively, in the Tony Houseman and Lower Neches River WMAs. Details of these impacts are shown in Table 7-1. Approximately 34.6 acres would be right-of-way impacts, while approximately 45.5 acres are remainders that would be not affected by construction, but cut-off from the rest of TPWD property in the area. In the Tony Houseman WMA, approximately 1.5 acres of the right-of-way impacts are forested wetlands and adjacent waters. In the Lower Neches WMA, approximately 19.8 acres of the right-of-way are wetlands, with the majority of impacts occurring to coastal marsh. The wetland impacts have been evaluated and quantified with the WVA model along with the other impacts of this plan. The plan would not impact any TPWD structures. All impacts are fully compensated by the overall mitigation plan described for the Orange 3 CSRM project. TPWD has agreed that the feasibility-level impact analysis is sufficient at this time, pending additional study and consultation during the PED phase as planned by USACE. Final approval or concurrence by TPWD cannot occur until requirements of Chapter 26 of the Parks and Wildlife Code are met, and that would occur after the project is authorized. At this time, no obstacles to this approval have been identified.

Table 7-1: Impacts on TPWD Property

	Acres of TPWD Property Impacts								
Property Name	BH	Swamp	Fresh	Intmd	Brackish	Water	Other	Remnants	Total
Tony Houseman WMA	0.5	0.4				0.7	0.0	0.2	1.7
Lower Neches River WMA									
Adams Bayou Unit		1.4	4.8	1.5		0.3	3.6	7.2	18.8
Old River Unit	0.2	0.0	3.9	0.0	2.8	0.2	10.0	37.3	54.5
Nelda Stark Unit	2.6		0.5				1.1	0.8	5.0
Total	3.3	1.8	9.2	1.6	2.8	1.1	14.8	45.5	80.1

7.1.2 Port Arthur and Vicinity CSRM Plan

No Action Alternative. State-managed lands in the vicinity would continue to be conserved and managed for the benefit of fish and wildlife resources through the period of analysis. The Big Hill Unit of the J.D. Murphree WMA is located on the west bank of Taylor Bayou, adjacent to the southwest levee of the existing Port Arthur HFP system.

Recommended Plan. No direct or indirect impacts on TPWD property or other protected lands are expected in conjunction with improvements to the Port Arthur CSMR Plan.

7.1.3 Freeport and Vicinity CSRM Plan

No Action Alternative. State-managed lands in the vicinity of the Freeport HFP system would continue to be conserved and managed for the benefit of fish and wildlife resources through the period of analysis. The Brazoria NWR and Justin Hurst WMA are located near the east and west boundaries, respectively, of the existing Freeport HFP system. These lands would continue to be managed for conservation and the benefit of fish of wildlife resources through the period of analysis.

Recommended Plan. No direct or indirect impacts on USFWS or TPWD property are expected in conjunction with improvements to the Freeport CSRM Plan.

7.2 PHYSICAL AND HYDROLOGICAL CHARACTERISTICS

7.2.1 Orange 3 CSRM Plan

No Action Alternative. The existing Sabine-Neches Waterway (SNWW) 40-foot deep-draft navigation channel passes through the study area, following the Orange-Jefferson County line.

Deepening of the existing channel to -48 feet MLLW was authorized by the Water Resources Reform and Development Act (WRRDA) of 2014. Deepening the channel would allow the saltwater wedge in the deep draft navigation channel to reach further inland and increase salinity in the lower Neches and Sabine River channels, as well as Sabine Lake (USACE, 2011). Since construction of the deeper channel is likely in the foreseeable future, projected FWP salinities from the SNWW feasibility study have been utilized as the FWOP salinities for impact evaluation in this study.

Future rates of freshwater inflow and RSLC are likely to result in significant changes in the FWOP condition for the study area (National Research Council [NRC], 1987; Intergovernmental Panel on Climate Change [IPCC], 2013; Milliken et al., 2008a). FWOP forecasts of salinity, marsh loss, and related impacts on plant and animal communities in the study area are important in establishing the baseline condition against which FWP impacts are measured. Project impacts and costs have been assessed against 50-year projections of the three potential rates of RSLC calculated for Sabine Pass, TX (Low – 1.63 feet; Intermediate – 2.32 feet; and High – 4.51 feet).

The high, generally flat terrace between the Sabine and Neches Rivers is on average 10 feet higher than the surrounding floodplains of the two rivers. Similarly, on the west bank of the Neches River, the flat coastal plain averages 10 to 15 feet higher than the floodplain. Extensive marshes line the Neches River floodplain on both sides of the river; however, the majority occur on the east side in Orange County. On the Sabine River, extensive marshes extend east from the river into Louisiana. In Texas, the narrow floodplains of Cow and Adams Bayous are lined with narrow fringes of forested wetlands, which give way to large marshes where they reach the Sabine River. These are the largest drainages in the Orange County area and are nearly the only drainages flowing east into the Sabine River. The western edge of the Orange County upland is drained by numerous, evenly spaced, small drainages, which cut from the upland to the large marshes in the Neches River floodplain. A few even smaller drainages flow into the Neches floodplain from the Jefferson County side. A map of the Sabine regions drainages and sub-basins is shown in Figure 7-1.

In the existing condition, freshwater inflows from the upland areas to marshes and forested wetlands in the floodplain are being conveyed primarily through existing stream channels. The majority of the time, flows are directed toward channels and ditches that discharge into the floodplain through existing drainages. Water flows into the Sabine and Neches Rivers through channels with incised beds, and in some cases flows spread out directly into wetland areas. Overland sheet flow is generally temporary, occurring during intense or long duration rain events. The degree to which shallow groundwater aquifers may contribute flows to the floodplain is unknown, but groundwater flows are assumed to be a minor contributor. It is believed that marshes in the floodplain rely primarily on rainfall and tidal push for inundation.

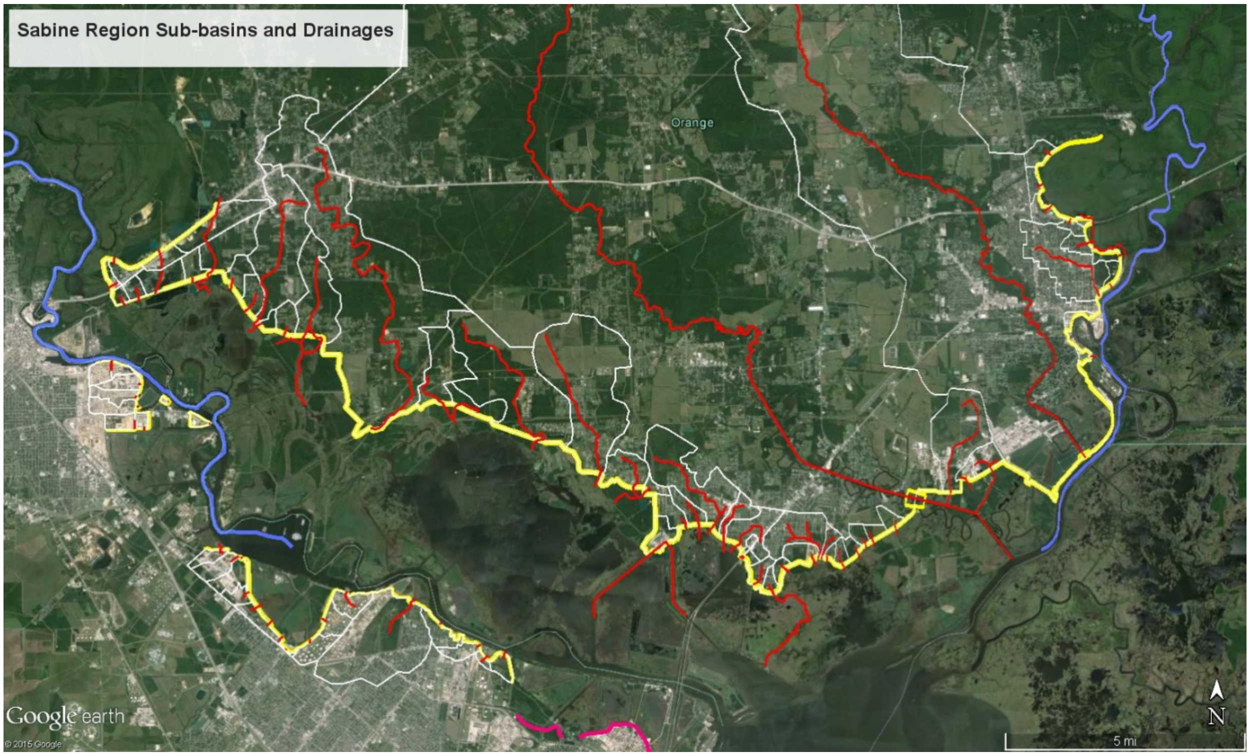

Figure 7-1: Sabine Regions Sub-basins and Drainages

The relatively high difference in elevation between the floodplain and the uplands will protect most of the developed upland areas from the effects of RSLC for the period of analysis. However, the larger tidal prism and higher water elevations will result in higher water levels in the large and small drainages, which cut from the uplands to the river valleys. Marshes may migrate further inland along these drainages as a result of the higher RSLC conditions.

Recommended Plan. Construction of the Orange CSRM Plan would result in a new levee/floodwall system around the southern upland/floodplain margin of Orange County . Such a system could potentially affect freshwater inflows to the floodplain downstream of the levee system by blocking or redirecting flows, and by inhibiting tidal flows into marshes located upstream of the levee system. The design of the levee/floodwall system would minimize these impacts to the greatest extent possible through the inclusion of an extensive culvert system that would allow flows through the levee at essentially FWOP conditions. Since discharge patterns and flows through the proposed Orange 3 CSRM system should be similar to future without-project conditions, impacts to sediment transport would be minimal. In addition, an analysis of potential effects of the Adams and Cow Bayou surge gates (presented in Appendix D), indicates that these gates would have little impact on sediment transport if designed to maximize flows during storm events. Flows in those bayous are very slow and the tidal prisms are very limited, so even a constriction as large as 50 percent would have negligible impacts on water surface elevations and salinities, even during large storm events. Under median flows and the maximum constriction assumed for the modeling, some impacts to maximum inlet velocity and wetland water surface elevation are possible if surge coincides with a large freshwater inflow event. These impacts can and will be mitigated by inclusion of design elements, such as vertical lift gates next to the surge gates and gated culverts in the adjacent levee system.

7.2.1.1 Design Accommodations to Minimize Impacts

Gated culverts would be placed everywhere the red drainage lines intersect the yellow levee alignment shown in Figure 7-1. Sluice gate culverts are planned for use everywhere there are tidal flows; flap gate culverts may be utilized in upstream areas above tidal influence. The levee alignment, drainage basins and proposed culvert locations were evaluated in detail using aerial images to check for smaller, secondary drainages where culverts would also be needed to maintain flows to adjacent wetlands. Approximately 13 new culverts, recommended as a result of this analysis, have been incorporated into the project design where additional connectivity appeared to be needed.

Culverts have been designed to maintain existing flows for a 100-year rainfall event, with an additional 10 percent to account for the predicted increase in rainfall due to climate change over the period of analysis. The sluice gates would remain open except when surge risk reduction is needed; they would be closed temporarily for a short period before and after a storm occurs. Flap gate culverts would provide for one-way flow downstream from the levee system. Both culvert types will be designed with longer spans and lower heights than would typically be used in an attempt to replicate the natural drainage profile.

In the existing condition, freshwater inflows from the upland areas to marshes and forested wetlands in the floodplain are being conveyed primarily through existing stream channels. The majority of the time, flows are directed toward channels and ditches that discharge into the floodplain through existing drainages. A channel would be constructed along the inside of the levee system to collect flows and direct them into the existing stream channels, replicating the flow pattern of the majority of flows entering the floodplain. Impacts from overland flows are expected to be minimal because these flows are minor and temporary.

During a surge event, the sluice gates in the culverts would be closed; pumps would be used to pump rainfall runoff from the interior to the exterior. The pumps are being conservatively sized to avoid floodplain impacts on the interior of the levee system, and to allow overbank flooding in the streams in the floodplain outside of the levee during high flow events. Hydrologic flows in the

FWP condition would thus be very similar to FWOP flows in location, duration, and magnitude, both inside and outside of the levee system.

Based on these assumptions, it was determined that the levee would have negligible impacts on the general hydrology of the floodplain both inside and outside of the levee system. Because this determination rests heavily on these assumptions, resource agencies have requested to be involved in the development of the Operation Manual during the PED phase and during subsequent periodic reviews when the Operation Plan is reevaluated to determine project performance under future conditions, including potentially higher than anticipated rates of RSLC.

The potential for hydrologic impacts of proposed surge gates on Adams and Cow Bayous was evaluated using ERDC's DOWSMM desktop hydrologic model. This modeling indicates negligible impacts on the water surface elevation and salinity within Adams and Cow Bayous from potential constrictions to the channel cross-section with the proposed surge gates in their normal open condition. This was determined by a sensitivity analysis conducted on the inlet size for each bayou, based on the assumption that construction of the gates would result in some reduction of the cross-section while open to daily flows. In the analysis, bayou cross-sections were reduced by a wide range of estimated parameters, up to a maximum 75 percent constriction. It was determined that the limited tidal prism associated with the bayous results in minimal energy loss across the connection between the bayous and the Sabine River, and therefore, constriction of this access point results in little change in the tidal energy passing into the bayou. The insensitivity of the water surface elevation and the salinity impacts gives high confidence that the general conclusion associated with this study is robust; constriction of the inlet, even significant constriction, results in minimal impacts on water surface elevation and salinity within the bayous.

The extent to which these constrictions would impound stormwater within the bayous was also examined by evaluating the effects of a significant rainfall event (Tropical Storm Allison) that had been captured in the median flow simulation. Once again, this analysis applies to the normal, open condition of the gate and evaluated the impacts of rainfall not associated with a significant storm surge event. Given the type of structures currently being evaluated (sector gates on the navigation channels with one or more flanking vertical lift gates to maintain flows on one or both sides of the navigation gates), it is estimated that existing flows may be reduced by a maximum of 50 percent. The DOWSMM analysis showed that, even for a 50 percent constriction, the volume of water resulting from such a storm could still pass through the constriction with little impact on upstream stage. There was no attempt made to determine if this storm event represented a project flood, and hence a larger storm could have a more significant impact.

Impacts related to the temporary closure of the gates were also considered to determine whether fisheries migration would be impacted with short-term surge-related gate closures. The degree of impact would be influenced by the timing and duration of a structure closure relative to peak migration seasons. At this time, it is assumed that the return interval for storm surges high enough to threaten the project area would be 10 to 15 years. Gates and culverts would need to be closed for large storm events, even if the storm occur more frequently than this predicted return period. The Operating Plan for the gates and culverts has not yet been developed, but the estimated closure time (one week for each storm event or up to two weeks for periodic maintenance) would result in only minor and temporary impacts to fisheries access. It is not anticipated that the gates, once closed, would remain closed for an extended period. The project design includes a pump system that would significantly reduce the flood duration upstream of the structures after when the gates are closed. It must be noted, however, that should the final structure design of the Cow and Adams surge gates reduce the cross section of the bayous by more than 50 percent, additional modeling and environmental analysis would be needed to more thoroughly characterize potential hydrologic impacts of the gate structures.

7.2.1.2 Unavoidable Indirect Impacts

Despite all efforts to minimize impacts, some indirect functional impacts of the Orange 3 CSRM Plan remain. These are related to fisheries access impacts on the extensive marshes in the lower Cow and Adams Bayous floodplains from the Cow and Adams Bayou surge gate structures, and to localized hydrologic impacts caused by levee system location and construction.

Based on all of the above analyses and assumptions, it appears that the only significant impact of the Cow and Adam Bayous surge gate structures would be reductions in fisheries access to estuarine marshes associated with the day-to-day operation in the open condition. The fisheries impacts are discussed in detail in the section on fish and wildlife impacts below.

A few localized indirect hydrologic impacts remaining after avoidance and minimization efforts were also identified. An analysis of the location of the levee system alignment identified small areas that would be impounded between the new levee and terrace bluff. These impoundments would result in the loss of small stands of swamp and bottomland hardwood. Construction of the Cow Bayou gate structure and levee system would indirectly affect a few areas both inside and outside the levee system by permanently disrupting tidal connections. Tidal access to one bottomland hardwood area outside of the levee would also be permanently disrupted by levee construction activities. Indirect impacts in the vicinity of the Cow Bayou structure could be higher under the Intermediate and High RSLC, as wetlands could have persisted and migrated further inland in without the hydrologic disruptions caused by gate construction. Specific information on these losses is provided in the Coastal Marsh and Forested Wetland impact sections below.

The indirect wetland impacts described above have been captured and quantified with WVA modeling that is described in detail in Appendix O. Impacts calculated for the Intermediate RSLC condition were utilized to determine compensatory mitigation.

7.2.2 Port Arthur and Vicinity CSRM Plan

No Action Alternative. The area served by the existing Port Arthur HFP System is densely covered with residential, commercial, and industrial development with a few isolated wetland areas. Drainages flow primarily into the Neches River to the north, the Sabine-Neches Canal to the east, and Taylors Bayou to the west. The configuration of the HFP would continue to be maintained at the existing dimensions. Higher water levels associated with Intermediate and High RSLC could result in overtopping during future storm surges.

Recommended Plan. The Port Arthur CSRM Plan improvements would not result in physical impacts on the floodplain or hydrology; no changes in the general layout of the right-of-way are planned. Interior drainage would be managed in the same manner as the Orange CSRM Plan, such that improvements would have negligible impacts on the general hydrology of the floodplain both inside and outside of the levee system. No impacts on the large marsh systems west of the Port Arthur CSRM Plan are expected.

7.2.3 Freeport and Vicinity CSRM Plan

No Action Alternative. The existing Freeport Harbor Project (FHP) 45-foot deep-draft navigation channel extends from deep water in the Gulf of Mexico into the south-central area of the existing Freeport HFP system. Freeport Harbor is located on the Old Brazos River Channel, which dead-ends near State Highway 288. The waterway is heavily developed with industrial and commercial properties, including petrochemical manufacturing and storage terminals, warehousing, and related businesses. Deepening of the existing channel to 56 feet MLLW was authorized by the Water Resources Reform and Development Act (WRRDA) of 2014. Deepening the channel is not expected to have significant effects on salinity or circulation since proximity to the Gulf and lack of freshwater inflows make existing salinities in the channel very high.

Future rates of freshwater inflow and RSLC are likely to result in significant changes in the FWOP condition for the study area (National Research Council [NRC], 1987; Intergovernmental Panel on Climate Change [IPCC], 2013; Milliken et al., 2008a). FWOP forecasts of salinity, marsh loss, and related impacts on plant and animal communities in the study area are important in establishing the baseline condition against which FWP impacts are measured. Project impacts and costs have been assessed against 50-year projections of the three potential rates of RSLC calculated for Freeport, TX (Low – 1.26 feet; Intermediate – 1.94 feet; and High – 4.13 feet).

The area within the Freeport HFP system is dense industrial and commercial development, with small residential areas. No natural wetlands are present in the majority of this area; however, marsh and forested wetlands are present in areas adjacent to Oyster Creek on the northeastern side of the system. Existing interior drainage systems have maintained sufficient flows to allow these areas to persist despite their location within the levee system.

Recommended Plan. The Freeport CSRM Plan would replace floodwalls, raise levees, and install resiliency features. Improvements would be made within the existing project right-of-way and thus would have little impact on physical characteristics of the system. A surge gate structure, similar to those proposed for Cow and Adams Bayous in the Sabine region, is proposed for the DOW Barge Canal. This is a man-made, dead-end, industrial canal lying in the center of the existing Freeport HFP system; no wetlands lie along the canal. The gate would normally remain open, being closed for short periods before and after expected storm surges. Construction of the gate would result in some degree of flow constriction, but effects on salinity and water surface elevation would be low because of the limited tidal prism associated with the canal.

7.3 COASTAL PRAIRIE

7.3.1 Sabine Region CSRM Plans

The Orange 3 and Port Arthur and Vicinity CSRM Plans are combined for this impact evaluation.

No Action Alternative. No remnant tracts of native tall grass or salty prairies have been identified in the Sabine region project areas.

Recommended Plan. Recommended Plan improvements would be contained within the existing right-of-way; no impacts on coastal prairie are anticipated.

7.3.2 Freeport and Vicinity CSRM Plan

No Action Alternative. Coastal prairie would continue to be critically imperiled in the Brazoria region. No remnant tracts of native tall grass or salty prairies have been identified in the study area. The nearest known prairie restoration sites are located in the Brazoria and San Bernard NWRs, located east and west of the Brazoria study area.

Recommended Plan. Improvements would be contained within the existing right-of-way. No impacts to coastal prairie are anticipated.

7.4 COASTAL MARSH

7.4.1 Orange 3 CSRM Plan

No Action Alternative. Tens of thousands of acres of coastal marsh are present in the study area, located primarily in the floodplains of the Sabine and Neches Rivers, as well as Cow and Adams Bayous. These marshes would be expected to persist, with some areas undergoing slow wetland loss and conversion to open water over the period of analysis. In the lower Neches River Valley, this conversion is caused by subsidence and faulting (sometimes related to oil and gas production), dredged canals, alteration of hydrologic regime (due to channelization and placement of dredged material), decreased input of fluvial sediment (due to upstream dams), and construction of artificial levees (White and Tremblay 1995). Similar factors are responsible for marsh loss in the Sabine River Basin. Recent wetland loss rates (1984-2014) have been calculated by USGS for 12 subunits of the study area by analyzing multiple dates of cloud-free Landsat imagery from 1984-2014 (USGS 2014). The loss rates range from a low of 0.0052 percent per year in the Bessie Heights area on the Neches River, to a high of 0.0982 percent per year in the Old River Cove area along the north shore of Sabine Lake. These rates would be expected to increase under the Intermediate and High RSLC scenarios. This expectation is based on the negative relationship between RSLC and wetland loss rates that has been observed in coastwide non-fresh marshes outside of active deltaic influences in Louisiana (USACE, 2013).

Recommended Plan. Direct impacts from construction of the 27-mile-long levee/floodwall system in Orange County would result in the loss of about 105.3 acres of coastal marsh (fresh – 24.3 acres; intermediate – 6.8 acres; brackish – 74.2.0 acres) and 49.0 AAHUs. The right-of-way was sized to include lands needed to construct a levee or floodwall suitable for the Intermediate RSLC scenario plus additional lands needed for construction, and it was assumed that all wetlands within the right-of-way would be permanently lost due to construction. The plan currently calls for all earthen material for the levee system to be obtained from approved, commercial, upland borrow sources. If new borrow areas are identified during final feasibility planning or prior to construction, these areas will be evaluated for impacts in coordination with the resource agencies and the appropriate NEPA document will be prepared. Staging areas needed to support construction have been located in previously disturbed or non-wetland upland areas.

Construction of the new levee system would also result in some indirect impacts resulting in the loss of marsh. A careful examination of the proposed alignment identified several areas where marsh would be impounded between the levee or floodwall and the upland bluff, or where hydrologic connections would be permanently disrupted by levee system construction. These indirect impacts would result in the loss of about 97.7 acres of intermediate and brackish marsh and 43.7 AAHUs.

The direct and indirect coastal marsh impacts described above have been illustrated, captured, and quantified with WVA modeling that is described in detail in Appendix O. Impacts calculated for the Intermediate RSLC condition were utilized to determine compensatory mitigation.

7.4.2 Port Arthur and Vicinity CSRM Plan

No Action Alternative. Fresh and intermediate wetlands are located within the existing levee system, with the majority clustered in a low-lying central area. Some wetlands are located along the exterior perimeter of the levee system, along the Neches River and Taylor Bayou. The floodplain marshes are experiencing wetland loss rates similar to marshes in Orange County, but would be expected to persist through the period of analysis.

Recommended Plan. Improvements from the Port Arthur CSRM Plan would result in no impacts on coastal marsh. All construction activities would be confined to the existing right-of-way or immediately adjacent industrial areas.

7.4.3 Freeport and Vicinity CSRM Plan

No Action Alternative. No natural wetlands are present in the majority of the area served by the existing Freeport HFP system; however, marsh and forested wetlands are present in areas adjacent to Oyster Creek on the northeastern side of the system. These areas would be expected to persist through the period of analysis.

Recommended Plan. No coastal marsh would be impacted by construction of the Freeport CSRM Plan. Recommended Plan improvements would be made within the existing project right-of-way and thus will have no impact on coastal marsh. BMPs would be utilized to ensure no inadvertent filling of adjacent marsh areas during construction.

7.5 FORESTED WETLANDS

7.5.1 Orange 3 CSRM Plan

No Action Alternative. Thousands of acres of forested wetlands are present in the study area, located primarily in the upper floodplains of the Sabine and Neches River, and along Cow and Adams Bayous. Isolated stands of bottomland hardwoods are also scattered across the undeveloped interior of Orange County. Swamps would be subject to increasing stress due to salinity increases associated with RSLC. It is expected that some of the forested wetlands would be lost to development over the period of analysis. Generally, development activities are regulated under Section 404 of the Clean Water Act, and these losses would likely be replaced by required compensatory mitigation. Other unregulated losses would also be expected, especially in relation to silviculture and borrow area activities that are expected to continue in the study area. Depending upon specific circumstances, these activities may not be regulated and forested wetland losses would not be replaced.

Recommended Plan. Direct impacts during construction of the new levee system would result in the loss of about 54.9 acres of forested wetland (swamp –10.6 acres; bottomland hardwood – 44.3 acres), resulting in the loss of 37.4 AAHUs. The right-of-way was sized to include lands need to construct a levee or floodwall suitable for the Intermediate RSLC scenario plus additional lands needed for construction, and it was assumed that all wetlands within the right-of-way would be permanently lost due to construction.

Construction of the new levee system would also result in some indirect forested wetland impacts. Approximately 14.6 acres of swamp and bottomland hardwoods would be impounded between the levee or floodwall and the upland bluff, or would be adversely affected by disrupted tidal access. These impacts are expected to result in the eventual loss of the forested wetlands, represented by a loss of 5.2 AAHUs.

The direct and indirect coastal marsh impacts described above have been captured and quantified with WVA modeling that is described in detail in Appendix O. Impacts calculated for the Intermediate RSLC condition were utilized to determine compensatory mitigation.

7.5.2 Port Arthur and Vicinity CSRM Plan

No Action Alternative. Small pockets of forested wetlands (primarily bottomland hardwoods) are scattered through the less densely developed areas within the levee system. A few small bottomland hardwood areas are located adjacent to the levees along the Neches River. It is expected that some of the forested wetlands would be lost to development over the period of analysis. Generally, development activities are regulated under Section 404 of the Clean Water Act, and these losses would likely be replaced by required compensatory mitigation.

Recommended Plan. Recommended Plan improvements would result in no impacts on forested wetlands. All construction activities would be confined to the existing right-of-way or immediately adjacent industrial areas.

7.5.3 Freeport and Vicinity CSRM Plan

No Action Alternative. Small pockets of forested wetlands (primarily bottomland hardwoods) are scattered through the less densely developed areas within the levee system. The greatest concentration is scattered along the levees adjacent to Oyster Creek. It is expected that some of the forested wetlands would be lost to development over the period of analysis. Generally, development activities are regulated under Section 404 of the Clean Water Act, and these losses would likely be replaced by required compensatory mitigation.

Recommended Plan. All improvements would be made within the existing project right-of-way and thus would have no impact on forested wetlands. Best management practices would be utilized to ensure no inadvertent impacts on adjacent wetland forests during construction.

7.6 IMPACTS TO FISH AND WILDLIFE AND THEIR HABITATS

7.6.1 Fish and Wildlife Impacts

7.6.1.1 Sabine Region CSRM Plans

The Orange 3 and Port Arthur and Vicinity CSRM Plans are combined for this impact evaluation.

No Action Alternative. Natural habitats within the Orange 3 CSRM Plan construction right-of-way would continue to provide cover, roosting, foraging, and nesting habitat for fish and wildlife during the period of analysis. Some marsh may convert to open water in the Sabine and Neches River floodplains, but most of the wetland habitats would be expected to persist over the 50-year period of analysis. In Orange County on the Sabine River and in the vicinity of Bridge City, the majority of the upland/floodplain transition in the area considered for the new levee alignment is lined by development or placement areas. Between Bridge City and Rose City, most of the upland/floodplain transition is undeveloped.

In Jefferson County, the transition from the uplands to the Neches floodplain in the area affected by the CSRM plan is lined with continuous urban or industrial development. Wildlife accesses the floodplain using narrow corridors through development or crossing over leveed placement areas, in addition to passing through natural areas. Fishery access is unobstructed in most streams and bayous. Fish and wildlife access is unobstructed across the levees of the existing Port Arthur HFP levee system, on the northeast and southwest sides of the system. The right-of-way of the existing system is maintained as cleared, grassy levee with side slopes, and as floodwall systems. Existing culverts are open in their normal, operating condition; they are closed for short periods before and after storm surge events.

Recommended Plan. Direct impacts of construction of the Orange 3 CSRM Plan would result in the destruction of approximately 160.2 acres of natural fish and wildlife habitat over the 50-year period of analysis; indirect impacts described above would result in the loss of approximately 112.3 acres of forested wetlands and marsh. No direct or indirect impacts on fish and wildlife habitat would be expected from construction of the Port Arthur and Vicinity CSRM Plan. During construction, fish and wildlife would be able to move out of construction corridors into adjacent habitat and avoid harm; however, competition for remaining habitat might result in a small reduction in wildlife productivity. BMPs would be enforced to prevent fill material from entering nearby wetlands or waters. Forest clearing during construction would be conducted during the fall or winter to minimize impacts on nesting migratory birds, when practicable. Forested areas in the construction right-of-way would be surveyed prior to construction to avoid impacting nesting bald eagles. Adverse impacts to bald eagle nesting locations would be avoided in accordance with the National Bald and Golden Eagle Management Guidelines, as recommended by the USFWS CAR for this project. Terrestrial wildlife would be able to cross-earthen levee segments to access remaining habitat on either side, as it does now across the levees of the Port Arthur HFP. Floodwall segments would generally be located in developed areas and limited in length; wildlife would be able to utilize nearby levee segments for access as needed. Fisheries access would be maintained at FWOP levels with only negligible impacts as described in the physical and hydrological impacts section.

The Cow and Adam Bayous surge gate structures would result in functional impacts to fisheries access and minor effects on sediments, nutrients and organic matter transfer in extensive marshes in the bayou floodplains upstream of the gated structures (Figures 7-2 and 7-3) from day-to-day operation in the open condition. These impacts could be expected to affect approximately 1,300 and 900 acres of coastal marsh in the Cow and Adams Bayou floodplains, respectively, resulting in the loss of 50.5 AAHUs over the period of analysis. The upstream limit of the affected areas, defined to include all upstream marshes in the bayou floodplains, is approximately 7.7 stream miles upstream of the Cow Bayou structure and 4.4 stream miles upstream of the Adams Bayou structure.

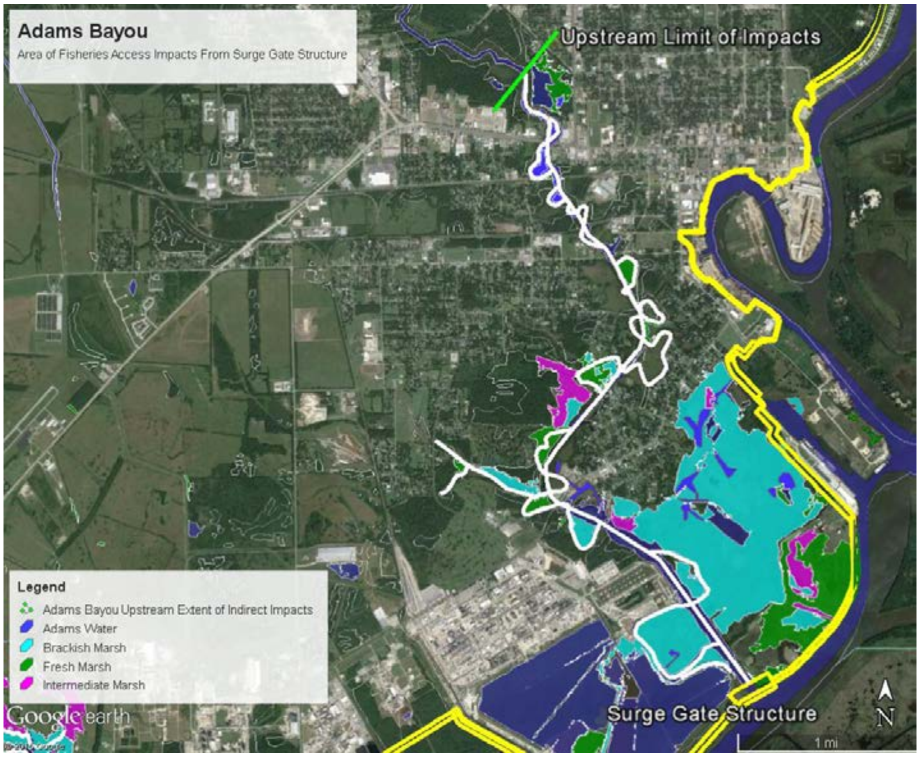

Figure 7-2: Adams Bayou Indirect Fisheries Impact of Surge Gate Structure

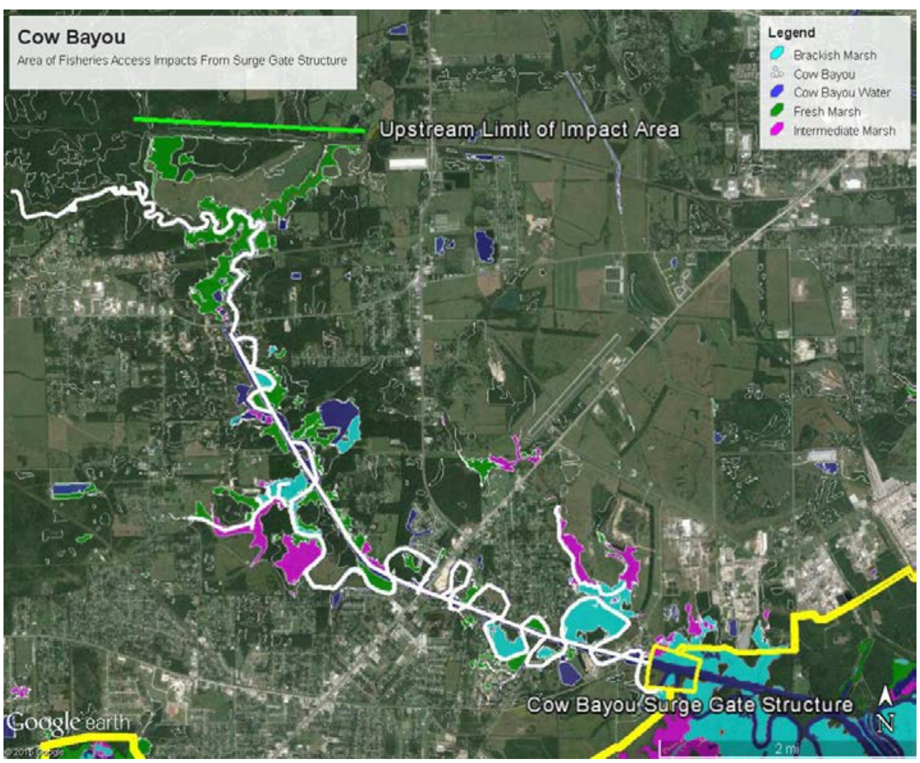

Figure 7-3: Cow Bayou Indirect Fisheries Impact of Surge Gate Structure

According to the NMFS (2008), the ability of estuarine dependent marine fishery organisms to migrate to and from coastal habitats decreases as structural restrictions increase, thereby reducing fishery production (Hartman et al. 1987; Rogers et al. 1992; Rozas and Minello 1999). The physical ability (i.e., swimming speed) to navigate through a structure is not the only factor influencing fish passage. Both behavioral and physical responses govern migration and affect passage of fishery organisms through structures. These responses may vary by species and life stage. In addition, most marine fishery species are relatively planktonic in early life stages and are dependent on tidal movement to access coastal marsh nursery areas. For this reason, in general, the greater the flow through a structure into a hydrologically affected wetland area, the greater the marine fishery production functions provided by that area. It should not be assumed that structures that have been determined to provide sufficient drainage capacity also optimize or provide adequate fishery passage. Structures constructed along the sides of Cow and Adams Bayou would interfere with organism movement into and out of the bayou, but this impact could be minimized by following specific NMFS design recommendations.

Since only preliminary information on the Cow and Adams gate structures is available at this time, the WVA indirect impacts analysis assumed that the structures would reduce the cross-sectional area of the bayous by 50 percent. Final structural designs would incorporate fisheries-friendly considerations recommended by NMFS (2008) to the greatest extent possible. If it is determined during PED that the final feasibility design would reduce the cross-sectional area of the bayou inlets by more than 50 percent, impacts will be reevaluated and additional investigations conducted as needed. The direct and indirect coastal marsh impacts described above have been captured and quantified with WVA modeling that is described in detail in Appendix O.

7.6.1.2 Freeport and Vicinity CSRM Plan

No Action Alternative. The right-of-way of the existing Freeport HFP system is maintained as cleared, grassy levee and side slope areas, and as floodwall systems. Natural habitats adjacent to the construction right-of-way would continue to provide cover, roosting, foraging, and nesting habitat for wildlife during the period of analysis. The exterior levees follow Oyster Creek on the east and the Brazos River Diversion Channel on the west. Wildlife access is unobstructed across the levees along these levee segments.

Recommended Plan. Freeport and Vicinity CSRM Plan improvements would be accomplished within the existing right-of-way. During construction, fish and wildlife would be able to move out of construction corridors into adjacent habitat and avoid harm. BMPs would be enforced to prevent fill material from entering nearby wetlands or waters. Forest clearing during construction would be conducted during the fall or winter to minimize impacts on nesting migratory birds, when practicable. Terrestrial wildlife would be able to cross-earthen levee segments to access remaining habitat on either side. Floodwall segments would generally be located in developed areas and limited in length; wildlife would be able to utilize nearby levee segments for access as needed. There is little potential for bald eagle nests in the vicinity of the levee system because of the low quality and size of forested wetlands in the area.

7.6.2 Essential Fish Habitat Impacts

7.6.2.1 Sabine Region CSRM Plans

The Orange 3 and Port Arthur and Vicinity CSRM Plans are combined for this impact evaluation because EFH conditions and impacts are similar.

No Action Alternative. Estuarine habitats in the study area (estuarine emergent marsh, estuarine submerged aquatic vegetation, and estuarine mud/soft bottoms) would continue to be open and available for use by fish and shellfish through the period of analysis. Shallow open water estuarine areas are likely to increase and estuarine emergent marsh is likely to decrease as a result of RSLC.

Recommended Plan. Direct and indirect impacts associated with construction of the Orange 3 CSRM Plan would result in the loss of about 203.0 acres of estuarine emergent marsh over the period of analysis. Marsh acres include water within the marsh and small drainages; some SAV in the estuarine marsh areas would also be lost. These acres would be replaced by in-kind mitigation in the amount determined using the WVA model and the CE/ICA incremental analysis; all impacts would be fully compensated with the restoration of estuarine emergent marsh and shallow water.

Construction of the Cow and Adams Bayous surge gates would result in the loss of approximately 11 acres of estuarine soft bottom EFH. This is the area estimated for the footings of the gate structures. This water area has been included in the WVA impact analysis, and the loss will be fully compensated by shallow water restoration in association with marsh mitigation.

Construction would result in the temporary burial of benthic organisms and temporary increases in water column turbidity in the vicinity of the Cow and Adams Bayous gates. Recovery of benthic macroinvertebrates following burial is typically rapid (recovering within months rather than years) (VanDerWal et al., 2011; Wilber et al., 2006; Wilber and Clarke, 2001), and consequently no long-term effects are expected. The displacement of finfish and shrimp species (including estuarine dependent organisms that serve as prey for Federally managed species) during levee system construction would be temporary and individuals should move back into these specific areas once the project is completed.

The Cow and Adam Bayous surge gate structures would constrict flows in these bayous while in their normal open condition, resulting in functional fisheries access impacts on a total of about 2,137 acres of estuarine emergent marsh in the bayou floodplains upstream of the gated structures. These impacts could be expected to affect approximately 1,235 and 902 acres of coastal marsh in the Cow and Adams Bayou floodplains, respectively, resulting in the loss of 50.5 AAHUs over the period of analysis. The functional loss to these marsh systems would be replaced by the mitigation plan's marsh restoration, in the amount determined using the WVA model and the CE/ICA incremental analysis; all impacts would be fully compensated with the restoration of estuarine emergent marsh and shallow water.

No impacts on EFH are expected from the Port Arthur CSRM Plan. In most areas, construction would take place within the existing right-of-way and from barges in adjacent waterways. No improvements are proposed in the vicinity of the two gates along Taylor Bayou on the southwest side of the system.

7.6.2.2 Freeport and Vicinity CSRM Plan

No Action Alternative. Estuarine habitats in the study area (estuarine emergent marsh, estuarine submerged aquatic vegetation, and estuarine mud/soft bottoms) would continue to be open and available for use by fish and shellfish through the period of analysis. Shallow open water estuarine areas are likely to increase and estuarine emergent marsh is likely to decrease as a result of RSLC.

Recommended Plan. EFH would not be significantly affected by construction of the Freeport CSRM Plan. Construction of a surge gate at the mouth of the DOW Barge Canal would permanently affect up to 3 acres of soft bottom. However, there is no estuarine emergent marsh or other natural habitat lining the canal, tidal energy and flushing is low, water quality is poor, and the canal provides little benefit to shell or finfish that may enter it. Therefore, impacts on EFH would be negligible. The displacement of finfish and shrimp species (including estuarine dependent organisms that serve as prey for Federally managed species) during gate construction would likely be temporary and individuals should move back into these specific areas once the project is completed. The potential harm to some individual finfish and shellfish from temporary turbidity-related impacts would be minimal and would not reduce any populations of Federally managed species or their prey.

7.6.3 Threatened and Endangered Species Impacts

This evaluation was combined for the Sabine and Brazoria regions, as listed species are generally the same for both.

No Action Alternative. Hopper dredging at the SNWW and Freeport Entrance Channels would continue with potential for takes of threatened and endangered green, Kemp's ridley, loggerhead, and hawksbill sea turtles. These potential impacts are addressed in the November 19, 2003, Gulf Regional Biological Opinion (GRBO) to USACE on Hopper Dredging of Navigation Channels and Borrow Areas in the U.S. Gulf of Mexico, and Revision 2 to the GRBO, issued January 9, 2007, for USACE dredging projects on the Gulf Coast. Existing threats to the twelve remaining listed and three candidate species described below would be expected to be minor, as most of the species rarely occur, and some do not occur, in the project areas.

Recommended Plan. The Orange 3 CSRM Plan and the Port Arthur and Freeport and Vicinities CSRM Plans would have no effect on the following listed animal species: piping plover, red knot, whooping crane, the West Indian manatee, four whale species (fin, humpback, sei, and sperm), four sea turtle species (green, Kemp's ridley, loggerhead, and hawksbill), and four coral species (lobed star, mountainous star, boulder star, and elkhorn). The CSRM plans would also have no effect on the following Candidate species: Sprague's pipit, and two freshwater mussel species (smooth pimpleback and Texas fawnsfoot). No critical habitat is located in the project areas. The details of this assessment may be found in the USACE Biological Assessment (Appendix J).

7.7 WATER AND SEDIMENT QUALITY IMPACTS

7.7.1 No Action Alternative

7.7.1.1 Sabine Region CSRM Plans

No Action Alternative. Several stream segments in the Sabine region have been classified by TCEQ (2014) as non-supporting for aquatic life, recreation, fish consumption, and general uses. Sampling of tidal segments of the Sabine and Neches Rivers and the GIWW (ID # 501, 702) has identified undesirable levels of bacteria (Enterococcus and E-coli) and PCB's in edible fish tissues. Tidal segments of small streams such as Little Cypress, Adams Bayou, Gum Gully, Cow Bayou, Coon Bayou, and Cole Creek (ID #'s 501B, 508, 508B, 511, 511B, and 511C) have low flows, little tidal energy, high dissolved solids, and high turbidity due to a heavy clay substrate and forest detritus; they generally report depressed levels of dissolved oxygen and undesirable levels of bacteria and certain nutrients. Little Cypress Bayou also exhibits water toxicity, as do the lower segments of the Neches River and Star Lake Canal, near the confluence of the Neches River and Sabine Lake. Freshwater stream segments in the Sabine region generally have higher water quality than do tidal segments, with a few, such as Adams Bayou, Gum Gully, Cow Bayou, Taylor Bayou/North Fork, and Alligator Bayou (ID # 508A, 508B, 511A, 701, and 702A, reporting depressed levels of dissolved oxygen and high bacteria levels.

An implementation plan has been developed to improve water quality for support of recreational and aquatic life uses for the Cow and Adams Bayou watersheds (Orange County Stakeholder Advisory Group, 2015). The plan addresses nonpoint discharges from failing onsite sewage facilities, pastures, forests, and urban runoff, as well as primary point sources such as wastewater treatment facilities and illicit discharges. Water quality will improve marginally over the period of analysis if the stakeholders are successful in reducing existing discharges. Circulation and tidal flows may increase as RSLC increases tidal flows into the region.

Shoaled sediments in the Sabine region are fine-textured (mean percent clay is 76 percent) and generally of good quality, as evidenced by testing of water and sediments in conjunction with maintenance dredging of existing navigation channels and proposed modifications for the SNWW (USACE, 2011; SOL, 2012). A routine water and sediment testing contract is planned in the near future to support USACE maintenance dredging of the Neches River Channel; sediment testing for dioxin has been added due to the historic presence of paper mills in the region.

7.7.1.2 Freeport and Vicinity CSRM Plan

In the Brazoria region, only one stream has been classified as impaired; Oyster Creek (ID # 1109) is identified as non-supporting for recreation use due to undesirable levels of bacteria. Shoaled sediments in the navigation channels are generally of good quality, a evidenced by testing of water and sediments in conjunction with maintenance dredging of existing navigation channels and proposed modifications for the Freeport Harbor Channel (USACE 2012), and the mouth of the San Bernard River (USACE 2008).

7.7.2 Recommended Plan

7.7.2.1 Sabine Region CSRM Plans

Fill material required to construct the Orange 3 CSRM Plan would be obtained from approved, upland, commercial borrow sources that have undergone contaminant testing. If it is necessary, during the PED or Construction Phase, to designate new borrow areas, these areas would be evaluated for environmental impacts prior to use. If adverse effects to the environment would occur with their development, the proposed action would be coordinated with resource agencies and NEPA documents prepared as required by CEQ regulations.

A Clean Water Act Section 404(b) (1) Evaluation is presented in Appendix H. The majority of the fill material would be placed in upland areas; however, approximately 160 acres of marsh and forested wetlands would be directly impacted by the placement of fill material by bulldozers and possibly drag-line cranes, or excavation to construct floodwalls. The proposed alignment has been located to minimize, to the greatest extent practicable, impacts on the Neches and Sabine River floodplains and to avoid and minimize impacts on the aquatic ecosystem. Unavoidable, significant impacts would be fully mitigated. A detailed description of these wetland impacts is provided in Appendix O.

Construction of the Cow and Adams Bayou surge gates would result in temporary increases in water column turbidity in the vicinity of the Cow and Adams Bayou gates. These bayous are normally turbid due to the high clay content of bayou sediments. No long-term effects from temporary turbidity increases are expected. However, because of the potential for contaminants in the Sabine and Neches Rivers, the areas to be disturbed by construction of the Adams and Cow Bayous surge gates will be tested prior to construction during the PED phase. In addition, the right-of-way for other locations where construction would require significant disturbance in aquatic environments would be reviewed, and sediment testing would be conducted in those locations if warranted. If contaminated sediments are identified by testing, a plan to avoid or remediate will be developed by USACE and the non-Federal sponsor, and a new National Environmental Policy Act (NEPA) document would be prepared if needed.

Discharges of fill material into wetlands and waterways adjacent to the upland fill or excavation areas would be minimized by the use of silt curtains to minimize turbidity impacts; forestry BMPs, such as water bars and diversion ditches, would be utilized if needed to stabilize disturbed forest floors and prevent erosion. Potential impacts on flows and interior flooding were described above in the section on impacts on physical and hydrological characteristics of the Sabine Region. The potential for hydrologic impacts on Adams and Cow Bayous was evaluated, and modeling indicates negligible impacts on the water surface elevation and salinity within Adams and Cow Bayous from potential constrictions to the channel cross-section with the proposed surge gates in their normal open condition. Hydrologic flows in the FWP condition would be very similar to FWOP flows in location, duration, and magnitude, both inside and outside of the levee system. Culverts have been designed to maintain existing flows for a 100-year rainfall event, with an additional 10 percent to account for the predicted increase in rainfall due to climate change over the period of analysis. The negligible indirect impacts would not be expected to exceed established Total Maximum Daily Loads (TMDLs) for Adams and Cow Bayous and their tributaries.

Shoaled sediments from the SNWW are proposed for use in constructing the marsh mitigation features of the Orange 3 mitigation plan. Shoaled sediments in the Sabine region are fine-textured (mean percent clay is 76 percent) and generally of good quality, as evidenced by testing of water and sediments in conjunction with maintenance dredging of existing navigation channels and proposed modifications for the SNWW (USACE, 2011; SOL, 2012). SNWW sediments are routinely used for beneficial use projects, both on private and TPWD properties in the region. A routine water and sediment testing contract is planned in the near future to support USACE maintenance dredging of the Neches River Channel; sediment testing for dioxin has been added due to recent information confirming the historic presence of paper mills in the region. The USACE would evaluate the results of O&M sediment testing of the Neches River Channel maintenance material, and if warranted based upon the results of this testing and evaluation, conduct additional sediment testing prior to construction to confirm the suitability of SNWW sediments for use in marsh mitigation features. The risk of identifying insufficient quantities of suitable sediment for the mitigation features is considered to be low based on the large quantity of shoaled sediments available in adjacent navigation channels, routine O&M water and sediment testing results, and the acceptability of this material for several recent Neches River beneficial use projects.

Construction of improvements to the Port Arthur CSRM Plan would have minimal impacts on water quality. No changes would occur to the existing alignment and pump facilities would be improved or maintained to provide for future daily flows and flood waters. At this time, it is assumed that fill material for the levee improvements would be obtained from commercial borrow sources. Discharges of fill material into adjacent wetlands and waterways would be minimized by the use of silt curtains and other BMPs.

7.7.2.2 Freeport and Vicinity CSRM Plan

Recommended Plan. Fill material required to construct the Freeport and Vicinity CSRM Plan would be obtained from commercial borrow sources. Testing to ensure that the material is free of contaminants will be conducted prior to use if the commercial facility has not already done so. If it is necessary, during the PED or Construction Phase, to designate new borrow areas, these areas would be evaluated for environmental impacts prior to use. If adverse effects to the environment would occur with their development, the proposed action would be coordinated with resource agencies and NEPA documents prepared as required by CEQ regulations. Construction would have minimal impacts on water quality as construction would occur within the existing project right-of-way. No changes would occur to the existing alignment and pump facilities would be improved or maintained to provide for future daily flows and flood waters. Hydraulic and hydrologic effects of the proposed surge gate on the DOW Barge Canal are expected to minimal because it is a dead-end, man-made channel with no freshwater inflows. Discharges of fill material into adjacent wetlands and waterways will be minimized by the use of silt curtains and other BMPs. A Clean Water Act Section 404(b)(1) Evaluation is presented in Appendix H.

7.8 AIR QUALITY IMPACTS

7.8.1 No Action Alternative - All CSRM Plans

The Sabine Region is located in the BPA AQCR. According to EPA Region 6, this region has been re-designated as in attainment for the 1997 8-hour Ozone NAAQS (EPA 2015). Further, the Sabine region is designated as in attainment for all other criteria pollutants.

Brazoria County is located within the HGB AQCR as defined in the Texas State Implementation Plan (SIP), adopted in 1972 and revisions thereafter. The area is currently designated as severe nonattainment for the 8-hour ozone (1997) standard and marginal nonattainment for the 8-hour ozone (2008) standard. The HGB AQCR is in attainment for all other criteria pollutants.

7.8.2 Recommended Plan

7.8.2.1 Air Emission Impacts

Air emissions of the Orange 3, Port Arthur and Vicinity, and Freeport and Vicinity CSRM Plans were modeled and the results are presented in Appendix I. The air emission impacts assessed in this report are based on preliminary construction estimates and schedules for alternatives evaluated for the TSP. The impact assessments utilized conservatively-high duration and quantity estimates to ensure that all potential impacts were identified and disclosed for review. The construction estimates and schedules for the Recommended Plan fall below the estimates used for the modeling presented below. The EPA software package Motor Vehicle Emissions Simulator (MOVES) 2014 was utilized to generate emission factors based on the types of construction equipment and vehicles anticipated. Air quality impacts would be expected to be temporary and confined to the duration of the construction events. Sources of air quality changes from the Recommended Plan are expected to result from direct emissions from construction and demolition equipment, such as cranes, excavators, bulldozers, concrete pumps, saws, and generators, and indirect emissions from commuting workers and delivery vehicles such as cars, pickup trucks, flatbed trucks, dump trucks, and concrete trucks. The equipment lists, along with their proposed operations, are quite lengthy; they have not been included in the appendix but are available upon request.

Total modeled emissions (tons/year) for each CSRM Plan in the BPA AQCR are provided in Table 7-2, and the total modeled emissions for the Freeport and Vicinity CSRM Plan in the HGB ACQR are provided in Table 7-3. Per 40 CFR Part 93, Chapter 153, a conformity determination would be required for each criteria pollutant or precursor where the total of direct and indirect emissions of the criteria pollutant or precursor in a nonattainment or maintenance area caused by a Federal action would equal or exceed minimum thresholds defined in the regulation. These General Conformity thresholds are presented in Appendix I.

Table 7-2: Air Quality Impacts in the BPA AQCR

Year	Alternatives	Airshed	Pollutant (tons/year)						
			CO	NOx	PM-10	PM-2.5	SO_2	VOC	Lead
2020	Orange	Sabine	21.0	25.7	2.1	2.0	0.1	5.8	0.0
2021	Orange	Sabine	21.0	25.7	2.1	2.0	0.1	5.8	0.0
2022	Orange	Sabine	21.0	25.7	2.1	2.0	0.1	5.8	0.0
2023	Beaumont	Sabine	30.6	37.4	2.9	2.8	0.1	9.0	0.0
2023	Orange	Sabine	21.0	25.7	2.1	2.0	0.1	5.8	0.0
2024	Port Arthur	Sabine	17.9	44.4	2.8	2.7	0.1	6.6	0.0
2024	Orange	Sabine	21.0	25.7	2.1	2.0	0.1	5.8	0.0
2025	Port Arthur	Sabine	17.9	44.4	2.8	2.7	0.1	6.6	0.0
2025	Orange	Sabine	21.0	25.7	2.1	2.0	0.1	5.8	0.0
2026	Port Arthur	Sabine	17.9	44.4	2.8	2.7	0.1	6.6	0.0
2026	Orange	Sabine	21.0	25.7	2.1	2.0	0.1	5.8	0.0
2027	Port Arthur	Sabine	17.9	44.4	2.8	2.7	0.1	6.6	0.0
2027	Orange	Sabine	21.0	25.7	2.1	2.0	0.1	5.8	0.0
2028	Jefferson	Sabine	16.9	26.3	1.8	1.8	0.1	4.9	0.0
2029	Jefferson	Sabine	16.9	26.3	1.8	1.8	0.1	4.9	0.0

CO=carbon monoxide, NOx=nitrous oxides, PM-10=particulate matter less than 10 microns, PM-2.5=particulate matter less than 2.5 microns, SO_2=Sulphur dioxide, VOC=volatile organic carbons

Table 7-3: Air Quality Impacts in the HGB AQCR

Year	Alternative	Airshed	Pollutant (tons/year)						
			CO	NOx	PM-10	PM-2.5	SO_2	VOC	Lead
2020	Freeport	HGB	12.2	3.0	0.5	0.4	0.0	2.3	0.0
2021	Freeport	HGB	12.1	3.0	0.5	0.4	0.0	2.3	0.0
2022	Freeport	HGB	12.1	3.0	0.5	0.4	0.0	2.3	0.0

CO=carbon monoxide, NOx=nitrous oxides, PM-10=particulate matter less than 10 microns, PM-2.5=particulate matter less than 2.5 microns, SO_2=Sulphur dioxide, VOC=volatile organic carbons

The BPA ACQR is classified as in attainment for all NAAQS pollutants and, therefore, the General Conformity Rule does not apply. The single greatest increase of any criteria pollutant from all projects within the region is 70.1 tons/year of nitrous oxides (NOx) (2024 – 2027). Since the General Conformity Rule *de minimis* thresholds do not apply and the total emissions from all activities are demonstrated to be below the significance thresholds, the Recommended Plan would not have significant impacts on ambient air quality within the region.

The HGB AQCR is classified as marginal nonattainment for the 2008 ozone NAAQS, and severe Nonattainment for the 1997 ozone NAAQS. Therefore, the General Conformity Rule applies to the precursors of ozone (NOx and volatile organic compounds or VOC) resulting from the TSP. The *de minimis* thresholds are 25 tons/year for NOx and VOC. Emissions of NOx and VOC are estimated to increase by 3.0 tons/year and 2.3 tons/year, respectively, for years 2020 to 2022; therefore, the *de minimis* thresholds are not exceeded and a conformity determination is not required. Emissions from the other criteria pollutants are demonstrated to be below the significance thresholds identified above. Because the TSP levels fall below the *de minimis* thresholds for non-attainment pollutants and are below significance levels for attainment pollutants, the Recommended Plan would not have significant impacts on ambient air quality within the HGB region.

In order to reduce impacts associated with emissions of particulate matter and other pollutants, the following control measures will be included in construction contracts, as applicable and practicable.

Fugitive Dust Source Controls:

- Stabilize heavily used unpaved construction roads with a non-toxic soil stabilizer or soil weighting agent. This agent cannot result in the loss of vegetation or increase other environmental impacts.
- During grading, use water as necessary on disturbed areas in construction sites to control visible plumes.
- Vehicle Speed:

  Limit speeds to 25 miles per hour on stabilized unpaved roads as long as such speeds do not create visible dust emissions.

  Limit speeds to 10 miles per hour or less on unpaved areas within construction sites on un-stabilized (and unpaved) roads.

  Post visible speed limit signs at construction site entrances.
- Inspect and wash construction equipment vehicle tires, as necessary, so they are free of dirt before entering paved roadways, if applicable.
- Provide gravel ramps of at least 20 feet in length at tire washing/cleaning stations, and ensure construction vehicles exit construction sites through treated entrance roadways, unless an alternative route has been approved by appropriate lead agencies, if applicable.
- Use sandbags or equivalent effective measures to prevent run-off to roadways in construction areas adjacent to paved roadways. For those contracts in which one is required, ensure consistency with the Storm Water Pollution Prevention Plan.
- Sweep the first 500 feet of paved roads exiting construction sites, other unpaved roads en route from the construction site, or construction staging areas whenever dirt or runoff from construction activity is visible on paved roads, or at least twice daily or less during period of precipitation.

- Cover or treat soil storage piles with appropriate dust suppressant compounds and disturbed areas that remain inactive for longer than 10 days. Provide vehicles, which are used to transport solid bulk material on public roadways and that have potential to cause visible emissions, with covers. Alternatively, sufficiently wet and load materials onto the trucks in a manner to provide at least one foot of freeboard.
- Use wind erosion control techniques (such as windbreaks, water, chemical dust suppressants, and/or vegetation) where soils are disturbed in construction, access and maintenance routes, and materials stock pile areas. Keep related windbreaks in place until the soil is stabilized or permanently covered with vegetation.

Mobile and Stationary Source Controls

- Plan construction scheduling to minimize vehicle trips.
- Limit idling of heavy equipment to less than 5 minutes and verify through unscheduled inspections.

Administrative Controls

- Develop a construction traffic and parking management plan that maintains traffic flow and plan construction to minimize vehicle trips.
- Identify any sensitive receptors in the project area, such as children, elderly, and the infirm, and locate construction equipment and staging zones away from sensitive receptors and building air intakes.

7.8.2.2 Greenhouse Gas Impacts

Air emissions from the operation of internal combustion engines that produce exhaust result in GHG emissions that could contribute to global climate change. The Council on Environmental Quality (CEQ) published Final Guidance on Consideration of Greenhouse Gas Emissions and the Effects of Climate Change on National Environmental Policy Act Reviews, August 1, 2016 (CEQ 2016). The guidance recommends that Federal agencies use projected GHG emissions associated with proposed actions as a proxy for assessing potential effects on climate change. GHG emissions per year should be considered in a qualitative and quantitative manner in NEPA reporting; however, there are no implementing regulations to direct development of these analyses for federal projects. All emissions would come from individual mobile internal combustion engines in on-road and non-road equipment, and it is likely that the total GHG emissions from mobile sources for the three elements of the Recommended Plan would exceed 25,000 metric tons per year of carbon dioxide (CO2)-equivalent (CO2e) per year.

Except for the NAAQS pollutants emitted by these mobile sources as indicated above, the same GHG emissions would occur for every mobile vehicle and piece of equipment regardless of whether the Recommended Plan is implemented. The vehicles and equipment would be used elsewhere by the project contractors on other construction projects, but not necessarily in the two airsheds affected by the Recommended Plan. Since GHG are not listed as NAAQS pollutants subject to regulation under the Texas SIP, and no listed pollutants are generated above *de minimis* levels, and the Recommended Plan would not result in any new stationary emission sources, detailed analysis of GHG emissions was not performed.

However, based on comparison to a similar waterfront construction project, temporary GHG emissions from construction and commuting vehicles are expected to vary between 4,500 and 14,000 tons of CO^2 and CO^2 equivalents per year in the Sabine airshed and approximately 3,200 tons of CO^2 and CO^2 equivalent per year in the Brazoria airshed. Emissions reduction practices could be implemented.

Non-road diesel and gasoline engines can contribute significantly too many pollutant loads, including GHGs. In recent years, EPA has set standards for engines used in most new construction equipment. However, because construction equipment can last 25-30 years, it will take many years before existing equipment is fully replaced by newer, cleaner-burning equipment. With this in mind, EPA developed the Clean Construction USA program to assist operators of heavy non-road, diesel-powered equipment to reduce emissions from older engines that are in operation today. Emission reduction methods include:

- Idle-reduction practices that save money, reduce emissions, add fuel savings, extend engine life, and provide a safer and better work environment for equipment operators;
- Switching to ultra-low-sulfur fuel, which in addition to reducing sulfur (non-GHG) emissions, improves engine efficiency by reducing wear, deposits, and oil degradation;
- Retrofitting equipment to reduce emissions; and
- Installing catalysts and filters verified by EPA to ensure emissions reduction and durability of retrofit technologies. Engine upgrade kits are also available and can be installed during routinely scheduled engine rebuilds.

Roughly one-third of the temporary annual GHG emission impacts are estimated to come from delivery vehicles and worker commuter vehicles. As an additional mitigation measure, construction contractors and the USACE can encourage alternate transportation means. The encouragement of alternative transportation methods, including carpooling, public transportation, and use of local labor could potentially reduce these GHG emissions by as much as 40 percent. Incentives for these initiatives can include preferred parking for carpoolers.

With implementation of these reduction measures, total GHG emissions may reasonably be reduced by up to 25 percent over the lifespan of the projects, resulting in emission rates as low as between 3,375 and 10,500 tons of CO^2 and CO^2 equivalents per year in the Sabine airshed and approximately 2,400 tons of CO^2 and CO^2 equivalent per year in the Brazoria airshed.

7.9 NOISE IMPACTS

The No Action Alternative will be discussed separately for each of the CSRM Plans, but the Recommended Plan condition discussion has been combined for all the Sabine and Brazoria region plans since the impacts will be similar for all.

7.9.1 No Action Alternative for all CSRM Plans

7.9.1.1 Orange CSRM Plan

Ambient noise levels in the vicinity of the proposed Orange CSRM Plan vary from natural noise levels found in undeveloped, rural areas of southwest Orange County to noise levels associated with urban areas and industrial sites in south Orange County. The Orange 3 CSRM Plan construction area contains about 190 residences located adjacent to the proposed Orange 3 right-of-way. About 25 residences are located 30-40 feet from the right-of-way, 80 are located from 100-600 feet away, and the remainder are located between 50 and 100 feet from the proposed right-of-way. Numerous schools are located in the general area in southern Orange County; the closest is located one-third of a mile from the right-of-way and the rest are more than 0.5 mile away. Only one hospital is located in Orange and it is more than 2 miles from the proposed right-of-way.

7.9.1.2 Port Arthur and Vicinity CSRM Plan

In the vicinity of the existing Port Arthur HFP project, ambient noises are associated with dense urban and industrial development, and barge and ship traffic on the deep draft navigation channels. Residents along the ship channels are also exposed to temporary noise levels associated with occasional maintenance dredging of these channels.

Approximately 180 residences are located adjacent to the existing HFP system. Most of these are located about 100 feet from the existing levee or floodwall centerline. Numerous schools are located in the general area, with the closest four located at least one-half mile away. None of the area hospitals are located closer than 1 mile from the project, and three are located 2 or more miles distant.

7.9.1.3 Freeport and Vicinity CSRM Plan

In the vicinity of the existing Freeport HFP project, ambient noises are associated with industrial development and minor residential urban development, in addition to noises associated with ship traffic on the deep- and shallow-draft navigation channels. Residents near the ship channels are also exposed to temporary noise levels associated with occasional maintenance dredging of these channels.

Approximately 105 residences are located adjacent to the existing Freeport HFP system, divided roughly equally between Freeport and Oyster Creek. The existing right-of-way passes immediately adjacent to the Freeport Public Library, Brazosport High School, Freeport Intermediate, and one large apartment complex. None of these are located near the levee system segments to be reconstructed by the CSRM Plan. Numerous other schools in the area are located at least one-half mile away. There are no major hospitals located in the area protected by the existing HFP system. The majority of the structures are located over 200 feet away.

7.9.2 Recommended Plan

None of the CSRM Plans are expected to result in significant long-term noise impacts. No new permanent noise sources would be installed as part of the Recommended Plan; noise impacts would be temporary, occurring during construction only. The Plans would, however, create short-term noise level increases for noise-sensitive receivers located close to the construction zone. Construction activities near sensitive receptors such as residences, schools, and hospitals would be conducted solely during normal daylight working hours; no construction activities would occur during evening or night hours. All of the residences located adjacent to the Orange 3 and Port Arthur and Vicinity CSRM Plans temporary right-of-way, and all of the residences located adjacent to the Oyster Creek, East Storm Levee and Tide Gate Levee portion of the Freeport temporary right-of-way would be exposed to the construction-related noise levels described below. No construction is proposed for the part of the existing Freeport system that passes immediately adjacent to the Freeport Public Library, Brazosport High School, Freeport Intermediate, and one large apartment complex.

EPA identifies a 24-hour exposure level of 70 logarithmic A-weighted decibels (dBA) as the maximum level of environmental noise, which will prevent any measurable hearing loss over a lifetime (U.S. EPA 2015). This is an average over a 24-hour period. Occasional higher noise levels can be consistent with a 24-hour average of 70 dBA if a sufficient amount of relative quiet is experienced for the remaining period of time.

Noise levels related to construction would be based upon the actual number and type of equipment operating in one location at a specific time, and would also fluctuate as equipment is maneuvered throughout the construction right-of-way. Some of the temporary construction activities associated with levee system improvements are expected to generate noise above the 70-dBA level at times during each day. Typical temporary noise levels that could be associated with construction include 73 dBA for large front end loaders from a distance of 100 feet, 86 dBA for off-road haul trucks at 50 feet, 88 dBA for unloading crane at 50 feet, and 90 dBA for vibratory sheet piling at 100 feet (Epsilon Associates 2006). For comparison, typical interior home noise levels are about 50 dBA. Construction activities would be limited to daylight hours to reduce average daily impacts to nearby residents. Contractors would be required to comply with local noise ordinances during construction. There is potential for vibrations associated with construction of some floodwall improvements to affect nearby structures. These effects would be evaluated during detailed design.

Construction of the surge gates in Adams and Cow Bayous (Orange 3 CSRM Plan) and the Dow Barge Canal (Freeport and Vicinity CSRM Plan) would result in temporary and minor noise impacts on aquatic life. It is anticipated that coffer dams would be constructed to facilitate gate construction and thus noise impacts on aquatic life from construction of the gates themselves would be minimal. Pile drivers and draglines could be used to construct the coffer dams and open channels around the coffer dams would be maintained at all times. Fish and other aquatic life would be able to move away from the area of noise impacts, thus minimizing the temporary effects. Similar types of noise impacts, though smaller in scale, would expected with construction of floodwalls at the Alligator Bayou, Lakeside and Port Acres pump stations as part of the Port Arthur and Vicinity CSRM Plan.

7.10 HAZARDOUS, TOXIC, AND RADIOACTIVE WASTE IMPACTS

The construction rights-of-way for the three CSRM plans evaluated for the Recommended Plan have been investigated for the presence of hazardous materials, hazardous waste, and the potential for contamination by current or past industrial or other activities. A detailed report of this investigation is provided as Appendix N. The locations of HTRW areas of concern discussed below are limited to those in the Recommended Plan alignments. All are identified in Appendix N by latitude and longitude. For the purposes of this investigation, a risk to the proposed levee and floodwall alignments is defined as the presence of an HTRW contamination site or HTRW generation site on or adjacent to an alignment, the presence of an activity with the potential for contamination adjacent to or within 0.25 mile of an alignment, or the presence of a past HTRW contamination site or activity adjacent to or within 0.25 mile of an alignment. Except for large oil refining and chemical plants, small HTRW sites such as commercial gas stations in excess of 0.25 mile from the alignment corridor do not pose an environmental risk to the project.

HTRW concerns were investigated through a review of state and Federal databases maintained to monitor permits and activities regulated by state and Federal agencies, such as the TCEQ and the EPA. Envirosite Corporation was contracted to search relevant environmental databases for sites and activities on or near the levee and floodwall alignments. The EPA's Enforcement and Compliance History Online website was visited to identify past HTRW incidents or permit noncompliance violations for sites identified in the Envirosite Corporation database reviews, primarily violations of the Clean Air Act (CAA), CWA, and RCRA. In addition, historical USGS topographic maps and historical aerial photographs were obtained along the levee and floodwall alignments to identify former industrial or other activities that may have contributed to HTRW contamination in the project areas. The volume of material examined for this report is too large to include in the appendix (over 28,500 pages of reports and maps), but the data are available in electronic format from USACE for further review.

7.10.1 Orange CSRM Plan

7.10.1.1 No Action Alternative

Facilities which store or produce hazardous materials are described for the Orange 3 CSRM Plan's construction area in Appendix N. In addition to these facilities, numerous pipelines transporting hazardous materials for shipment or further processing cross the proposed alignment. The locations of all identified HTRW sites and pipeline crossings discussed here are shown on maps in Appendix N.

The proposed construction right-of-way for the Orange 3 CSRM Plan runs near numerous chemical manufacturing and other industrial facilities, including the Port of Orange and several ship-building yards. Research identified seven major HTRW sites and facilities near or adjacent to the proposed alignment. "Major" refers to size; it refers to an HTRW site that is a large plant with a mapable footprint, as opposed to a minor facility that can only be indicated by a point on a map. All are currently operating industrial facilities and listed in databases identifying the generation, handling, or release of hazardous materials and waste. The largest of these, DuPont-Invista (Sabine River Works), maintains several large wastewater treatment and cooling ponds along the proposed alignment. The other operating HTRW facilities are Signal International (Front Street Yard), Conrad Orange Shipbuilding, Lanxess, Honeywell, Chevron Phillips Chemical Company, and Firestone Polymers (Firestone Synthetic Rubber and Latex Company). One former industrial hazardous waste disposal site, owned by WMW Holding Company, has been closed by TCEQ and classified as clean.

The Orange 3 CSRM project area would continue to be subject to future risks of storm surge impacts, and related potential impacts of petrochemical spills from the facilities identified in this report. These industries have emergency operating plans, which help reduce the risks of spills caused by tropical storm impacts, but impacts can occur with storms of great magnitude or when storms spin up quickly and come ashore with little advance warning.

7.10.1.2 Recommended Plan

The general HTRW risk associated with construction of the levee alignment in Orange County is classified as low, since no unresolved current or recent hazardous material releases in about the last 15 years were found, and no significant recent RCRA or CWA permit violations were identified in the proposed construction right-of-way. Most of the refineries and chemical plants had numerous CAA violations in the past or currently in effect due to stack emissions, but these do not raise the risk of ground-based HTRW contamination. One facility which stores hazardous materials (Chemical Storage and Loading) is located outside the Orange 3 CSRM Plan; it would need to continue to provide its own risk reduction from surge impacts. The other facilities, which store crude oil, or manufacture gasoline and other petrochemicals such as industrial polymers, synthetic rubber, and other chemicals would experience lower risks of spills associated with storm surge impacts if the CSRM Plan is implemented.

Some of the construction areas for the Orange 3 CSRM Plan are located in or immediately adjacent to industrial sites that have a history of generating, handling or storing hazardous or toxic materials. Because of this proximity, additional HTRW risk information would be collected with a Phase I assessment during the PED phase to determine if there is potential for construction to disturb previously unknown contaminated sediments or groundwater. In addition, submerged water bottoms to be disturbed by construction of the Adams and Cow Bayou sector gates would be tested for contaminants prior to construction.

7.10.2 Port Arthur and Vicinity CSRM Plan

7.10.2.1 No Action Alternative

The Port Arthur CSRM alignment lies adjacent to three large petroleum and petrochemical facilities – Texaco Chemical Company (Neches Plant), Total Refinery-BASF Chemicals, and the Valero Port Arthur Refinery. A smaller chemical facility, Calabrian Corporation, is located about 900 feet away. Motiva Enterprises - Port Arthur Refinery, currently with the largest refining capacity in the U.S., is located in Port Arthur, but is over 1 mile away from the construction right-of-way. One National Priority List (NPL) Superfund area on Star Canal is located adjacent to the northwestern most HFPP alignment. EPA is currently preparing an agreement to implement remediation, which will involve removal of sediment from Star Bayou (EPA 2015).

The project area would continue to be subject to future risks of I-wall overtopping due to storm surge, and related potential impacts of petrochemical spills. These industries have emergency operating plans, which help reduce the risks of spills caused by tropical storm impacts, but impacts can occur with storms of great magnitude or when storms spin up quickly and come ashore with little advance warning.

7.10.2.2 Recommended Plan

Total Refinery-BASF Chemicals and Valero have had numerous CAA violations in the past or currently in effect due to stack emissions, but these do not raise the risk of ground-based HTRW contamination. No currently active spills or land/water releases of hazardous materials were found for these facilities or others in the area. Therefore, the Port Arthur project area is classified as a generally low risk for HTRW impacts associated with reconstruction of portions of the levee system. The facilities in the Port Arthur area, which store crude oil, or manufacture gasoline, petrochemicals, and liquid sulfur dioxide, would experience lower risks of spills associated with storm surge impacts if the CSRM Plan is implemented.

Some of the construction areas for the Port Arthur CSRM Plan are located in or immediately adjacent to industrial sites that have a history of generating, handling or storing hazardous or toxic materials. Because of this proximity, additional HTRW risk information would be collected with a Phase I assessment during the PED phase to determine if there is potential for construction to disturb previously unknown contaminated sediments or groundwater. No CSRM Plan construction activities are proposed for the alignment in the vicinity of this NPL site.

7.10.3 Freeport and Vicinity CSRM Plan

7.10.3.1 No Action Alternative

The Freeport and Vicinity CSRM Plan alignment lies adjacent to six operating chemical and petroleum industrial facilities: Nalco Freeport Plant, Chemical Specialties, Air Liquide Freeport HYCO Plant, and three separate sites associated with Dow Chemical Company (the Texas Operations Plant, the Oyster Creek plant, and Dow Chemical Shipping). Other chemical and refining facilities are located in close proximity to the alignment, including numerous shipping points along the Port of Freeport and GIWW shipping corridors. The alignment lies adjacent to petroleum bulk stations, storage tanks, and pipelines. It passes adjacent to Freeport Liquid Natural Gas (LNG) Receiving Storage and the Tejas Power natural gas transmission pipeline and a natural gas gathering system (Galveston Island Gathering System). The proposed alignment corridor also crosses the Bryan Mound Strategic Petroleum Reserve facility located on the Brazos River. There is a large, 48-inch buried pipeline connecting the Bryan Mound facility to the refineries at Texas City to the northeast, but the exact location of this pipeline is not known. There are numerous pipeline crossings along the proposed levee and floodwall alignments. Many of the pipeline crossings transport hazardous materials between processing facilities, and others transport finished products to shipping terminals. The project area would continue to be subject to future risks of levee system overtopping impacts, and related potential impacts of petrochemical spills. These industries have emergency operating plans, which help reduce the risks of spills caused by tropical storm impacts, but impacts can occur with storms of great magnitude or when storms spin-up quickly and come ashore with little advance warning.

7.10.3.2 Recommended Plan

The general risk level for the Freeport area is indicated as low, since no current or recent unresolved RCRA or CWA releases were identified for any of the industrial facilities in the Freeport area in about the last 15 years. Many of the facilities have ongoing CAA violations due to stack emissions. The facilities in the Freeport area, which store crude oil, or manufacture petrochemicals, industrial gases, and other chemicals, would experience lower risks of spills associated with storm surge impacts if the CSRM Plan is implemented. Some of the construction areas for the Freeport CSRM Plan are located in or immediately adjacent to industrial sites that have a history of generating, handling or storing hazardous or toxic materials. Because of this proximity, additional HTRW risk information would be collected with a Phase I assessment during the PED phase to determine if there is potential for construction to disturb previously unknown contaminated sediments or groundwater. Pipeline crossings are identified as points of concern along the proposed alignments where special caution should be exercised during construction to avoid damage to the pipelines and release of hazardous materials into the environment.

7.11 CULTURAL RESOURCE IMPACTS

7.11.1 No Action Alternative – All CSRM Plans

The proposed project area for the S2G Study is located along the upper Texas coast and has been occupied by humans since the Paleoindian period dating to around 11,500 BP. The study area is characterized by upland coastal prairies dissected by streams and rivers and extensive bay and estuarine systems along the coast. The study area is primarily drained by the Sabine River, the Trinity River, the San Jacinto River, Buffalo Bayou, and the Brazos River. Sediments in the region are generally fluvial sandy and silty clays overlying Pleistocene-aged clay. Prehistoric sites are commonly found within these upper sediments along streams and rivers and along the shorelines of the bays and gulf coast, close to prime areas for resource exploitation. These sites include campsites, dense shell middens, and cemeteries containing projectile points, stone, bone, and shell tools, aquatic and terrestrial faunal remains, hearth features, ceramics, and in some cases human remains and associated funerary objects. Historic-age resources in the region consist of farmsteads and ranches, houses, buildings, bridges, tunnels, oil industry structures, cemeteries, lighthouses, shipwrecks, and the ruins of these buildings and structures. Although historic-age resources can occur anywhere, these sites tend to be concentrated in small towns and urban areas, along roads, and within current and historic navigation paths. Shipwrecks may also occur in numerous locales due to the dynamic nature of the sea floor and bay bottoms and the lack of navigation improvements until the latter part of the nineteenth century. These dynamic conditions can result in shifting shoals and reefs that endanger ships, as well as bury their wrecks as shorelines and bars migrate through time.

A preliminary assessment of the cultural resources within the region was conducted using a desktop review of the databases maintained by the Texas Historical Commission and the Texas Archeological Research Laboratory for terrestrial and marine cultural resources, as well as the shipwreck and obstruction databases of the National Oceanic and Atmospheric Administration and the Bureau of Ocean Energy Management. There are over 3,600 cultural resources located within this region of the upper Texas Coast. These cultural resources include National Historic Landmarks, NRHP listed properties, archeological sites, cemeteries, historical markers, and shipwrecks and submerged resources. The National Historic Landmarks in the six-county study area are all located in the Galveston Region. These are the San Jacinto Battlefield, the Battleship Texas, and the Tall Ship Elissa, as well as National Historic Landmark Districts, the Galveston Strand Historic District and the Galveston East End Historic District. The NRHP Properties are generally located in urban areas and consist of historic houses, commercial and government buildings, and structures. NRHP Properties in the Sabine Region include the Navy Park Historic District, W.H. Stark House, Sims House, and Woodmen of the World Lodge. These are all located in the area that would be protected by the Port Arthur and Vicinity CSRM Plan. NRHP Properties in the Galveston Region include the Main Street/Market Square Historic District, Pomeroy Homestead, Ross S. Sterling House, Ashbel Smith Building, Fort Travis, Washburn Tunnel, and others. NRHP Properties in Brazoria are generally located in more inland areas of the county, with the southernmost property located in Lake Jackson, just inland of the Freeport and Vicinity CSRM project area.

Within the areas of the proposed Orange 3 CSRM Plan, the study area was examined within 200 feet of the proposed work for archeological resources and cemeteries and 1,500 feet for historic structures and buildings. There are a total of eight archeological sites (41OR15, OR39, OR59, OR60, OR70, BO4, BO119, and BO121), four NRHP Properties (Navy Park Historic District, W.H. Stark House, Sims House, and the Woodmen of the World Lodge), and three cemeteries

(Evergreen, Thomas, and an unknown cemetery) within this study area. There are also 25 historical markers within the study area; however, only one of these, the Niblett's Bluff marker in Orange, is more than 50 years old, having been erected in 1964.

7.11.2 Recommended Plan – All CSRM Plans

The primary considerations concerning cultural resources are threats from direct impacts on intact terrestrial archeological sites and indirect impacts on historic structures and buildings from new construction and improvements. A large portion of the study area has been altered for industrial and commercial use, especially in the cities of Orange, Port Arthur, and Freeport. As such, these urban areas have a low probability for intact prehistoric archeological sites to occur. However, there is a moderate to high potential for encountering historic-age archeological sites and cemeteries, as well as historic-age structures and buildings. In those areas outside of the urban centers, the potential for encountering prehistoric archeological sites is moderate to high. There are no proposed actions within marine environments and therefore no potential to impact submerged cultural resources.

The Area of Potential Effect (APE) for this project will be the footprint of the Recommended Plan for direct impacts on archeological resources plus a 1,500-foot buffer for indirect impacts on standing structures or buildings. The Orange 3 CSRM Plan construction right-of-way overlaps with five archeological sites and two cemeteries. Additionally, there are four National Register Properties within 1,500 feet of the proposed levee system (Navy Park Historic District, W.H. Stark House, Sims House, and the Woodmen of the World Lodge), all of which would experience reduced risk of storm surge damages with construction of the new levee system. The five archeological sites in Orange County (41OR15, OR39, OR59, OR60, and OR70) are all prehistoric sites that have poorly delineated boundaries, insufficient documentation, and have not been evaluated for NRHP eligibility. All of these sites have the potential to be directly impacted by construction activities. The two cemeteries also have a potential to be directly affected by levee construction as their recorded boundaries overlap with the proposed project area. These cemeteries, the Thomas cemetery and an unknown cemetery, are not well documented and their locations may not be accurate within the existing state databases.

There are numerous cultural resources that occur near the APE for the Port Arthur and Freeport CSRM Plans; however, most of these resources occur outside of the areas proposed for improvements. In Port Arthur, there are no cultural resources that overlap with the areas for proposed improvements along the existing hurricane risk reduction system. However, there are three archeological sites (41BO4, BO119, and BO121) that are within proximity to the proposed improvement areas along the Freeport hurricane protection system. These three sites all occur along Oyster Creek, are poorly delineated, lack sufficient documentation, and have not been evaluated for NRHP eligibility.

Based on the current information for the proposed levee construction and improvements, there is a potential to affect historic properties and cemeteries. These effects consist of direct impacts from earth moving and excavation activities related to construction and potential indirect effects on historic structures such as diminished viewshed from the raising of levees and floodwalls. The USACE recommends intensive cultural resources investigations to identify and evaluate any historic properties within proposed construction areas. The scope of these investigations will be determined in concert with the Texas SHPO and Native American Tribes and in accordance with the Programmatic Agreement for this project (Appendix L).

7.12 PRIME AND UNIQUE FARMLANDS

Prime and other unique farmlands in the CSRM plan areas were mapped using the NRCS Web Soil Survey website (USDA 2015). Custom Soil Reports and soil maps were downloaded for each area and area available upon request. Soils were clipped from the USDA database to calculate prime farmland impacts of CSRM Plan construction right-of-ways.

7.12.1 Orange 3 CSRM Plan

7.12.1.1 No Action Alternative

Mapped soil units identified as prime, unique, statewide, or locally important farmlands (hereafter referred to as prime or otherwise important farmland) under the Farmland Protection Policy Act (FPPA) occur within the proposed construction rights-of-way in Orange County. Units identified by the NRCS in the construction area are, in descending order of prevalence, Ijam clay, Orcadia-Urban land complex, Orcadia-Anahuac complex, Aris-Spindletop complex, Orcadia-Aris complex, Neches coarse sand, Leton loam, Neel-Urban Land Complex, Orcadia silt loam, and Franeau clay (U.S. Department of Agriculture [USDA] 2015). Impacts on prime farmland during the FWOP condition would occur primarily from industrial, commercial and/or residential development, and continue according to expected trends of population growth and development in each area.

7.12.1.2 Recommended Plan

The Orange 3 CSRM Plan would permanently convert approximately 36 acres of prime farmland, as defined by the NRCS Web Soil Survey (USDA 2015), into a CSRM levee system. Approximately 61 additional acres would be temporarily unavailable for agriculture while in use as construction staging areas. About 78 percent of the area to be impacted by construction (about

125 acres) is classified as prime farmland. Recent aerial photographs were reviewed to determine the current status of mapped units located within the right-of-way, and approximately 22 percent (28 acres) were found to be developed or in use as pipeline right-of-ways or roadways. Therefore, about 36 acres of prime or otherwise important farmland would be converted to a non-agricultural use. This represents less than 0.1 percent of the total “land in farms” reported by the Orange County 2012 agriculture census (USDA 2012). The undeveloped prime farmland areas that would be impacted are fragmented, surrounded by development, and not currently used for agriculture. The proposed alignment has been designed to follow the upland/wetland margin to the greatest extent possible. Almost all of the lands north of the alignment are developed urban, suburban, and industrial areas. Almost all of the lands south of the alignment are bottomland wetlands, which are not farmed; other areas are industrial cooling ponds or placement areas. The westernmost 2.3 miles of the alignment extends inland away from the upland/wetland margin, with a few tracts south of the alignment which appear to be used for pasture. Only one small area of the construction right-of-way itself (about 6 acres in size) appears to have been farmed recently; levees for rice farming are present in the area.

Construction of the Orange 3 CSRM Plan would not make areas outside of the alignment unfarmable; interior drainage patterns would be maintained at FWOP conditions and access across the levee system would be possible. Any areas compatible with agricultural use that occur in the vicinity of the proposed alignment would remain fully compatible with agricultural use after project construction. Impacts on prime and otherwise important farmlands have been minimized to the greatest extent practicable.

7.12.2 Port Arthur and Vicinity CSRM Plan

7.12.2.1 No Action Alternative

No prime or otherwise important farmlands are located within the proposed construction right-of-way of the existing HFP project in Jefferson County, Texas.

7.12.2.2 Recommended Plan

The Port Arthur and Vicinity CSRM Plan would have no impacts on prime and unique farmlands. Construction activities would be restricted to the existing levee system right-of-way, with the exception of a few small areas within existing industrial complexes.

7.12.3 Freeport and Vicinity CSRM Plan

7.12.3.1 No Action Alternative

No prime or otherwise important farmlands are located within the right-of-way of the existing HFP project in Brazoria County, Texas. Mapped soil units identified as prime or otherwise important farmland are present in one small area on Oyster Creek proposed for right-of-way expansion under the Freeport and Vicinity CSRM Plan. These soils are Asa silt loam and Asa silty loam (USDA 2015).

7.12.3.2 Recommended Plan

The Freeport and Vicinity CSRM Plan would have no impacts on prime and unique farmlands. Construction activities would be restricted to the existing levee system right-of-way.

7.13 FLOODPLAIN IMPACTS

7.13.1 EO 11988

EO 11988 (Floodplain Management) requires Federal agencies to avoid "to the extent possible the long and short-term adverse impacts associated with the occupancy and modification of floodplains and to avoid direct and indirect support of floodplain development wherever there is a practicable alternative." In accomplishing this objective, "each agency shall provide leadership and shall take action to reduce the risk of flood loss, to minimize the impact of floods on human safety, health, and welfare, and to restore and preserve the natural and beneficial values served by floodplains in carrying out its responsibilities" for:

- Acquiring, managing, and disposing of Federal lands and facilities;
- Providing Federally undertaken, financed, or assisted construction and improvements; and
- Conducting Federal activities and programs affecting land use, including but not limited to water and related land resources planning, regulation, and licensing activities.

USACE ER 1165-2-26 contains the USACE's policy and guidance for implementing EO 11988. Per ER 1165-2-26, the USACE must first determine whether there are practicable alternatives to placing a proposed project in a floodplain. In addition, ER 1165-2-26 specifies that all reasonable factors should be taken into consideration when determining practicability. These factors are conservation, economics, visual elements, natural and beneficial values served by floodplains, impact of floods on human safety, locational advantage, the functional need for locating the development in the floodplain, historic values, fish and wildlife habitat values, endangered and threatened species, Federal and state designations of wild and scenic rivers, refuges, etc., and, in general, the needs and welfare of the people.

7.13.2 EO 11988 Eight-Step Analysis

To assist in complying with EO 11988, the USACE has issued guidance (USACE ER 1165-2-26), as it pertains to planning, design, and construction of USACE projects. The Water Resources Council Floodplain Management Guidelines for implementation of EO 11988, as referenced in USACE ER 1165-2-26, requires an eight-step process that agencies should carry out as part of their decision-making on projects that have potential impacts on, or are sited within, the floodplain. The eight steps reflect the decision-making process required in Section 2(a) of EO 11988. In order to demonstrate the Proposed Action complies with EO 11988 and to address related public safety concerns, the following documentation is provided. The existing floodplain management activities, including National Flood Insurance Program related actions and requirements are described. This is followed by a response to the eight-step process.

1. *Determine if the proposed action is in the base floodplain.*

Yes, the Proposed Action lies within the base floodplain. The proposed action includes three separate project areas. Two of the areas currently have existing hurricane flood risk reduction systems that lie in the base floodplain. The proposed action for the third project area includes the construction of new levee and floodwalls, which will also lie in the base floodplain.

2. *If the action is in the base floodplain, identify and evaluate practicable alternatives to the action or to location of the action in base floodplain.*

Alternatives have been evaluated and not carried forward, as they were either not practicable or did not meet the goals of the Proposed Action. Coastal storm flood risks are addressed by the Proposed Action. The proposed coastal flood risk management plan is located within the base floodplain and includes modifications to two existing hurricane flood risk reduction systems. A coastal flood risk analysis followed the "Principles and Guidelines for Water and Related Land Resources," dated March 1983, including evaluation of contributions to NED and reducing potential life-safety risk. Plan formulation and screening of plans described in this Feasibility Report, Chapter 5, is the basis for concluding there are no practicable alternatives to locating the proposed flood risk management plan in the base floodplain. The main Federal objective of reducing coastal flood risk cannot be achieved by alternatives outside the floodplain. All structural alternatives considered were located in the base floodplain.

Practicable nonstructural alternatives like flood proofing, structure relocation, permanent evacuation, and instrumentation were considered. Flood proofing, structure relocation and permanent evacuation were removed from consideration because they were not viable for broad application across the three project areas and were not economically viable.

3. *State whether the proposed action would induce development in the base floodplain.*

The Proposed Action would not induce development in the base floodplain. The Proposed Action would occur in areas that are highly urbanized among the three counties, all of which have substantial industrial investment. Urban development would remain behind the existing hurricane flood risk reduction systems and behind the proposed new levees and floodwalls. The cities of Beaumont, Port Arthur, and Freeport all participants in the National Flood Insurance Program (NFIP) which specifies how cities that participate should manage floodplain development, particularly through zoning ordinances and building codes. No indication exists that these cities have any intention of opting out of the NFIP at any point in the future.

4. *Identify the impacts in the base floodplain of the proposed action and any induced development.*

Impacts within the base floodplain are presented in Chapter 4. Potential impacts on the base floodplain are described for the Proposed Action. Impacts on fish and wildlife, cultural resources, recreation, sediment flow, and other floodplain resources are considered in the Feasibility Report and Engineering Appendix. Avoidance and minimization of impacts on existing floodplain resources has been considered in the development of the Proposed Action. Most of the expected losses or impacts on existing floodplain resources are expected to be compensated by the benefits provided by the Proposed Action. Mitigation requirements for the Proposed Action are described in Section 6.1.3.

5. *Describe measures available to minimize adverse impacts on the natural and beneficial floodplain values.*

Avoidance and minimization efforts for all resources are described in Section 6.1.3. A summary of the potential environmental impacts of the Proposed Action are described in Section 6.1.3. Direct impacts of the Proposed Action would result in the loss of approximately 160 wetland acres from construction of the new levee-floodwall system. Approximately 112 acres would be lost over time due to indirect hydrologic effects, and indirect, functional fisheries access impacts to 2137 acres of the extensive marshes in the lower Cow and Adams Bayous floodplains. In total, 69.5 acres of forested wetland and 2,340 acres of coastal marsh would be impacted. Mitigation would be needed to compensate for a loss of 42.7 AAHUs from forested wetlands and 143.3 AAHUs from coastal wetlands.

6. *Describe the effect of the above topics on any reevaluation of alternatives and on the final plan selection*

A re-evaluation of alternatives was not required because of considering the topics listed above. There are no remaining unmitigated adverse effects on natural and beneficial floodplain due to implementation of the Proposed Action.

7. *Finding and Explanation*

EO 11988 requires Federal agencies to avoid, to the extent possible, the long- and short-term adverse impacts associated with the occupancy and modification of flood plains and to avoid direct and indirect support of floodplain development wherever there is a practicable alternative. The Proposed Action does not support direct or indirect floodplain development within the base floodplain. As stated in Section 6.2 “Description Of The Recommended Plan” the current design does obtain a 1% level of risk reduction throughout the length of the system, but the system is only authorized to address storm surge caused by hurricane and tropical storm events, not rainfall events or riverine events. The federal action would only change the more recent base flood advisory maps (post Ike) and future flood advisory maps if they were are based on storm surge impacts. FEMA Floodplain management guidelines would still require updates to the base flood elevations based on changing rainfall impacts and day-to-day tidal impacts from changes in RSLR.

The action is not likely to induce development in low lying areas due to the fact that there would still be a significant economic costs to overcome for developing in these areas under both the FWOP and FWP conditions. Many of these areas are wetlands and would still flood from rainfall and riverine events. As stated in Chapter 6, the levee system would only be closed for storm surge events. Existing local building codes would still require developments to build above the 100 yr stage for rainfall/riverine impacts, and with an open levee system, the stage is still going to increase over time because of RSLR impacts. Existing local building codes would require significant amounts of fill material for new developments in low lying areas. These areas would still be in jurisdictional wetland and would require compensatory mitigation for impacting these areas. These two factors and the existing available upland areas for development, at a much lower cost, would limit the development in these areas.

In addition, the loss of natural and beneficial flood plain values would also be minimized through future floodplain management plan and zoning rules since the NFS has an obligation relating to the operation of the project, specifically pump station capacities, to prevent encroachments that would impact the utility of the project when the pump station is operating. The NFS will be required to comply with flood plain management requirements and ensure that project features such as pump stations would not be impacted by developments in the areas behind the risk reduction system. The pump system is designed to match the existing gravity drainage capacity when the system is closed. The NFS would have a responsibility to ensure that this operation of the project features is maintained.

USACE and the study's NFS have led public outreach efforts to make local communities aware of actions in the floodplain, starting with the NEPA scoping meeting, and will continue throughout the study process. These scoping meetings are described in Section 9.1. A public and agency review of the DIFR-EIS have been conducted and relevant public and agency comments have been considered in preparing the FIFR-EIS.

8. Critical Actions

The Proposed Action is the most responsive to the planning objectives established in the Feasibility Report and is consistent with the requirements of this Executive Order. The Proposed Action is the most practicable alternative to minimize both short- and long-term adverse impacts associated with modification and occupancy of the base floodplain while maintaining the avoidance of direct and indirect development in the floodplain. The Proposed Action also seeks to minimize impacts on health and human safety and, where possible, to preserve the natural and beneficial uses of the floodplain.

Although the project is intended to prevent damages to structures and infrastructure and is not intended to reduce the risk to loss of life during major storm events, the project does continue to enhance community resilience and better protect critical federal assets from the impacts of flooding. Even under exceedance events (>1%), the system's resilient design, will allow for reduced damages when compared to the FWOP conditions.

7.14 SOCIOECONOMIC IMPACTS (ENVIRONMENTAL JUSTICE)

EO 12898 directs Federal agencies to determine whether the Preferred Alternative would have a disproportionate adverse impact on minority or low-income population groups within the project area. Based on the findings of an environmental justice review, presented earlier in this report and based on data presented in Appendix R, the Sabine and Brazoria elements of the Recommended Plan would not significantly disproportionately affect low-income or minority populations.

7.14.1 No Action Alternative – All CSRM Plans

The population in Orange County within the Orange 3 CSRM Plan area has been identified as being approximately 79 percent white in the aggregate, but with at least seven census blocks showing populations in which minorities make up more than 50 percent. Jefferson County, for the Port Arthur and Vicinity CSRM Plan, by contrast has an aggregate white population of 45 percent and 20 census blocks showing minority populations over 50 percent. The population in Brazoria County for the Freeport and Vicinity CSRM Plan has an aggregate racial makeup of 61 percent white and 39 percent minority. Ten census blocks have populations that have minority populations that are over 50 percent. No evidence exists showing concentrations of low-income populations that could potentially be disproportionately impacted by a Federal action in any of the project areas for the three counties.

7.14.2 Recommended Plan – All CSRM Plans

The Orange 3 CSRM Plan involves the construction of new levees and floodwalls, thereby potentially impacting the population in Orange County. Based on the proposed footprint, one Census block with over 50 percent minority population would be impacted with the construction of the levee/floodwall. Public involvement will need to continue to ensure no disproportionate impacts occur for these residents. The other two project areas consist of existing hurricane flood risk reduction systems where impacts from construction activities would be less intrusive; therefore, the potential for disproportionate adverse impacts is considered to be negligible.

7.15 PROTECTION OF CHILDREN FROM ENVIRONMENTAL AND SAFETY RISKS

EO 13045 requires that Federal agencies evaluate their programs or activities to determine if they would result in disproportionate environmental health and safety risks to children. Children may be more or less sensitive than adults to equivalent levels of exposure to environmental pollutants. In addition, there may be age-related differences in types and levels of exposure.

7.15.1 No Action Alternative – All CSRM Plans

All of the CSRM project areas (Orange 3, Port Arthur and Freeport) would continue to be subject to existing and increasing future risks of storm surge impacts, and related potential impacts of petrochemical spills. These industries have emergency operating plans, which help reduce the risks of spills caused by tropical storm impacts, but impacts can occur with storms of great magnitude or when storms spin up quickly and come ashore with little advance warning. Given the high density of petrochemical industries in these areas, FWOP risks of storm surge impacts would continue to place children living in the project areas at risk to environmental pollutant exposures.

7.15.2 Recommended Plan – All CSRM Plans

All three of the CSRM Plans would reduce potential risks to children's health and safety associated with contaminant spills resulting from storm surge impacts on industrial facilities in the project area. Children residing in Orange County would receive risk reduction that does not exist at this time, and risks to residents residing within the existing Port Arthur and Freeport CSRM project areas would be reduced. Construction of the CSRM plans is not expected to increase risks to children’s health and safety.

7.16 HAZARDOUS WILDLIFE ATTRACTANTS ON OR NEAR AIRPORTS

7.16.1 No Action Alternative

Due to the increasing concern about aircraft-wildlife strikes, the FAA has implemented standards, practices, and recommendations for holders of Airport Operating Certificates issued under Title 14, CFR Part 139, Certification of Airports, Subpart D (Part 139), to comply with the wildlife hazard management requirements of Part 139. Airports that have received Federal grant-in-aid assistance must use these standards.

When considering proposed dredged material placement, BU features, and mitigation areas, developers must take into account whether the proposed action would increase wildlife hazards. The FAA recommends minimum separation criteria for land use practices that attract hazardous wildlife to the vicinity of airports. These criteria include land uses that cause movement of hazardous wildlife onto, into, or across the airport’s approach or departure airspace or air operations area (AOA).

These separation criteria include:

- Perimeter A: For airports serving piston-powered aircraft, hazardous wildlife attractants must be 5,000 feet from the nearest AOA;
- Perimeter B: For airports serving turbine-powered aircraft, hazardous wildlife attractants must be 10,000 feet from the nearest AOA; and
- Perimeter C: 5-mile range to protect approach, departure, and circling airspace.

7.16.1.1 Sabine Region CSRM Plans

Airports within the Sabine region that must comply with these standards are the Orange County and Southeast Texas Regional airports.

7.16.1.2 Freeport and Vicinity CSRM Plan

The Texas Gulf Coast Regional Airport is the closest airport serving the Freeport area. It is located 7 miles northwest of the northernmost extent of the Freeport and Vicinity CSRM Plan, between Lake Jackson and Angleton.

7.16.2 Recommended Plan

7.16.2.1 Sabine-Region CSRM Plans

No features of the Port Arthur and Vicinity CSRM Plan fall within any of the separation perimeters for either airport. None of the Orange 3 CSRM Plan features fall within any of the separation perimeters for the Southeast Texas Regional Airport.

Two potential wildlife attractant features (proposed marsh mitigation areas 28 and 29) of the Orange 3 CSRM Plan fall within Perimeter C of the Orange County Airport, but are well outside of Perimeters A and B. The lands proposed for mitigation sites 28 and 29 are currently undeveloped. Almost all of the area is owned by TPWD and managed for fish and wildlife habitat. A small strip of land along the northern edge of proposed mitigation area 29 is privately-owned. It is comprised of submerged lands and emergent estuarine marsh that also serves as fish and wildlife habitat. Marsh restoration in these areas would not change the land use of this area, and therefore land-use after construction would be compatible with airport operations.

7.16.2.2 Freeport and Vicinity CSRM Plan

No features of the Freeport and Vicinity CSRM Plan fall within any of the separation perimeters, and thus construction would have no effect on airport operations.

7.17 CUMULATIVE IMPACTS

Cumulative impacts are defined in 40 CFR 1508.7 as . . . " the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time." Cumulative impacts for the TSP were assessed in accordance with CEQ guidance.

7.17.1 Sabine Region

7.17.1.1 Sabine Region Past or Present Actions

Past, present, and reasonably foreseeable projects/activities within the study area were compared to the Recommended Plan to determine whether the Recommended Plan, when combined with the impacts of other actions, could have cumulatively significant impacts on the environment.

Sabine-Neches Waterway 40-foot Channel. Channel and port improvements began in 1885 when Army Engineers completed construction of the east and west jetties (Alperin, 1977). Relying on an artificial channel dredged from Sabine Pass and following the western shore of Sabine Lake, the Port Arthur International Public Port was established in 1899. A 9-foot-deep canal was later dug in the Neches River from the Port Arthur Ship Channel to Beaumont in 1908. Multiple subsequent channel improvement projects have resulted in the current 40-foot mean low tide (MLT) authorized depth and a 77-mile-long channel from Port Arthur to Beaumont. In 1912, a 25-foot MLT navigation channel was constructed from the mouth of the Neches River, across the northern edge of Sabine Lake, and up the Sabine River to near the City of Orange, Texas. Also part of the SNWW, the Sabine River Channel was deepened to 30 feet MLT in 1922 and remains at that depth today.

GIWW – Texas Section, Main Channel and Tributaries. Construction of the GIWW between the Sabine River and Galveston Bay began in 1925. Originally 9 feet MLT by 100 feet wide, it was later enlarged to its current authorized dimensions of 12 feet MLT by 125 feet. As it leaves Louisiana, the GIWW follows the Sabine River and connects with the SNWW approximately 3 miles below Orange, Texas. The GIWW then follows the Sabine River Channel and the Sabine-Neches Canal to the head of the Port Arthur Canal, where it exits the SNWW and continues westward to Galveston Bay.

Port Arthur and Vicinity HFPP. Hurricane-flood protection projects at Freeport and Port Arthur were authorized in 1962 (USACE 2005). The Port Arthur HFFP includes approximately 33.1 miles of protective works, including about 27.8 miles of earthen levees and 5.3 miles of concrete and steel sheet pile floodwalls. The system includes 12 pump stations, which remove accumulated rainfall from the protected area. The system surrounds a 60-square-mile area around Port Arthur and nearby smaller cities such as Groves, Lakeview, and Port Acres.

Port of Beaumont Intermodal Improvement Projects. Extensive capital improvements to the Port of Beaumont have recently been completed on both sides of the Neches River (Port of Beaumont 2015). A new 250-acre petroleum terminal has been constructed north of the Neches River in Orange County; intermodal connections include new roadways, ship, and barge docks. Rail lines and storage have been expanded on both sides of the river. More than 80 acres of all-weather, open storage has been constructed south of the Port. Other Port improvements include a general cargo wharf, repairs of bulkheads and upgrades of lots, a new double layberth for military vessels and a new 90,000-square-foot transit shed in Orange County, and an extension of the main Harbor Island east wharf on the Beaumont side. A new office-building complex has been erected to house the U.S. Surface Deployment and Distribution Command's 842nd Transportation Battalion.

Various Neches River Marsh Restoration Projects. TWPD has restored large areas of marsh in the Old River and Nelda Stark units of the Lower Neches WMA with the beneficial use of dredged material (BUDM) from the SNWW. Marsh has also been created in the Rose City and Old River areas as part of mitigation for private projects or National Resource Damage Assessments. In addition, the Sabine-Neches Navigation District and USACE restored marsh in the Bessie Heights area under a Section 204 Continuing Authorities Program project. In all, hundreds of acres of marsh have been restored along the north shore of Neches River south of Interstate 10.

7.17.1.2 Sabine Region Reasonably Foreseeable Future Actions

SNWW Channel Improvement Project (48-Foot MLLW). The 48-Foot SNWW Channel Improvement Project was authorized by the 2014 Water Resources Reform and Development Act (WRRDA). The SNWW to Beaumont would be deepened to 48 feet MLLW and the Sabine Bank Channel would be extended an additional 13.2 miles into the Gulf. In addition, the Taylor Bayou channels and turning basins would be deepened and widened, and three new anchorage/turning basins would be constructed on the Neches River. Beneficial use features and mitigation measures have been developed that effectively avoid or mitigate all environmental impacts. Extensive BUDM features would be constructed with new work and maintenance material along the lower Neches River as part of this project.

Port Arthur LNG and Pipeline. Sempra LNG, through its affiliate Port Arthur LNG, L.L.C., has amended a previous proposal for a liquefied natural gas (LNG) import facility to propose construction of a new natural gas liquefaction and export terminal and pipeline system in Jefferson County, Texas (Port Arthur LNG 2015). Located southwest of the junction of the GIWW and SNWW south of Port Arthur, the facility would include two liquefaction trains, a natural gas liquids (NGL) loading/unloading facility and storage area, marine berths, and three storage tanks. The project would interconnect with intra- and interstate pipelines lying north and south of this area. Port Arthur LNG has obtained U.S. Department of Energy (DOE) approval for export of domestically produced LNG to Free Trade Agreement countries. Completion of the Federal Energy Regulatory Commission pre-filing process is pending. If approved, commercial operations could possibly begin in 2021.

7.17.1.3 Sabine Region Resource Impact Evaluation

Land use and cumulative environmental impacts in the Sabine Region are related historically to the development of three major industries in East Texas: commercial lumbering, shipbuilding and crude oil/petrochemical production/refining. The spread of railroads into the forests of east Texas in the last quarter of the nineteenth century spurred the growth of the commercial timber industry throughout the region, which experienced such rapid growth that by the turn of the twentieth century, logging was the primary economic activity in the Sabine Region (Texas Beyond History, 2015). This changed quickly with the advent of the twentieth century. In 1901, the discovery of the Spindletop oilfield south of Beaumont stimulated the explosive growth of the oil industry, which remains a primary economic driver in the region to this day (Texas State Historical Association, 2015). Storage facilities, pipelines, and major refining units were built in Beaumont, Port Arthur, and Orange; these facilities have grown and spread, generally located close to navigation channels and highways throughout the area. By 1920, most of the forests on lands acquired by the big lumber mills had been harvested, and tangled thickets of second growth hardwoods began to grow in their place. Although the majority of forested wetlands in the study area are secondary growth, many stands are mature enough that they provide medium to high habitat values. The commercial lumber industry's dominance has declined but the commercial lumber industry remains active; managed timber stands are prevalent in the area today. Construction of deep-draft navigation channels into the area by 1908 and the accessibility of timber stimulated the growth of ship building industries in Orange, which were expanded rapidly to meet demands during both world wars. This industry was a primary driver in the growth of the City of Orange but only remnants remain along the Sabine River Channel today.

Agricultural production, recreation and conservation areas have also influenced this area's land use history. One part of the extensive J.D. Murphree WMA is located southwest of the Port Arthur HFPP, and several units (Nelda Stark, Old River and Adams Bayou) of the Lower Neches WMA are scattered along the Neches and Sabine River bottomland areas. The Tony Houseman WMA is located in the bottomlands of the Sabine River near the City of Orange. These state-owned lands will be protected and managed to provide fish and wildlife habitat for the foreseeable future. Agriculture, dominated by cattle grazing and rice production, is not a major economic driver in the area.

The existing SNWW 40-foot navigation project has increased salinity intrusion by providing an avenue for the salt-water wedge to travel further inland than it would have otherwise (USACE 2011). Subsidence, exacerbated by oil/gas/water withdrawal, has also led to permanent inundation and loss of forested wetlands and marsh, and smaller access canals for oil/gas exploration have opened interior marsh areas to salinity intrusion and marsh loss. Construction of PAs lining the banks of the SNWW and construction of the GIWW have altered natural channel and overland flows, blocking or diverting freshwater flows into large areas of interior marsh. All of these factors collectively have resulted in the widespread conversion of fresh marshes to brackish marshes, and the loss of thousands of acres of marsh in the lower reach of the Neches River.

Nationally, wetland impacts and losses in coastal watersheds are directly tied to population pressures and wetland conversion (Stedman and Dahl 2008). Estuarine emergent mash of the U.S. Gulf Coast decreased by 5.2 percent from 2004 to 2009, with about 2,211,674 acres remaining in 2009. Palustrine emergent marsh decreased by 0.1%, with about 2,788,005 acres remaining. Freshwater forested wetlands decreased by 3.4 percent, with about 7,063,638 acres remaining in 2009.

In the Texas coastal zone, changes in wetland and aquatic habitats have been evaluated for the period from 1955 to 1992 (Moulton et. al., 1997). Overall, Texas coastal wetlands sustained an estimated net loss of 210,590 acres over this period. Estuarine emergent marsh decreased by 8.2 percent, with about 355,632 acres remaining in 1992. Palustrine emergent wetlands decreased by 29 percent, with about 571,867 acres remaining. Palustrine forested wetlands decreased by 10.9 percent with about 789,808 acres remaining.

Changes in wetland and aquatic habitats between 1956 and 2004 have been evaluated for the Orange County area (Tremblay and Calnan, 2009). The study area was divided into separate geographic areas, including the portions of the Sabine and Neches River watersheds that would be affected by the proposed Orange 3 CSRM Plan. For the entire study area, emergent wetlands increased at the average rate of 27 acres/year and estuarine open water increased at an even greater average rate of 106 acres/year. Forested and scrub/shrub wetlands decreased over the same time period by 370 acres/year. Part of the expansion of open water was due to subsidence and RSLC. While palustrine marsh was replaced primarily by uplands, roughly 78 percent of the increase in estuarine marsh was in areas previously mapped as palustrine marsh. Forested wetlands suffered the largest losses in this period, being harvested and cleared for agricultural and residential purposes, primarily in the upper reaches of the river valleys and bayous.

Based upon the mapped acres of estuarine, palustrine and forest wetlands in the Sabine and Neches River areas, the S2G project would result in the loss of about 3.8 percent of the remaining estuarine marsh, 0.2 percent of the remaining palustrine marsh, and about 0.8 percent of remaining forested wetlands in the affected Orange County area. When compared to the coastal zone of Texas, the project would result in the loss of about 0.05 percent of estuarine emergent, 0.002 percent of palustrine emergent, and 0.01 percent of forested wetlands. Even though percentages would be expected to increase when compared to more recent data, the percentage losses of the

Recommended Plan would be very small. Percentage impacts when compared to the coterminous United States are much smaller. The project would result in the loss of about 0.008 percent of estuarine emergent, 0.0004 percent of palustrine emergent, and 0.001 percent of forested wetlands.

Significant environmental impacts of public and private projects constructed after passage of NEPA have been addressed by compensation plans that fully mitigated impacts on the environment. Implementation of the SNWW 48-foot project would result in extensive BUDM marsh restoration in the Neches River floodplain, as will continued marsh restoration efforts by TPWD in the Lower Neches WMA.

Impacts of the Recommended Plan in the Sabine Region would not be sufficient, when combined with past, present, and reasonably foreseeable future impacts, to lead to significant degradation of the region's environment. Construction of the Port Arthur and Vicinity CSRM Plan would result in negligible environmental impacts. Direct and indirect impacts of the Recommended Plan on wetlands from construction of the Orange 3 CSRM Plan would be fully mitigated with a plan that compensates for both the quantity and quality of impacts to forested wetlands and marshes. Loss of about 178.7 acres of estuarine marsh would be mitigated by restoration of about 390 acres of brackish and intermediate marsh. Loss of about 24.3 acres of palustrine marsh would be mitigated by restoration of about 63 acres of fresh marsh. Loss of about 69.5 acres of forested wetland would be mitigated by preservation in perpetuity of about 559 acres of bottomland hardwoods and cypress-tupelo swamp. Marsh mitigation efforts would complement current and future marsh restoration efforts by TPWD and USACE.

The Orange 3 CSRM Plan would add a total of 27 miles of new levee/floodwall system in Orange County along the upland terrace/floodplain margin. The Port Arthur and Vicinity CSRM Plan would primarily focus on improvements to the existing 31 mile-long levee system, but it would also construct about one-third of a mile of new levee in Jefferson County; this new segment would have negligible wetland impacts. About 58 miles of placement area or hunting/fishing club dikes in Orange and northern Jefferson counties have created freshwater impoundments in the floodplains of the Sabine and Neches Rivers. About 18 miles of dikes in Orange County, and in Jefferson County along the Neches River surround industrial ponds.

For the Orange 3 CSRM Plan, levee and culvert design would maintain future tidal connectivity, resulting in negligible impacts on floodplains both inside and outside of the levee system. It would not impound wetlands upstream of the system. The new Orange CSRM system would have no impacts on threatened and endangered species. With the exception of fisheries access impacts on Adams and Cow Bayous, existing circulation, salinity, and sediment transport patterns would not be affected; water quality would be expected to remain generally the same. The indirect functional fisheries access impacts would be mitigated by restoration of marsh systems in the Neches River bottomland outside of the levee system, which are discussed above.

7.17.2 Brazoria Region

7.17.2.1 Brazoria Region Past or Present Actions

Freeport Harbor Jetties. The Rivers and Harbors Act (RHA) of June 14, 1880, provided for construction of jetties for controlling and improving the channel over the bar at the mouth of the Brazos River (Alperin, 1977). Currently, the jetties extend approximately 7,700 feet and 8,640 feet on the north and south sides of the channel, respectively.

GIWW Texas Section, Main Channel and Tributaries. Construction of the Federally authorized GIWW between Galveston Bay and the Brazos River began in the 1907 with a 5-foot-deep by 40-foot-wide channel (Alperin 1977). Subsequent improvements have resulted in its current authorized dimensions of 12 feet by 125 feet. The GIWW crosses the existing Freeport Harbor Channel near Mile 1.5.

Brazos River Diversion Channel. Due to excessive siltation and flooding problems at Freeport, this project was authorized by Congress on March 3, 1925, and USACE completed the project in 1929 (Alperin, 1977). A diversion dam was constructed about 7.0 miles above the original mouth of the Brazos River and a diversion channel was excavated to reroute the Brazos River from the new dam to an outlet in the Gulf about 6.5 miles southwest of the original mouth.

Freeport Harbor Channel 45-Foot Project. Originally authorized by the Rivers and Harbors Act of 1935, the navigation channel was deepened to its existing authorized 45-foot depth in 1978. The Freeport Harbor Channel Jetty and Outer Bar channels are currently maintained by USACE to a depth of 48 feet MLT at a width of 400 feet. These existing channels are approximately 6.3 miles long. The North Jetty was relocated north of its original location as part of these improvements; approximately 3,500 feet were added onshore to protect against flanking, and it was lengthened seaward by 500 feet. The South Jetty was also rehabilitated concurrent with the North Jetty improvements.

Freeport and Vicinity HFPP. The Freeport HFPP is a Federal project authorized in 1962 (USACE 2005). Approximately 42 square miles (including areas of Freeport, Velasco, Lake Jackson, Clute, Lake Barbara, and Oyster Creek) were enclosed by approximately 43 miles of levees, wave barriers, floodwalls, drainage structures, pumping plants, and a vertical-lift tide gate on the navigation channel.

Bryan Mound Strategic Petroleum Reserve (SPR). Constructed in 1979, the Bryan SPR storage facility occupies 500 acres at the southeast corner of the Freeport and Vicinity HFPP, close to port and terminal facilities at Freeport and the ConocoPhillips tank farm. The site has a total DOE-authorized storage capacity of approximately 232 million barrels as part of the United States' emergency oil supply (DOE, 2004). Two principal crude oil pipelines extend from the Bryan Mound salt dome: a 4-mile, 30-inch-diameter line to the ConocoPhillips terminal and docks; and a 46-inch line to the ARCO Pipeline Company terminal in Texas City, Texas.

Freeport LNG Phase I. Freeport LNG Development, LP was permitted to construct the new Freeport LNG Import Terminal Project on Quintana Island, across the GIWW from Freeport (FERC, 2004). The project included LNG ship docking and unloading facilities with a protected single berth equipped with mooring and breasting dolphins, unloading and return arms, reconfiguration of a storm risk reduction levee and a permanent access road, two 26-inch-diameter LNG transfer lines, one 16-inch-diameter vapor return line, and service lines, two double-walled LNG storage tanks, ancillary utilities, buildings, and service facilities at the LNG terminal, and 9.6 miles of 36-inch-diameter natural gas pipeline extending from the LNG import terminal to a proposed Stratton Ridge Meter Station (FERC, 2004). This first phase of the Freeport LNG Project was completed in April 2008 and is currently operational.

Port Freeport - Velasco Terminal. The Velasco Terminal is a large cargo terminal improvement project under construction at Port Freeport. With a total 2,400 linear feet of new berths planned, 800 feet have been built thus far (Port Freeport, 2012). The facility is designed to handle new-generation gantry cranes and vessels up to 48-foot draft. It will handle containerized and break-bulk cargo, with 90 acres of developable land with rail access. The new 800-foot-long Berth 7 with 20 acres for containerized and/or break-bulk cargo activity has been completed.

Freeport Harbor Channel Widening Project (Widening Project). Port Freeport has recently widened the Freeport Harbor Entrance Channel. The project site is located along the northern edge of the Freeport Harbor Jetty and Outer Bar channels. These are maintained by the USACE to a depth of 48 feet MLT and approximate length of 6.3 miles. The project widened, but did not deepen, the Jetty and Outer Bar Channels an additional 150 to 200 feet. The length of channel that was widened is 6.1 miles, of which 5.7 miles were widened by 200 feet, to a total 600-foot width.

7.17.2.2 Brazoria Region Reasonably Foreseeable Future Actions

Freeport Harbor Channel Improvement Project (Deepening Project) and General Reevaluation Report. Authorized by WRRDA 2014, the Freeport Harbor CIP would deepen the Outer Bar Channel from the Gulf of Mexico to 58 feet MLLW; deepen the Jetty Channel through the Lower Turning Basin to 56 MLLW; deepen the Main Channel from the Lower Turning Basin to the

Brazosport Turning Basin to 56 feet MLLW; deepen through the Upper Turning Basin to 51 feet MLLW; deepen and widen the lower 3,700 feet of the Stauffer Channel at a depth of 51 feet MLLW and width of 300 feet; and dredge the remainder of the Stauffer Channel to a depth of 26 feet MLLW. Mitigation measures have been developed to compensate for all unavoidable environmental impacts. A General Reevaluation Report is currently underway to reanalyze the completed study in response to changed conditions and assumptions. Completion of the draft integrated General Reevaluation Report and environmental assessment is currently scheduled for June 2018.

Freeport LNG Phase II. In July 2014, FERC authorized Freeport LNG Development, L.P. to site, construct and operate facilities to liquefy and export domestic natural gas from its existing LNG import terminal near Freeport, Texas (FERC 2014). In addition, FERC authorized Freeport LNG's Phase II Modification Project that will revamp the previously authorized but unconstructed Phase II Project. The Phase II Modification Project comprises three major components: reorientation of the Phase II dock, modification of the transfer facilities, and modification of access roads to the terminal.

7.17.2.3 Brazoria Region Resource Impact Evaluation

Historical land use and cumulative environmental impacts in the study area are dominated by the growth of petro-chemical, LNG, and other industrial facilities. This growth has been facilitated by the growth of the deep-draft port and shallow-draft navigation channels in the study area. Significant environmental impacts of public and private projects constructed after passage of NEPA have been addressed by compensation plans that mitigated impacts on the environment. The petro-chemical and other shipping-dependent industries, as well as recreation and conservation areas (NWRs, State Parks, State Historic Sites, and WMAs), have influenced this area's land use history, navigation channel development and maintenance, coastal transportation trends, and regional economic significance. Older projects and, in particular, the Brazos River Diversion Channel and the GIWW have modified the natural hydrology, changing tidal circulation, freshwater flows, and sedimentation patterns in significant ways.

Construction of the Brazos River Diversion Channel left the existing Freeport Harbor Channel navigation channel as a dead-end channel in the bed of the Old Brazos River channel, extending from the Gulf to a dam near State Highway 288. This segment of the Freeport Harbor Channel is relatively low in biological productivity and largely devoid of natural habitats. Existing vegetation is sparsely distributed, and no significant or sensitive terrestrial or aquatic habitats exist within or along the project area. The navigation channel is heavily developed with industrial and commercial properties, including petrochemical manufacturing, storage terminals, warehousing, and related businesses. The extensive levee system of the Freeport and Vicinities HFPP lines most of the waterways in this system and prevents overland flow from the entering the channel. Water quality in the navigation channel system is affected by high dissolved oxygen levels, and salinities approach Gulf levels because of proximity to the Gulf and lack of freshwater inflows.

The heavy sediment load of the Brazos River, which once nourished the Old Brazos River delta, is now being diverted through the Brazos River Diversion Channel to a point about 6 miles southwest of the old delta. Without this sediment source, the Old Brazos River delta is collapsing and is no longer serving as a nearshore sand source for nearby beaches, contributing to Gulf shoreline erosion in the area (Watson 2003). The Freeport Jetties and the offshore portion of the Freeport Harbor Navigation Channel also contribute to shoreline erosion by blocking or trapping longshore sediment transport along the Gulf shoreline.

The landlocked GIWW was constructed generally parallel to and inland of the Gulf shoreline to provide a protected channel for coastwide shallow draft navigation. It intersects the Freeport Harbor Navigation Channel (the Old Brazos River Channel) and the Brazos River Diversion Channel, as well as many other natural rivers near their debouchment into the Gulf. Freshwater flows from the river systems and tidal inflows divert into the GIWW, disrupting normal circulation and salinity patterns in the area near the GIWW and the Gulf shoreline.

Recreation and conservation areas (NWRs, State Parks, and WMAs), have influenced this area's land use history as well. The Brazoria and San Bernard NWR's border the Brazoria study area to the northeast and southwest of the project area. The Justin Hurst WMA and Quintana State Park are located along the Gulf shore, outside of the project area. These Federally and state-owned lands will be protected and managed to provide fish and wildlife habitat for the foreseeable future.

Impacts of the Recommended Plan in the Brazoria Region would not be sufficient, when combined with past, present and reasonably foreseeable future impacts, to lead to significant degradation of the region's environment. Modifications to the existing Freeport HFPP proposed as part of the Freeport and Vicinity CSRM Plan would have negligible environmental impacts. Modifications to the levee system would occur within the existing, disturbed right-of-way. No impacts on wetlands are anticipated. Existing circulation, salinity, and sediment transport patterns would not be affected; water quality would be expected to remain generally the same. No impacts on fish and wildlife, threatened or endangered species, or essential fish habitat are anticipated.

7.18 ANY ADVERSE ENVIRONMENTAL IMPACTS THAT CANNOT BE AVOIDED SHOULD THE RECOMMENDED PLAN BE IMPLEMENTED

The Recommended Plan would result in direct adverse impacts on benthos from construction of surge gates in Cow and Adams Bayous, but the majority of these impacts would be minor and temporary. The same gate structures would also result in functional impacts to fisheries access in these bayous. Construction of the new Orange 3 CSRM Plan would result in the loss of about 272.5 acres of marshes and forested wetlands. No other long-term environmental impacts are expected to occur as a result of the Recommended Plan.

7.19 ANY IRREVERSIBLE OR IRRETRIEVABLE COMMITMENTS OF RESOURCES INVOLVED IN THE IMPLEMENTATION OF THE RECOMMENDED PLAN

The labor, capital, and material resources expended in the planning and construction of this project are irreversible and irretrievable commitments of human, economic, and natural resources. Approximately 272.5 acres of marsh and forested wetlands would be lost from construction and operation of proposed improvements over the period of analysis, but these losses would be fully compensated with in-kind mitigation.

7.20 RELATIONSHIP BETWEEN LOCAL SHORT-TERM USES OF MAN'S ENVIRONMENT AND THE MAINTENANCE AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY

The construction of the Recommended Plan would result in the loss of 272.5 acres of wetlands over the 50-year period of analysis. These impacts would be fully mitigated in the same general area, resulting in no net loss of wetlands and preservation of the areas long-term productivity.

7.21 ENERGY AND NATURAL OR DEPLETABLE RESOURCE REQUIREMENTS AND CONSERVATION POTENTIAL OF VARIOUS ALTERNATIVES AND MITIGATION MEASURES

NEPA regulations in 40 CFR 1502.16 (e) and (f) require a discussion of project energy requirements and natural or depletable resource requirements, along with conservation potential of alternatives and mitigation measures in an EIS. Energy (fuel) would be required to construct the new levee system, and construct and reconstruct improvements to existing systems, but these are a short-term impacts. Electricity and fuel would be expended to operate and maintain the new Orange 3 CSMR Plan. However, most of the system is a passive levee/floodwall/culvert system which requires little to no energy to operate. Energy required to operate and maintain the Cow and Adams Bayou surge gates would be minor except during episodic surge and maintenance events.

Energy required to operate and maintain the Port Arthur and Vicinity and Freeport and Vicinity CSRM Plans would be essentially equivalent to that expended for the existing systems. Construction of the Recommended Plan would not result in a significant depletion of depletable energy or natural resources. They would, however, reduce the risk of serious disruptions in the Nation's energy and petrochemical supplies by reducing storm surge impacts on areas with a high density of large petrochemical facilities.

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8 IMPLEMENTATION REQUIREMENTS

This chapter provides a summary of the implementation requirements for the project in the final format.

8.1 DIVISION OF PLAN RESPONSIBILITIES AND COST-SHARING REQUIREMENTS

The Project Partnership Agreement (PPA) is a binding agreement between the Federal Government and the non-Federal sponsor, which must be approved and executed prior to the start of construction. The PPA sets forth the obligations of each party. The non-Federal sponsors must agree to meet the requirements for non-Federal responsibilities, which will be identified in future legal documents. Some of the likely responsibilities are:

- Provide 35 percent of initial project costs assigned to hurricane and storm damage reduction, and 100 percent of initial project costs assigned to protecting undeveloped private lands and other private shores which do not provide public benefits, as further specified below:
  1. Enter into an agreement that provides, prior to construction, 35 percent of design;
  2. Provide all lands, easements, and rights-of-way, and perform or ensure the performance of any relocations determined by the Federal Government to be necessary for the initial construction or the operation and maintenance of the project;
  3. Provide, during construction, any additional amounts as are necessary to make the total contribution equal to 35 percent of initial project costs assigned to hurricane and storm damage reduction, and 100 percent of initial project costs assigned to protecting undeveloped private lands and other private shores which do not provide public benefits;
- Do not use Federal funds to meet the non-Federal share of total project costs unless the Federal granting agency verifies in writing that the expenditure of such funds is authorized;
- Not less than once each year, inform affected interests of the extent of risk reduction afforded by the project;
- Agree to participate in and comply with applicable Federal floodplain management and flood insurance programs;
- Comply with Section 402 of the WRDA of 1986, as amended (33 U.S.C. 701b-12), which requires a non-Federal interest to prepare a floodplain management plan within one year after the date of signing a project cooperation agreement, and to implement such plan not later than one year after completion of construction of the project;
- Publicize floodplain information in the area concerned and provide this information to

zoning and other regulatory agencies for their use in adopting regulations, or taking other actions, to prevent unwise future development and to ensure compatibility with risk reduction levels provided by the project;

- Prevent obstructions or encroachments on the project (including prescribing and enforcing regulations to prevent such obstructions or encroachments) such as any new developments on project lands, easements, and rights-of-way or the addition of facilities which might reduce the level of risk reduction the project affords, hinder operation and maintenance of the project, or interfere with the project’s proper function;
- Comply with all applicable provisions of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, Public Law 91-646, as amended (42 U.S.C. 4601-4655), and the Uniform Regulations contained in 49 CFR Part 24, in acquiring lands, easements, and rights-of-way required for construction, operation, and maintenance of the project, including those necessary for relocations, the borrowing of materials, or the disposal of dredged or excavated material; and inform all affected persons of applicable benefits, policies, and procedures in connection with said Act;
- For so long as the project remains authorized, operate, maintain, repair, rehabilitate, and replace the project, or functional portions of the project, including any mitigation features, at no cost to the Federal Government, in a manner compatible with the project’s authorized purposes and in accordance with applicable Federal and state laws and regulations and any specific directions prescribed by the Federal Government;
- Give the Federal Government a right to enter, at reasonable times and in a reasonable manner, upon property that the non-Federal sponsor owns or controls for access to the project for the purpose of completing, inspecting, operating, maintaining, repairing, rehabilitating, or replacing the project;
- Hold and save the U.S. free from all damages arising from the construction, operation, maintenance, repair, rehabilitation, and replacement of the project and any betterments, except for damages due to the fault or negligence of the U.S. or its contractors;
- Keep and maintain books, records, documents, or other evidence pertaining to costs and expenses incurred pursuant to the project for a minimum of three years after the final accounting, and assure that such materials are reasonably available for examination, audit, or reproduction by the Federal Government;
- Comply with all applicable Federal laws and regulations, including, but not limited to: Section 601 of the Civil Rights Act of 1964 (42 U.S.C. 2000d) and Department of Defense Directive5500.11 issued pursuant thereto; the Age Discrimination Act of

1975 (42 U.S.C. 6102); the Rehabilitation Act of 1973, as amended (29 U.S.C. 794) and Army Regulation 600 7 issued pursuant thereto; and 40 U.S.C. 3141-3148 and 40 U.S.C. 3701-3708 (labor standards originally enacted as the Davis-Bacon Act, the Contract Work Hours and Safety Standards Act, and the Copeland Anti-Kickback Act);

- Perform, or ensure performance of, any investigations for hazardous substances that are determined necessary to identify the existence and extent of any hazardous substances regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Public Law 96-510, as amended (42 U.S.C. 9601-9675), that may exist in, on, or under lands, easements, or rights-of-way that the Federal Government determines to be required for construction, operation, and maintenance of the project. However, for lands that the Federal Government determines to be subject to the navigation servitude, only the Federal Government shall perform such investigations unless the Federal Government provides the non-Federal sponsor with prior specific written direction, in which case the non-Federal sponsor shall perform such investigations in accordance with such written direction;
- Assume, as between the Federal Government and the non-Federal sponsor, complete financial responsibility for all necessary cleanup and response costs of any hazardous substances regulated under CERCLA that are located in, on, or under lands, easements, or rights-of-way that the Federal Government determines to be required for construction, operation, and maintenance of the project;
- Agree, as between the Federal Government and the non-Federal sponsor, that the non-Federal sponsor shall be considered the operator of the project for the purpose of CERCLA liability, and to the maximum extent practicable, operate, maintain, repair, rehabilitate, and replace the project in a manner that will not cause liability to arise under CERCLA; and
- Comply with Section 221 of Public Law 91-611, Flood Control Act of 1970, as amended (42 U.S.C. 1962d-5b), and Section 103(j) of the WRDA of 1986, Public Law 99-662, as amended (33 U.S.C. 2213(j)), which provides that the Secretary of the Army shall not commence the construction of any water resources project or separable element thereof, until each non-Federal interest has entered into a written agreement to furnish its required cooperation for the project or separable element.

8.2 COST FOR THE RECOMMENDED PLAN

The cost estimate included here is intended to provide an estimate of total costs of the Recommended Plan. The Recommended Plan cost is included in Table 8-1.

Table 8-1: Estimate of Total First Costs of the Recommended Plan

Recommended Plan Feature	Estimated First Cost (Fiscal Year 2017) (October 2016)
Orange- CSRM Plan	$1,926,224,000
Port Arthur and Vicinity CSRM Plan	$729,069,000
Freeport and Vicinity CSRM Plan	$593,313,000
Total	$3,248,607,000

8.3 VIEWS OF NON-FEDERAL SPONSOR AND OTHERS

The existing Port Arthur and the Freeport HFPPs local sponsors have expressed interest in cost sharing for the Recommended Plan identified for the Port Arthur and Vicinity CSRM and the Freeport and Vicinity CSRM. The local sponsors responsible for operation and maintenance are the Jefferson County Drainage District No. 7 and the Velasco Drainage District (VDD), respectively. The local sponsor for Orange CSRM would be Orange County. They have also expressed interest in cost sharing for construction. A region wide systems approach for construction of Orange 3, Port Arthur and Freeport CSRM Plan, is being recommended to ensure that all of the benefits stated would be achieved.

8.4 IMPLEMENTATION PLAN

The final report recommends an implementation strategy that provides a region wide approach to providing risk reduction to the local communities. As described in section 6.3, concurrent construction of all three elements is being recommended to ensure that the regional economy would continue to operate after a storm event and the stress and hardship associated with hurricane storms would be lessened. The pre-construction and construction sequence, and time schedule of the recommended plan is dependent on the timeliness of this report's approval and allocation of funds by Congress, the foregoing construction procedures, and the ability of local interests to implement the items of local cooperation. These items of local cooperation are principally the furnishing of the required real estate easements by the three local construction sponsors. The construction schedule is based on a dedicated funding stream with the total duration of construction being 120 months (120 months for Orange 3, 72 months for both the Port Arthur and the Freeport portions of the recommendation).

In the areas of the Port Arthur and the Freeport recommendation, in order to effectively implement the plan, the construction sequence should focus on levees, floodwalls or structures which have the highest risk for failures under storm events before focusing on overall general system elevations. Additional work would occur during the design phase of the project but it would include the identification of construction reaches and prioritizing them for construction. In the areas of the Orange 3 CSRM Plan, in order to effectively implement the plan, the construction sequence should focus on implementing the initial levee lifts, while also closing off the two main conveyance channels for storm surge, Adams and Cow Bayou. These initial construction sequences could obtain some initial levels of risk reduction when combined with interim flood fighting measures.

8.5 COST-SHARING APPORTIONMENT

The Texas General Land Office (GLO), was the non-Federal sponsor for the feasibility study. The cost-share during the feasibility phase was 50% Federal and 50% non-Federal. Following the feasibility phase, the local construction sponsors, identified in the previous section will be the non-Federal Sponsor for the planning, design, construction, operation, maintenance, repair, replacement and rehabilitation of the project. The cost share for the planning, design and construction of the project will be 65% Federal and 35% non-Federal. The local construction sponsors must provide all project LERRD required for the project. OMRR&R of the project would be a 100% local construction sponsor's responsibility. A full description of the non-Federal and Federal responsibilities after the feasibility phase of the project is contained in Section 8.1 of this report. The total estimated annual OMRR&R cost is $5,468,000. Table 8-2 presents the cost apportionment of the Recommended Plan.

Table 8-2: Cost Apportionment of Recommended Plan

	Total	Federal	Non-Federal
Preconstruction Engineering and Design (PED)	$336,759,000	$218,893,350	$117,865,650
Construction	$2,723,934,000	$1,885,558,021	$838,375,979
Pipeline Relocations	$128,320,000	$0	$128,320,000
Lands, Easements, & ROW	$59,595,084	$7,143,884	$52,451,200
Total First Costs	$3,248,608,084	$2,111,595,255	$1,137,012,829
Cost Apportionment of by Elements of the Recommended Plan			
Orange	Total	Federal	Non-Federal
PED	$202,423,000	$131,574,950	$70,848,050
Construction	$1,622,510,000	$1,114,765,499	$507,744,501
Pipeline Relocations	$62,387,000		$62,387,000
Lands, Easements, & ROW	$38,905,004	$5,705,804	$33,199,200
Total First Costs	$1,926,225,004	$1,252,046,253	$674,178,751
Port Arthur	Total	Federal	Non-Federal

PED	$74,084,000	$48,154,600	$25,929,400
Construction	$607,128,000	$424,803,222	$182,324,778
Pipeline Relocations	$38,544,000		$38,544,000
Lands, Easements, & ROW	$9,313,080	$937,080	$8,376,000
Total First Costs	$729,069,080	$473,894,902	$255,174,178
Freeport	Total	Federal	Non-Federal
PED	$60,252,000	$39,163,800	$21,088,200
Construction	$494,296,000	$345,989,300	$148,306,700
Pipeline Relocations	$27,389,000		$27,389,000
Lands, Easements, & ROW	$11,377,000	$501,000	$10,876,000
	$593,314,000	$385,654,100	$207,659,900
Note: Total Cost Apportionment values maybe slightly different due to rounding			

8.6 RECOMMENDED PLAN AND RECENT USACE INITIATIVES

8.6.1 USACE Campaign Plan

The Recommended Plan addresses the Chief of Engineers Campaign Plan Goal 2: Deliver enduring and essential water resource solutions using effective transformation strategies.

Objective 2a: Modernize the Civil Works project planning program and process. This FIFR-EIS contributes to the objective defined within Goal 2. This report recommends specific solutions to water resource problems and opportunities based on risk-informed decisions. It was developed in close collaboration with stakeholders and partners. The SMART planning principles and risk-informed decision-making were applied in this study and the study complies with the 3x3x3 Rule, which establishes the timeframe and costs required to complete the study.

Objective 2c: Deliver quality solutions and services. This objective is measured by successfully meeting or exceeding established commitments for schedule, cost, and quality to ensure consistent, high-quality performance. A Cost and Schedule Risk Analysis and a Risk Management Plan was performed/developed to ensure the authorized cost limits are set and cost risks are managed with the Recommended Plan.

8.6.2 Environmental Operating Principles

Environmental consequences of construction and operation of the Recommended Plan have been considered in avoiding and minimizing impacts; remaining unavoidable impacts would be fully mitigated. Sustainability was an integral consideration in the development of flood risk reduction recommendations. A risk management and systems approach was developed with input from the USACE Risk Management Center and the Flood Risk Management Planning Center of Expertise; operation of the projects will also employ a risk management approach. Coordination with stakeholders and the general public began with four public scoping meetings, continued with stakeholder updates, and extensive resource agency input during impact modeling. Resource agency knowledge and evaluation methods developed for similar projects were applied in the impact analysis. A thorough NEPA and engineering analysis has ensured that we will meet our corporate responsibility and accountability for actions that may impact human and natural environments in the Sabine and Brazoria regions. This analysis will be transparent and communicated to all individuals and groups interested in USACE activities.

9 PUBLIC INVOLVEMENT

9.1 PUBLIC INVOLVEMENT ACTIVITIES

Extensive public scoping, stakeholder communication, and resource agency coordination were maintained throughout development of the Recommended Plan. Four scoping meetings were held in early 2012, which resulted in the identification of over 250 ideas addressing CSRM problems and ER opportunities in the six-county study area. The February 6, 2012, invitation to participate in meetings held in Beaumont, Seabrook, Galveston and Freeport, Texas, was published on the USACE-Galveston District website and sent to an extensive mail list.

Two stakeholder briefings were held in the spring of 2014 that focused primarily on communicating the goals and progress of the study with local governments and agencies. Continuous contact has been maintained with outside organizations that have been working to address the same problems as those addressed by this study. In particular, close communication has been maintained with the team at Texas A&M Galveston, which has been working to develop the Ike Dike proposal, the Severe Storm Prediction, Education and Evacuation from Disasters Center (a consortium of several universities headquartered at Rice University in Houston), which has been assessing a number of other CSRM, ER, and recreation initiatives for the Galveston Bay region, and the Gulf Coast Community Protection and Restoration District, which is preparing a report evaluating CSRM opportunities in the six-county study area.

9.2 SUMMARY OF NOTICE OF INTENT COMMENTS

USACE published the Notice of Intent (NOI) to prepare an EIS in the Federal Register on November 24, 2014. Written comments were accepted for a 30-day period following that notice. In total, about 20 written comments were received following the public meetings and NOI. The NOI and comments are presented in Appendix F. Comments made at the public meetings and in the written comments are summarized below.

The majority of the original public and agency comments received pertained to the Galveston Bay Region and to ER opportunities in general. The Audubon Society expressed concerns regarding Colonial Waterbird rookeries and piping plover critical habitat areas. Several rookery and critical habitat areas are within the project area, which provide nesting and feeding habitat, and are currently subject to erosion from storm damage, ship traffic and sand mining activities. The Port of Houston Authority (PHA) advised that solutions will need to reflect industry participation or sponsorship of projects, considering that public and private interests coexist along the coast. The feasibility of structural solutions on the Houston Ship Channel (HSC) need to be considered prior to implementation, as most of the current transportation systems that serve the HSC cannot appropriately accommodate proposed flood control structures without causing a disruption in the transportation of commerce. The City of Galveston and the general public also expressed interest in public and private partnerships, which can reduce the financial burden on taxpayers. The City of Galveston recommended that a sediment management plan be considered that encourages beneficial use of dredge materials for public and private projects such as beach preservation, beach nourishment, and establishment of a natural sand dune defense system. Local citizens and municipalities would also like to see conservation and enhancement of wetlands, in combination with responsible development, to prevent and mitigate impacts from severe weather and flood damage, specifically on Bolivar Peninsula and west end of Galveston Island. Multiple comments referenced flood control projects, greenspace, and conservation areas as practicable and effective examples.

In the Sabine region, Orange County expressed strong support for an evaluation of surge risk reduction for that county, including risk reduction for Chemical Row and the Entergy Power Plant. USACE was urged to evaluate levee and surge gate alternatives, and to utilize the Orange County Study, which evaluated several potential alternatives. Industrial facilities and the general public emphasized the need to protect petro-chemical facilities in the area, one of which is the largest refinery in the U.S. The general public was also concerned about maintaining or improving evacuation routes during storm emergencies. Jefferson County and Ducks Unlimited supported shoreline erosion control for the GIWW; this would prevent the loss of interior marshes that serve as storm buffers for inland communities. Comments from resource agencies focused on the need for marsh restoration on the lower Neches River and marshes near Sabine Pass, and dune and shoreline restoration of the Jefferson county shoreline, again as a means for buffering surge impacts. GIWW erosion, marsh, dune, and shoreline restoration will be addressed as part of the new USACE Jefferson County ER Feasibility Study being conducted in conjunction with Jefferson County and the Sabine-Neches Navigation District.

In the Brazoria region, the local sponsor of the Freeport Hurricane Flood Protection Project (HFPP) supported evaluation of storm surge impacts on the existing system. This would strengthen existing risk reduction of the dense petrochemical and residential development within the Freeport HFPP. Maintaining or improving evacuation routes were important to local citizens. Local interest groups and the general public expressed concern with maintaining a tidal connection with the Gulf at the San Bernard River, and the effect of altered circulation created by the GIWW intersection with the Brazos River Diversion Channel. Local citizens also expressed concern regarding the effect of the Brazos River Diversion Channel on sediment delivery to the Surfside area. Beach restoration in the Surfside area would protect nearby residences and help attenuate storm surge. Resource agencies recommended restoration of Follets Island, a barrier peninsula, as a means of buffering storm surge impacts on the Freeport mainland. Tidal circulation, sediment supply, and beach and marsh restoration will be addressed as part of the ongoing USACE Coastal Texas CSRM and ER Feasibility study, in conjunction with the Texas GLO

The Sierra Club provided comprehensive comments, which applied to the six-county study area. In general, they urged restoring natural coastal shoreline system features and urged restraint in the construction of structural systems that would encourage more development. They supported structural measures that are limited in size and focused on vulnerable, developed areas, and recommended targeted buyouts rather than structural alternatives in areas such as Surfside in the Brazoria Region. They urged working with nature and natural processes, as well as protecting shoreline features that provide natural erosion protection.

9.3 COMMENTS ON THE DIFR-EIS

The Notice of Availability and DIFR-EIS were released for public review and comment on September 11, 2015. All comments were due on October 26, 2015. Public meetings on the DIFR-EIS were held on October 6 and 8, 2015, in Beaumont and Freeport, Texas, respectively. Transcripts of these meetings and all comments received during the public comment period are provided in Appendix F. The comments are summarized below. USACE responses to all comments are also presented in Appendix F.

9.3.1 Summary of Public Comments

Comments were received from one city, two local governmental agencies, three companies, the Houston Sierra Club, and seven individuals from Bridge City and Freeport. Several individuals and one company asked for close-up maps, which were added to the Galveston District website during the public comment period. While supportive of the project, individuals and companies expressed concerns over impacts to their properties or operations during construction, or maintaining access through the structures after construction. The City of Port Neches asked that the Orange-Jefferson CSRM Plan be revised to exclude city recreational properties along the Neches River waterfront from the risk reduction plan. Port Freeport identified concerns with how the Freeport and Vicinity CSRM Plan design would impact one of their docks. Badische Anilin- & Sodafabrik (BASF) expressed concerns that the construction and operation of the Dow Barge Canal gate would interrupt their daily operations. The Velasco Drainage District (VDD) and the Sierra Club provided the most extensive comments, which are summarized below.

The VDD suggested that SWG revisit and improve our public notification process. Written notices were sent but not received by some entities; press releases were made but the local press did not respond. The VDD does not concur with USACE's requirement for steady state seepage evaluation and risk assessment of the levees in their system. They maintain that there is insufficient time during a coastal storm to reach a steady state sufficient to cause breeching. Other comments requested clarification for specific sections of the DIFR-EIS, additional information on specific engineering methodologies, and further explanation of specific plan recommendations.

The Sierra Club objected to our denial of their request for a time extension of the public comment period. The comment period opened on 11 Sep 2015 and their request for the extension was made on 21 Sep 2015. We denied their request at that time, but advised that we would reevaluate the need for an extension as the comment period progressed. No other public requests for an extension were received and the comment period was not formally extended. The Sierra Club also expressed concern that the final Recommended Plan and mitigation were not presented in the DIFR-EIS, and in general, requested that much more information and analyses be presented. Sierra Club comments requested further clarification on numerous topics that were covered in detail in the appendices, such as the comprehensive overview of the six counties, unintended consequence, hydrologic impacts of the new levee system and surge gates, historic property impacts, the economic analysis, and the WVA ecological modeling. The comments requested additional explanation regarding screening of structural and non-structural alternatives, cumulative impacts, O&M, and relative sea-level rise.

9.3.2 Summary of Resource Agency Comments

Comments were received from the following Federal and state resource agencies – the U.S. EPA, USFWS, NMFS Southeast Region Protected Resources Division (PRD) and HCD, NRCS, TPWD, TCEQ Water Quality Division and NEPA coordinator, the Texas GLO, and the Texas SHPO.

Several agencies concurred with our impact and compliance determinations or had few comments. The USFWS had no comments on the DIFR-EIS. SWG coordinated closely with USFWS and the agency has provided a Final Coordination Action Report for the project and a review of the Biological Assessment (BA). The NMFS concluded Endangered Species Act (ESA) consultation responsibilities based on the USACE "no effect." The NRCS reviewed the proposed new levee/floodwall system in Orange and Jefferson Counties and determined that the soils classified as Prime Farmland in the project area need not be given further consideration or protection because the impacts scored beneath the threshold score established by the Farmland Conversion Impact Rating for Corridor Type Projects. The GLO reviewed the DIFR-EIS for consistency with the Texas Coastal Management Program and determined that the proposed project is consistent with the program's goals and policies. The TCEQ NEPA coordinator agreed that the general conformity rules for compliance with national air quality standards do not apply to the TSP components in Orange and Jefferson Counties but they do apply to the Freeport and Vicinity

CSRM Plan in Brazoria County. However, because emissions are expected to be *de minimis*, TCEQ agreed that a general conformity determination is not required. The SHPO concurred with our proposal to execute a Programmatic Agreement to demonstrate compliance with the National Historic Preservation Act.

The NMFS-HCD and TWPD agreed with the impact analysis and confirmed that they wanted to participate in the development and review of the final mitigation plan. The HCD is supportive of the mitigation concept and the potential mitigation sites. They note that EFH impacts are uncertain because the TSP and assumptions underlying some impact assessments may change during final feasibility analysis. HCD provided a list of EFH Conservation Recommendations and SWG has provided an interim response since a determination of the acceptability of these recommendations will not be possible until the final Recommended Plan and mitigation plan are developed. TPWD noted that the TSP identified impacts to TPWD Wildlife Management Areas and that these impacts must be consistent with Chapter 26 of the Parks and Wildlife Code of Texas and Chapter 34 of the Texas Natural Resources Code, as well as TPWD policy. The TCEQ Water Quality Division provided comments requesting clarification of several concerns - the evaluation of practicable alternatives, interior drainage analysis, and impacts to sediment movement and tidal flows. TCEQ confirmed that they wanted to participate in development and review of the final mitigation plan. The EPA rated the Draft EIS as EC-2 (Environmental Concerns and Request Additional Information). EPA provided recommended mitigation measures for air contaminants and greenhouse gas emissions and suggested that they be included in the final Recommended Plan, as applicable and practicable. EPA also recommended further outreach to Native American tribes and environmental justice populations. Clarifications were requested on a number of issues including the scope of the study, the alternatives analysis, impacts to floodplains and wetlands, and the risk of disturbing contaminated soils. The EPA confirmed that they want to participate in development and review of the final mitigation plan.

9.4 DISTRIBUTION LIST*

A list of all Federal and state legislative representatives, agencies, organizations, and persons to whom the notice of availability for FIFR-EIS was sent is presented as Appendix T. Names shown in all caps are owners of properties that are in or adjacent to the Orange-Jefferson CSRM Plan right-of way or adjacent to the existing Port Arthur and Freeport and Vicinities CSRM Plan alignments.

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10 RECOMMENDATIONS

10.1 OVERVIEW

A diligent effort was made to coordinate and collaborate with resource agencies, local industry, and environmental interests throughout the study process and public meetings. Environmental resource concerns were addressed early in the study process to assure that adverse impacts were avoided to the maximum extent practicable. The recommendations contained herein reflect the information available at this time. To ensure the Recommended Plan complies with all applicable laws and policies and is acceptable to the public, this FIFR-EIS has undergone public, policy, and technical review. The study team has addressed any outstanding issues raised during the review and confirmed the analysis in this FIFR-EIS.

10.2 RECOMMENDATIONS

The recommendations contained herein reflect the information available at this time and current Departmental policies governing formulation of individual projects. They do not reflect program and budgeting priorities inherent in the formulation of a national Civil Works construction program nor the perspective of higher review levels within the Executive Branch. Consequently, the recommendations may be modified before they are transmitted to the Congress as proposals for authorizations and implementation funding. However, prior to transmittal to the Congress, the non-Federal sponsor, the state, interested Federal agencies, and other parties will be advised of any modifications and will be afforded an opportunity to comment further.

18 MAY 17
Date

Lars N. Zetterstrom, P.E.
Colonel, U.S. Army
Commanding

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12 INDEX*

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APPENDIX 6-A

SABINE TO GALVESTON PASS ENVIRONMENTAL MITIGATION PLAN

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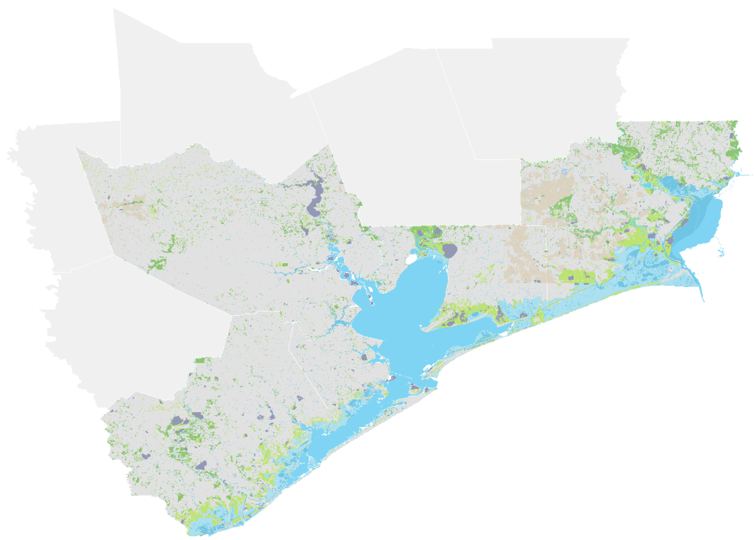
The Mitigation Plan

A closer look at the S2G Program Orange mitigation areas

Sabine Pass to Galveston Bay (S2G)
July 15, 2021



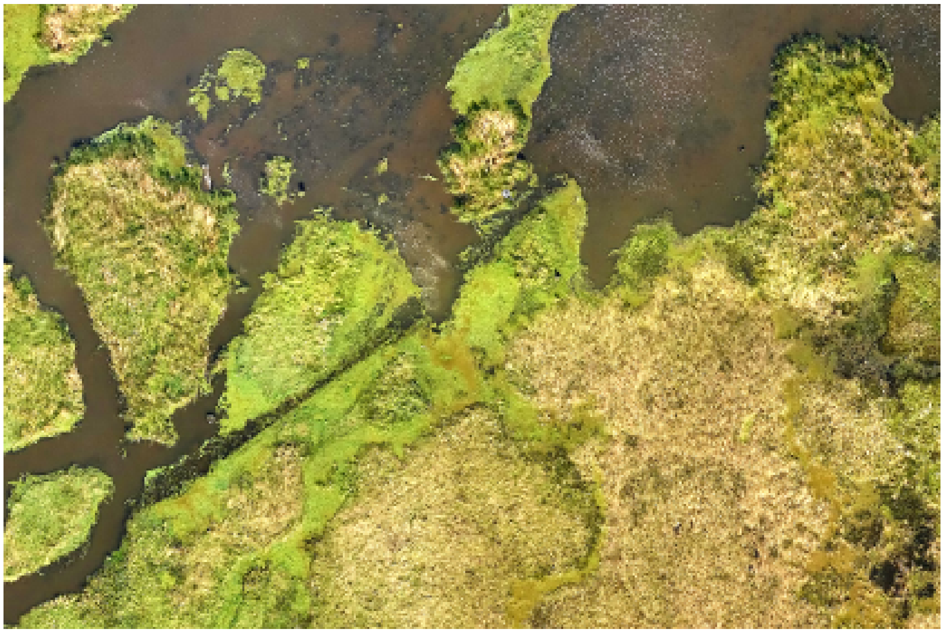
Background

The Sabine Pass to Galveston Bay (S2G) Coastal Storm Risk Management (CSRM) system is a ecologically sound plan that will mitigate coastal storm surge along certain regions of the Texas Coast. These highly populated areas are home to nationally significant environmental resources and wetlands.

These environmental resources and wetlands perform ecological functions, and produce certain goods and services that are valuable to humans.

WETLAND TYPE

- Estuarine and Marine Deepwater
- Estuarine and Marine Wetland
- Freshwater Emergent Wetland
- Freshwater Forested/Shrub Wetland
- Freshwater Pond
- Lake
- Other
- Riverine



Why are Watersheds Important?

- **Water Quality:** Wetlands are one of nature's most efficient water filters. Wetland plants and soils clean the water before it goes into groundwater or into rivers.

- **Nurseries:** Coastal near-shore wetlands serve as important nurseries for fish, crab, and other shellfish. The total economic impact of commercial fishing at the wholesale level is more than $400 million annually, employing about 30,000 coastal residents, all dependent on the wetlands! The total economic impact of saltwater sport fishing in Texas is almost $2 billion annually, employing about 25,000 coastal residents.

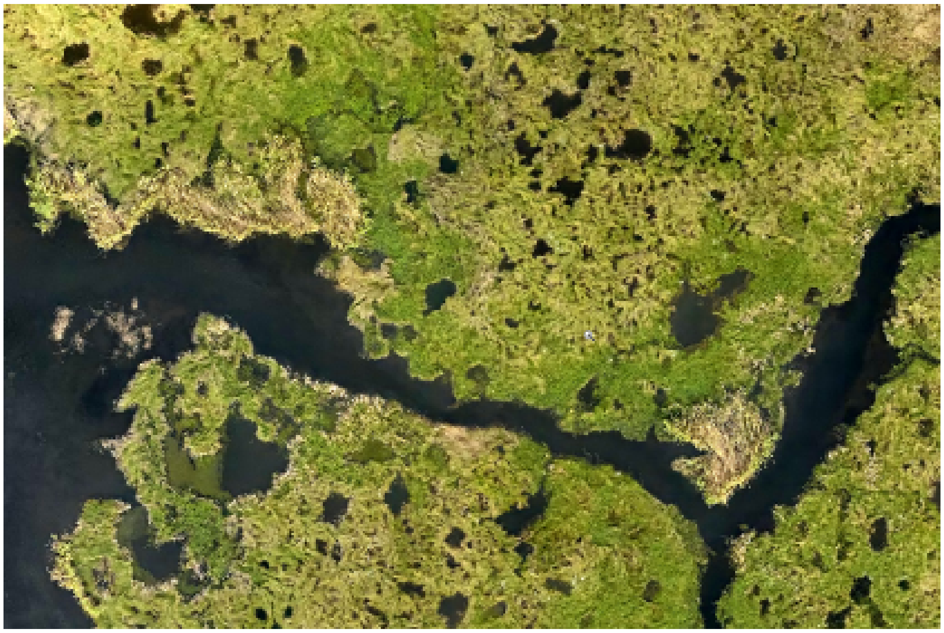
- **Wildlife Habitat:** Our coastal plain wetlands are home to many different kinds of animals. Birds from all over North America use Texas coastal habitats during migration and many species spend the winter on the coast.

- **Flood Buffers:** Wetlands reduce the severity of floods by acting as natural detention areas. Destruction of many wetlands has made downstream flooding much worse.

- **Erosion control:** Nearshore wetlands act as buffers to reduce shoreline erosion and stabilize banks.

- **Recreation:** In addition to fishing, hunting and bird-watching are also economically important. Wildlife watching is the fastest growing segment of the tourism industry. In 1996, 3.8 million U.S. residents spent $1.2 billion watching wildlife in Texas.

Source: TexasWetlands.org

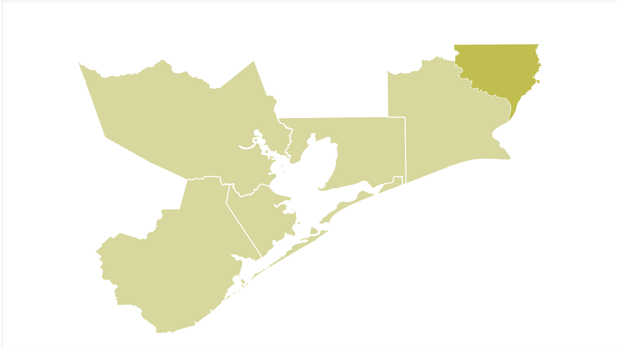


Acting with Environmental Responsibility

To address potential impacts and to prevent any impacts from significantly affecting the environment, the S2G Resource Agency Coordination Team worked to:

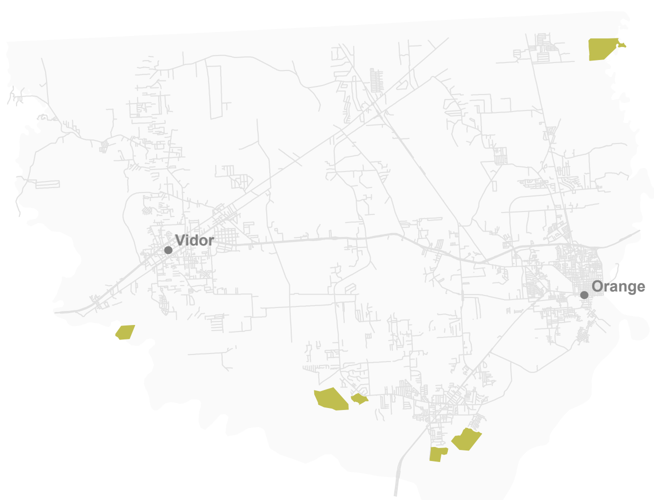
- **Avoid** impacts where possible; then
- **Minimize** impacts where they cannot be avoided, and finally
- **Mitigate** unavoidable impacts by restoring and creating habitats similar to what is expected to be lost.

To counteract impacts to forested wetlands and estuarine marsh associated with the Orange Project, the S2G program includes a compensatory mitigation component to preserve and restore wetland habitats located within Orange County.



Compensatory mitigation refers to the restoration, establishment, enhancement, or in certain circumstances preservation of wetlands, streams or other aquatic resources for the purpose of offsetting unavoidable adverse impacts to national wetlands and aquatic resource functions in wetlands.

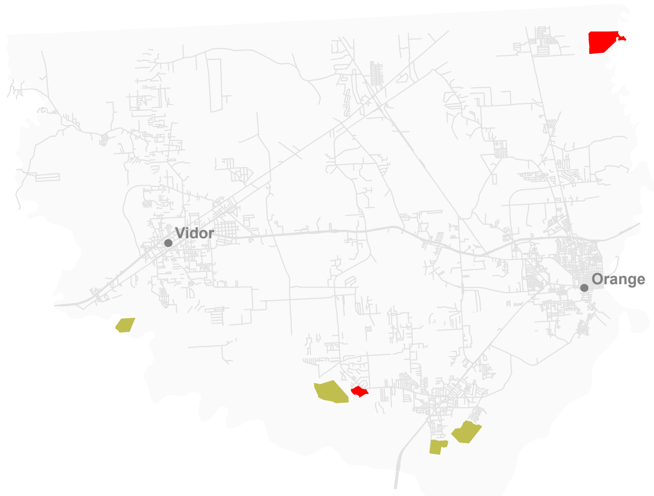
Mitigation Fact Sheet



The Mitigation Plan

Through Wetland Value Assessment modelling, the S2G Resource Agency Coordination Team identified mitigation areas across orange county to offset any direct or indirect impacts to local wetlands over the course of a 50-year period of analysis.

Estimated real estate, construction and monitoring/adaptive management costs were used to narrow down the the selected mitigation areas to six locations within Orange County.

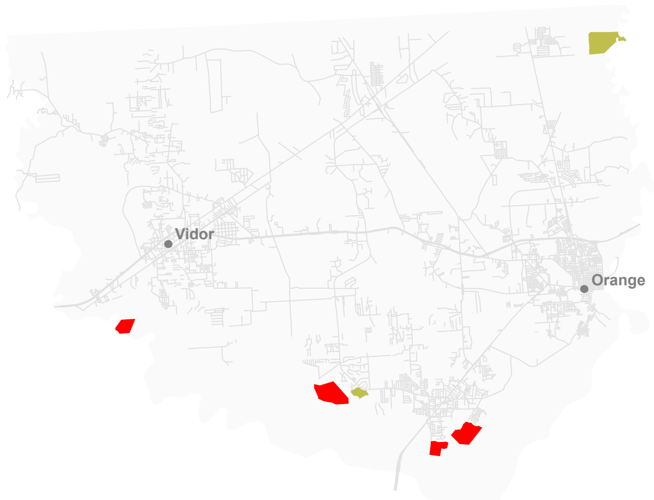


Preservation Areas

The S2G Program includes two forested wetland preservation areas (shown in red) to ensure permanent protection of the aquatic ecosystem:

1. **Sabine River Bottomlands Mitigation Area**
2. **Neches River in the Bessie Heights Mitigation Area**

These lands will be acquired during the construction phase of the project by a non-Federal sponsor (NFS) in accordance with Public Law 91-646.



Restoration Areas

The S2G Program includes four marsh wetland preservation areas (shown in red). These efforts will return natural wetland functions and characteristics to degraded wetlands.

1. **Fresh Marsh Mitigation Area***
2. **Intermediate Marsh Mitigation Area**
3. **Brackish Marsh Mitigation Area #1**
4. **Brackish Marsh Mitigation Area #2**

*The Fresh Marsh Mitigation Area is currently privately owned. Acquisition and preservation of this area will be acquired during the construction phase of the project by a non-Federal sponsor (NFS) in accordance with Public Law 91-646.

The remaining mitigation area properties are owned by Texas Parks and Wildlife Department.

Take a Closer Look...

Click the buttons below to view the six mitigation areas and associated wetlands in more detail:

Swamp and BH Preservation Area

Swamp and BH Preservation Area

Fresh Marsh Restoration Area

Intermediate Marsh Restoration Area

Brackish Marsh Restoration Areas

Construction Phase

The mitigation construction period for this project is estimated to be **10 years** in length and would begin as soon as possible after project construction is initiated. Construction would need to proceed on several areas concurrently. USACE would be responsible for monitoring, reporting and resource agency coordination during the Construction Phase.

Timeline

Year 1-2

Initiate construction of each area.

Year 3

Settlement and consolidation of the material collected.

Years 4-5

Channels and ponds would be created.

Year 6

Containment dikes or temporary erosion control features would be removed to encourage marsh plant growth and to maximize edge for aquatic organisms to utilize exterior and interior marsh areas. *Spartina patens* would be planted.

Year 7

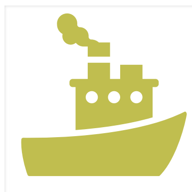
Replant 50 percent of *Spartina patens* plants, as needed. *Spartina alterniflora* and other native wetland vegetation is expected to grow in the mitigation areas during this time, as nearby seed sources are abundant.

Year 8

Invasive and nuisance vegetation will be removed to facilitate growth of native vegetation over the restored marsh areas.

Years 9-10

Baseline surveys of the forested wetland mitigation areas would be conducted to determine the extent of Chinese tallow cover of selected areas.



Shoaled Sediment Harvesting

Shoaled sediments from maintenance dredging of the adjacent deep-draft navigation channels of the Sabine-Neches Waterway (SNWW) would be used to restore marsh in areas of open water.

> SNWW sediments are routinely used for beneficial use projects, both on private and TPWD properties in the region.

The construction estimate assumes that shoaled material from SNWW's Sabine-Neches Canal B, which extends across the north end of Sabine Lake from the mouth of the Neches River to the mouth of the Sabine River, would be used to construct the Brackish Marsh Restoration Areas

Maintenance material from the SNWW's Neches River Channel might be used instead of, or in addition to, the Sabine-Neches Canal B material for these areas. Material from regularly scheduled maintenance dredging of nearby reaches of the Neches River Channel is proposed for construction of Fresh and Intermediate Marsh Restoration Areas.

O&M Phase

Upon completion of the mitigation area acquisition and construction, monitoring for ecological success would be initiated and would continue until ecological success is achieved, this is known as the **Operations and Maintenance (O&M)** phase. None of the mitigation plans include structures intended to last beyond the initial construction period, and therefore no long-term inspection of maintenance activities/costs are needed for the mitigation plan.

The non-Federal implementation sponsor would be responsible for monitoring, reporting and agency coordination during the O&M Phase. If one or more of the monitoring reports indicates that mitigation success is threatened, as determined by USACE and the NFS in coordination with the resource agencies, significant corrective actions would be necessary as described in the **Adaptive Management Plan**.

Forested Wetland O&M Objectives

Objective 1 - Preservation of Forested Wetland Mitigation Areas

If the targeted acreage of swamp is permanently lost due to detrimental changes in hydrologic conditions (flows and duration), severe hurricane damage or fire, actions to encourage reforestation, improve hydrologic conditions to enable reforestation, or acquire additional forested wetland acreage within the watershed would be required

Objective 2 - Management of Invasive Chinese Tallow

If acres of tallow infestation exceed 40 percent of existing swamp or BH acreage in the monitored blow-down areas or gaps, a tallow control program would be initiated to remove and control this species.

Emergent Marsh O&M Objectives

Objective 1 - Optimum Marsh Elevations

A rapid rise is sea level could lead to the death of marsh vegetation, which in this area generally leads to the loss of organic soils and the replacement of marsh by open water. If the rate of rise is higher than the intermediate level, it is probable that marsh accretion would not be able to keep up and additional material would be required to maintain functioning marsh systems in the mitigation areas. If O&M monitoring determines a need for physical modifications to maintain the functions and values of the mitigation measures in the future, arrangements would be made to pump dredged material to restore functional elevations.

Objective 2 - Control of invasive and nuisance plant species

Adaptive management actions to remove invasive/nuisance vegetation would be implemented if they comprise more than 5 percent of marsh cover in the restored marsh areas. USACE, in coordination with resource agencies, would determine if the percentage of invasive/nuisance vegetation is exceeding the specified percentage. The likelihood for the need to control invasive vegetation beyond Year 3 of the O&M phase would generally not become an issue in these marshes as long as the appropriate elevation is attained and native vegetation remains in place.