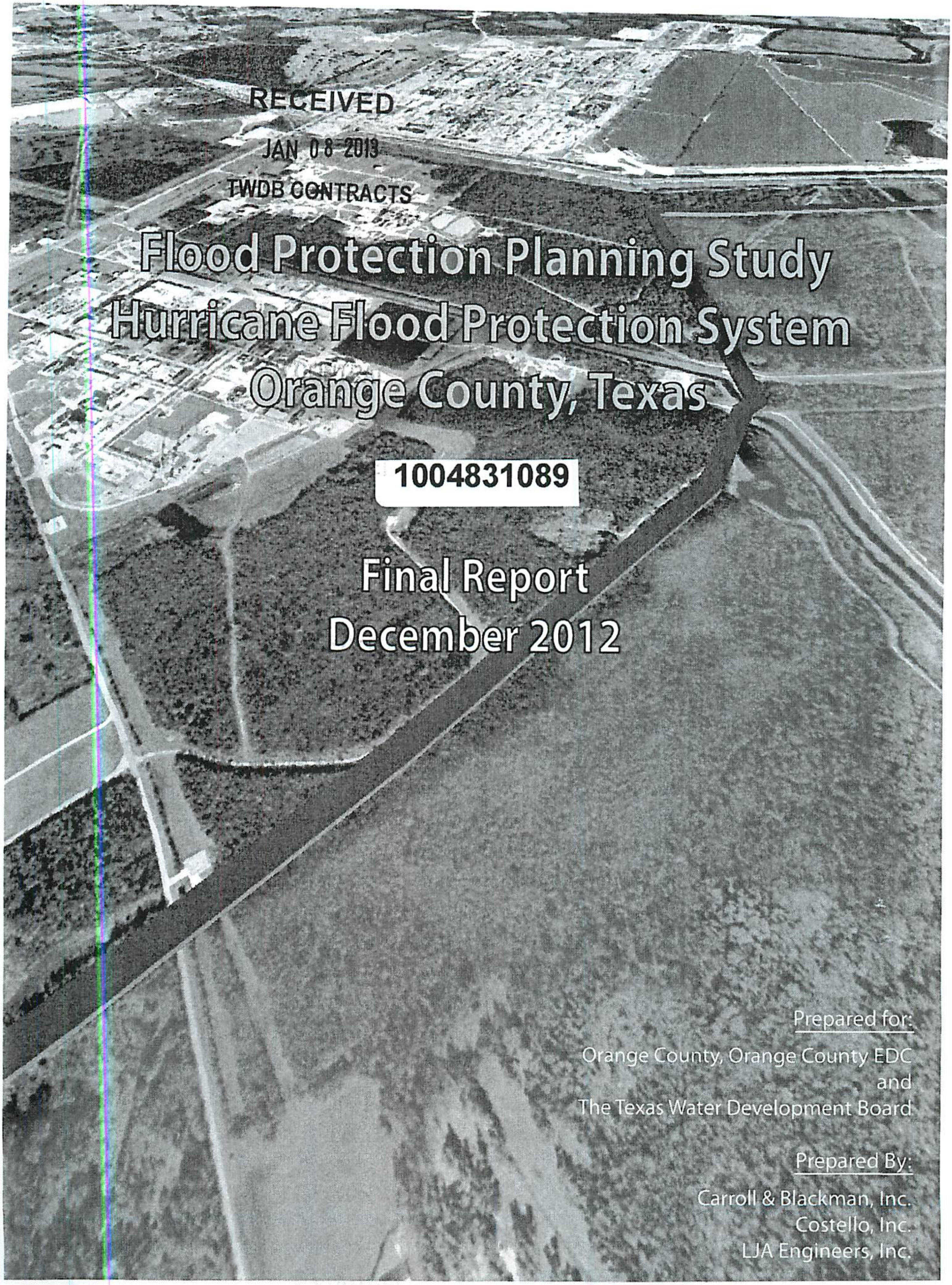

Flood Protection Planning Study
Hurricane Flood Protection System
Orange County, Texas

Final Report
December 2012

Prepared for:

Orange County, Orange County EDC
and
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Prepared By:

Carroll & Blackman, Inc.
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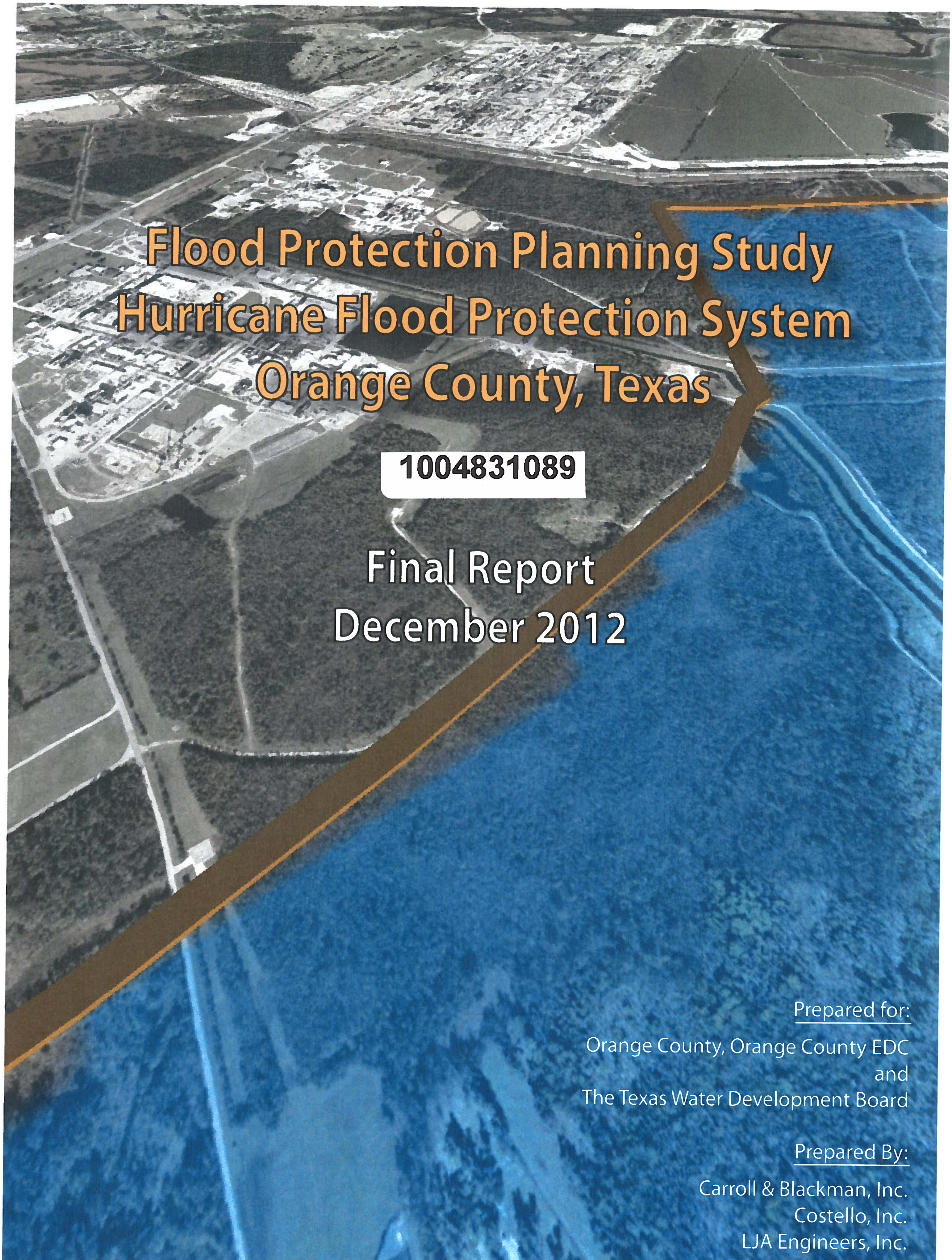

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FLOOD PROTECTION PLANNING STUDY

HURRICANE FLOOD PROTECTION SYSTEM
ORANGE COUNTY, TEXAS

Final Report
December 2012

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and
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Phone (512) 463-7847, Fax (512) 475-2053

November 16, 2012

Bobby Fillyaw
Executive Director
Orange County Economic Development Corporation
1201 Childers Road
Orange, Texas 77630

RE: Flood Protection Planning Grant Contract between the Texas Water Development Board (TWDB), Orange County (County) and the Orange County Economic Development Corporation (Corporation); TWDB Contract No. 1004831089, Draft Report Comments

Dear Mr. Fillyaw:

Staff members of the TWDB have completed a review of the draft report prepared under the above-referenced contract. ATTACHMENT I provides the comments resulting from this review. As stated in the TWDB contract, the County will consider incorporating draft report comments from the Executive Administrator as well as other reviewers into the final report. In addition, the County will include a copy of the Executive Administrator's draft report comments in the Final Report.

The TWDB looks forward to receiving one (1) electronic copy of the entire Final Report in Portable Document Format (PDF) and six (6) bound double-sided copies. **Please further note, that in compliance with Texas Administrative Code Chapters 206 and 213 (related to Accessibility and Usability of State Web Sites), the digital copy of the final report must comply with the requirements and standards specified in statute. For more information, visit http://www.sos.state.tx.us/tac/index.shtml.** If you have any questions on accessibility, please contact David Carter with the Contract Administration Division at (512) 936-6079 or David.Carter@twdb.texas.gov

The County shall also submit one (1) electronic copy of any computer programs or models, and, if applicable, an operations manual developed under the terms of this Contract.

If you have any questions concerning the contract, please contact Gilbert Ward, the TWDB's designated Contract Manager for this project at (512) 463-6418.

Sincerely,

Carolyn L. Brittin
Deputy Executive Administrator
Water Resources Planning and Information

Enclosures

c: Gilbert Ward, TWDB

ATTACHMENT I
Review of Draft Report of Contract No. 1004831089
Orange County, Texas

1. Executive Summary, 2nd paragraph on page 9; please correct the date the study was initiated.

2. Executive Summary, 1st paragraph on page 12; the first sentence is incomplete. Please correct as necessary.

3. Section 2.5.2; please provide the missing date of the third public meeting.

4. Section 5.4.2, last sentence; please provide the missing appendix letter for this reference.

5. Section 5.5.4, Table 5-6; the table appears to be missing the descriptive range of 400 acres to 640 acres, or perhaps the table has the incorrect description for the "Regional" drainage classification. Please review and correct as necessary.

6. Section 5.8 contains numerous references to data or exhibits provided within Appendix D; however the nomenclature to number the exhibits or data does not match the listings within the appendix. Please ensure that the numbering system used within the appendix is referenced properly in the text of the report.

7. Section 5.9 contains several statements regarding the use of 2010 census TIGER data. Please properly define the TIGER acronym (Topologically Integrated Geographic Encoding and Referencing), and also correct where the acronym is not properly capitalized within the text.

8. The text provided in Section 5.9 contains no reference to Table 5-13, or discussion of data compiled by the table. Please include in the final report.

9. Please be consistent within the text of the report and appendices when referring to the 100-year flood or 1% flood. Please use one or the other, but not synonymously.

10. Section 7 does not properly define the BCA acronym for Benefit Cost Analysis. Please define and be consistent when using the acronym.

11. Mitigation alternatives identified by the study are eligible for funding under the Board's financial assistance programs. Application requirements and eligibility criteria is identified by Board rules specified in Section 363 of the Texas Administrative Code. The report would be appropriate for use in support of an application to the Board for financing the proposed improvements. All additional information required by Board rules, 31 TAC 363.401-404, as well as necessary information to make legal findings as required by Texas Water Code Chapter 17.771-776, would be required at the time of loan application.

Table of Contents

LISTING OF TABLES

LISTING OF FIGURES

1. Executive Summary

The Purpose of this project is to reduce the risk of harm to residents, damage to property and infrastructure, and economic loss from hurricane generated floods in Orange County, Texas as occurred when Hurricane Ike made landfall along the upper Texas coast on September 13, 2008. It was one of the most destructive hurricanes to hit the United States. The flood caused by the storm surge devastated portions of the Galveston-Houston coastal area causing over $30 billion in damage and dozens of deaths.

In August of 2010, Orange County, Texas and the Orange County Economic Development Corporation executed a contract with the Texas Water Development Board for the development of a Flood Protection Planning Study for a Hurricane Flood Protection System. The study is being funded by a Texas Water Development Board Planning Grant with matching funds provided by Orange County. The project is supported by a steering committee (stakeholder group) consisting of Orange County municipalities, Orange County EDC, Port of Orange, Orange County Drainage District, and the Association of Plant Managers in Orange County.

This report details the complex interaction and combination of hurricane flood events, levels of protection, structural features and costs, environmental effects and impacts, assessment of benefits, and strategies for development of actual projects to achieve the County's objectives.

Levee and floodwall top elevations were based on available DRAFT FEMA mapping and elevation modeling. Additionally, the study team conducted modeling based on the updated and calibrated Advanced Circulation (ADCIRC) models. The analysis of Hurricane Ike included the calibrated Ike surge modeling as well as a "shifted" Ike track that would provide a "worst case" scenario for Orange County if Ike had (or a similar storm would have) made landfall in southeastern Jefferson County. According to the shifted Ike model runs, the most critical area for the combination of surge and wave generated elevation in Orange County is from the Neches River to Adams Bayou. However, the models also indicate that the critical elevations drop as the surge moves up the Sabine River towards IH10.

Analysis

The analysis for this study consisted of interior drainage analysis for drainage structure and pump station sizing, levee cross section design, floodwall section design, transportation crossings designs (gate structures and elevated roadways), pipeline crossings, major utility crossings, right-of-way requirements, excavation and embankment quantities, gate structure conceptual designs, cost estimates, and benefit cost analysis.

Additionally, alternative protection schemes were evaluated and compared to the no-action alternative. The protection schemes consisted of 1) county-wide protection with levee entirely in Orange County, 2) county-wide protection with a gate structure across the Neches River and tie-in to the Pt. Arthur levee system, and 3) protection of the Chemical Row area by a ring levee system which would provide a first phase of either county-wide protection alternative. An evaluation of construction of a saltwater barrier structure for protection of the Sabine River Authority of Texas freshwater intakes as part of the protection system project was also conducted.

The minimum level of protection considered by the study team is the 100 year recurrence interval as defined and mapped by the Federal Emergency Management Agency (FEMA), also referred to as the 1% probability of recurrence, or the 1% event, which is the minimum level to which FEMA will accredit levee systems with regard to the NFIP and the Flood Insurance Rate Maps (FIRMs). As described above, the ADCIRC model of the “worst case” event (for the purposes of this study) indicated resulting surge and wave heights considerably higher than the FEMA 100 year elevations.

Based on discussions with the project steering committee, the higher level of protection was chosen which would more than satisfy FEMA requirements while protecting the County from a direct hit from an “Ike level” event. The summary of top elevations utilized for preliminary design and cost estimating purposes is as follows.

Elevation 19 from tie in to Pt. Arthur system to Cow Bayou

Elevation 18 from Cow Bayou to Adams Bayou

Elevation 16 from Adams Bayou to IH 10

Elevation 12.5 from IH 10 to approximately 8 miles north of IH 10

For purposes of calculating right-of-way limits for the various sections of the levee system, 2 ft. was added to the top elevations shown which would account for potential sea level rise in the next 100 years.

The design rainfall event utilized for analysis of the interior drainage system is the FEMA benchmark 100 year rainfall event. Peak flows were developed for point locations where the interior drainage channels would drain through the proposed structural system. At these locations, proposed closure structures and pump stations will concurrently provide protection against storm surges and pumping capacity adequate to convey the 100 year runoff that may be associated with a tropical storm or hurricane event. The interior drainage system was not analyzed for capacity and ability to convey flows through the system to the outlet points.

Geotechnical feasibility of the proposed storm protection system was studied and consisted of review of available public information and data from in-house files relative to the general geology and soil conditions along the proposed alignments, identification of possible geotechnical concerns for the proposed alignments, preliminary assessment of possible levee and flood-wall cross-sections, and preparation of a discussion and considerations for additional study for the preliminary and final design.

Environmental and Cultural Resources studies were conducted utilizing existing resources and mapping including National Wetlands Inventory maps, RCRA and CERCLA databases, and the Texas Archeological Research Laboratory. Estimated costs were developed for potential mitigation of environmental impacts.

The Protection System design life is 100 years and is dependent on many factors related to the operation and maintenance of the system. Certain components of the system, such as pump stations will require more frequent maintenance and replacement due to the nature of those mechanical systems. It is the opinion of the study team that the life of the protection system can be extended significantly by strict adherence to all operation and maintenance policies and activities.

Orange County is bounded on the west and southwest by the Neches River, on the east by the Sabine River and to the south by Sabine Lake and the Sabine-Neches Canal. Both rivers serve as critical infrastructure for the area's extensive maritime industry. As a result, the potential impact to the maritime industry has been considered in the evaluation of feasibility of a hurricane flood protection system for the county.

A method for evaluating the benefits and drawbacks of each alternative in order to determine which alternative is the best selection for further analysis and implementation is critical to this feasibility study. Several methods were investigated during this study and no one method presented a comprehensive evaluation of costs, benefits, constructability, long-term performance, innovation, and other intangible aspects that would make a project desirable and achievable, therefore a number of criteria were combined which address various aspects of the projects and a grading system was developed to aid in the evaluation of each alternative. The grading system is based on the relative ranking of each alternative for each criterion. This system would then allow for a summary rank to be assigned to each alternative which should guide the decision process for selecting an alternative for further design.

The Preliminary Design process for the purposes of this study consists of utilization of design parameters described in Section 3 to develop preliminary designs to address the various alternative protection plans. The designs presented are schematic in character and represent systems and components that are currently in use in the United States and globally. The level of detail of the schematic designs is sufficient to develop costs estimates suitable for budget and funding development as well as for benefit-cost analyses. The primary features considered for the protection system are:

- Earthen Levees
- Concrete Floodwall (T-Wall)
- Closure Gate Structures – Navigable
- Closure Structures – Non-Navigable
- Highway and Roadway Crossings - Non-Gated
- Pipeline and Major Utility Crossings
- Pump Stations

The different components required for each section of the levee system were determined to develop an engineer's estimate of the probable construction costs of each alignment alternative. These include the earthen levee sections, floodwall sections, right-of-way acquisition, pump stations, interior drainage, transportation crossings, utility crossings and relocations, and non-construction costs. Quantities and unit costs were obtained from representative projects from 2010 to 2012 and detailed cost estimates for each major item were developed. The Total Cost Comparisons for all alternatives is shown in the following Table 1-1.

Table 1-1 Total Cost Comparisons of Alternatives

Alignment Alternative	Total Cost ($)	Grading System Rank
No-Action	$0	NA
Orange County Protection - East Bank of Neches River (SR + NR)	$1,472,000,000	63
Protection System on East & West Bank of Neches River (SR + NR + NRW)	$1,738,000,000	74
County-Wide Protection with Neches River Crossing (SR + NX)	$1,540,000,000	47
County-Wide Protection with Neches River Crossing and Sabine River Crossing (SR + NX + SRX)	$1,830,000,000	60
Protection of Industrial Complex (ID)	$212,000,000	35

Conclusions and Recommendations

Based on the analysis conducted, two alignment alternatives were selected for further investigation in a Preliminary Engineering Report (PER) based on the grade assessments and feasibility criteria. The PER should address the determination of final alignments of the levee/floodwall systems, design parameters and considerations for each system component, sizing and locations of pump stations and outfall/closure structures, roadway and railway crossings/closure structures, and design considerations and parameters for all pipeline, public utility and municipal utility crossings.

Selected Alternative

<u>Neches Crossing and Sabine River Alignment</u>

This alignment was selected because it met the requirement of providing county-wide protection for Orange County. Since this alternative also can provide protection to the west bank of the Neches River up to the City of Beaumont, it well exceeds that requirement. In addition to the grading rank, this alternative was chosen based on the Assessed Valuation Protected and Potential Flood Damage Losses Prevented. This alignment protects the industrial areas and the majority of the land area within Orange and Jefferson Counties.

<u>Industries Alignment</u>

This alignment was also selected based on the parameters of the Grading System and the Overall Construction Cost. This alignment protects the major industrial area within Orange County and will be further investigated to serve as the first phase of a larger future project in the region.

Project Delivery and Funding

The methods for the execution and delivery of and the funding of this project should be further investigated based on the availability of funding from either private or public sources. The detailed discussion and investigation of the various means are beyond the scope of this study and should be further investigated concurrently with the PER development discussed above.

Recommendations

The following recommendations for providing a hurricane flood protection system for Orange County are offered:

- Develop a phased approach to implementation of the project
- Develop a Preliminary Engineering Report (PER) which addresses the specific design requirements of the selected alternatives.
- Investigate potential funding and financing sources and methods in order to provide adequate funds for the design and construction of the project.
- Investigate methods for the maintenance and operations responsibilities of the system, through the creation of a separate public entity or the addition of such responsibilities to a department of an existing public entity.
- Develop system operational model and identify estimated costs for this system.

2. Introduction

Statement of Purpose and Need

The Purpose of this project is to reduce the risk of harm to residents, damage to property and infrastructure, and economic loss from hurricane generated floods in Orange County, Texas as occurred in 2008, when Hurricane Ike made landfall along the upper Texas coast.

Hurricane Ike struck the Texas Gulf Coast on September 13, 2008. It was one of the most destructive hurricanes to hit the United States. The flood caused by the storm surge devastated portions of the Galveston-Houston coastal area causing over $30 billion in damage and dozens of deaths.

In Orange County, the surge generated by the storm caused widespread flooding in industrial, commercial, and residential areas. The cities of Orange, Bridge City, West Orange, Pinehurst, Vidor, and Rose City, as well as unincorporated areas suffered extreme damages and are still in the process of recovery as of the date of this report. Approximately one-third of the City of Orange was flooded, being primarily the downtown and commercial districts of the city. Rose City also suffered major damages from the surge that traveled up the Neches River. Virtually 100% of Bridge City was flooded including most residential and commercial properties. It is estimated that 15 of approximately 3000 homes in the entire city were not flooded by Hurricane Ike's surge.

The "chemical row" area of Orange County also received major damage and production stoppage because of Ike's surge-generated floods. Estimates of damages and production losses exceed $500 million.

It is not the purpose of this study to dwell on and analyze in detail, the effects of Hurricane Ike on Orange County, but rather to consider the feasibility of structural and non-structural projects that would mitigate the impacts of future tropical storms and hurricanes, which are certain to occur.

2.1 General

In August of 2010, Orange County, Texas and the Orange County Economic Development Corporation executed a contract with the Texas Water Development Board for the development of a Flood Protection Planning Study for a Hurricane Flood Protection System. The study is being funded by a Texas Water Development Board Planning Grant with matching funds provided by Orange County. The project is supported by a stakeholder group consisting of Orange County municipalities, Orange County EDC, Port of Orange, Orange County Drainage District, and the Association of Plant Managers in Orange County.

The study team known as the Sabine-Neches Project Group (S-NPG) consists of the following engineering and environmental firms.

Carroll & Blackman, Inc. - Project manager and prime contract with Orange County, Texas
Costello Inc. – Engineering
LJA Engineering, Inc. – Engineering
Fugro Consultants, Inc. – Geotechnical Engineering
ARCADIS – Surge Modeling
Berg-Oliver Associates – Environmental
JS Ward Associates – Benefit-Cost and Financial

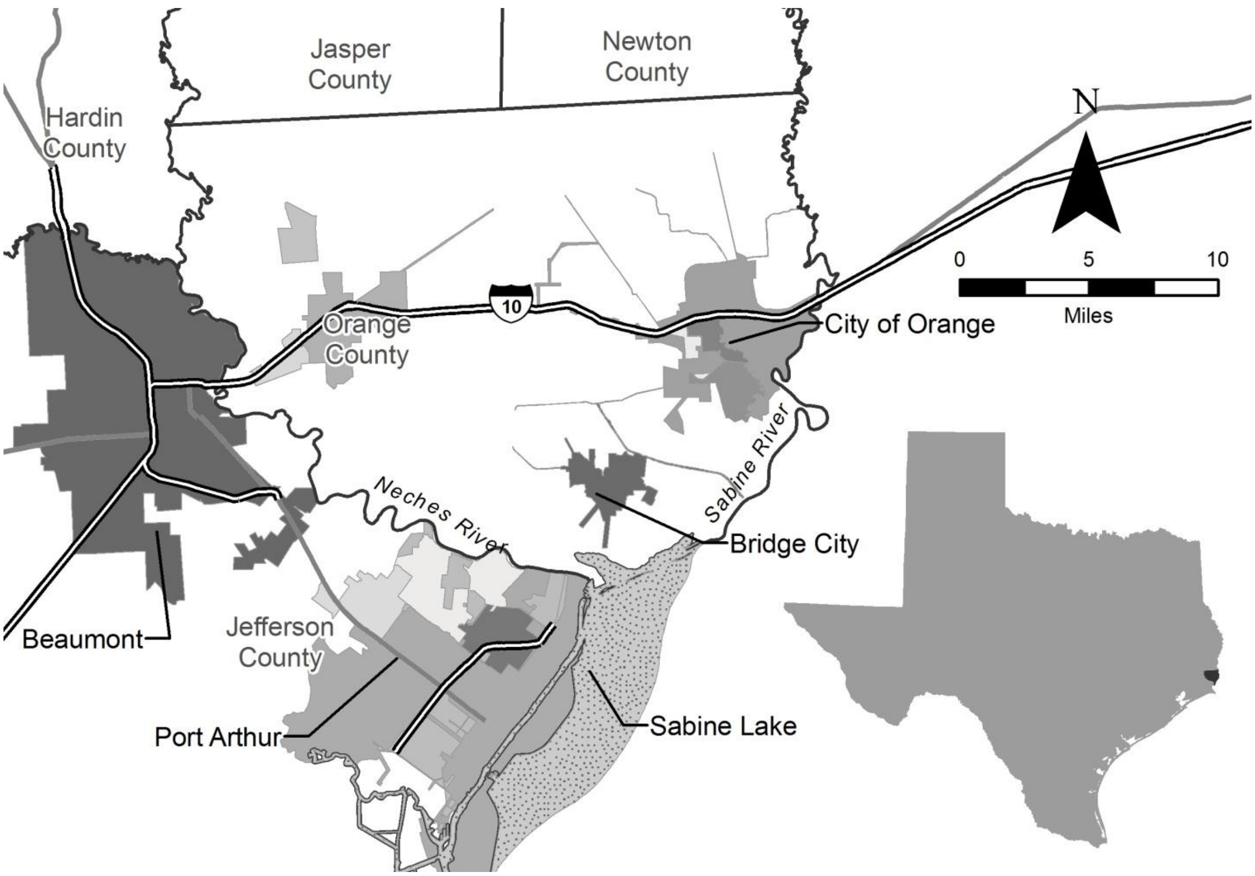

Figure 2-1 Location Map

2.2 Objective and Scope

The objective of the study is to consider and evaluate the feasibility of construction of a Hurricane Flood Protection System to provide the County with a strategy to address goals for flood protection and loss reduction. This report addresses the complex interaction and combination of hurricane flood events, levels of protection, structural features and costs, environmental effects, assessment of benefits, and strategies for development of actual projects to achieve the County's objectives.

The scope of the study encompasses many known flood control strategies and features which might consist of earthen levees, structural steel and concrete walls, gates, and pump stations. The study includes examination of the effects of a predictable hurricane surge event as well as the interior drainage of the protected areas. Much of the interior drainage network has not been studied. The feasibility of a county-wide protection system has not been considered prior to this study, and a smaller scale system has not been considered since the 1970's.

The scope as stated in the study team's contracts with Orange County is as follows. This report will address, in detail, all items in the stated scope which follows.

1.0 PROJECT MANAGEMENT AND STAKEHOLDER PROCESS
1.1 Stakeholder Process
1.2 Project Management
2.0 PRELIMINARY ENGINEERING
2.1 Design Parameter Identification
2.2 Levee Alignment Alternatives
2.3 Alignment Alternative Evaluations
2.4 Benefit-Cost Analysis
3.0 PROJECT LEGAL AND FINANCIAL STRUCTURE
4.0 FINAL REPORT AND RECOMMENDATIONS

2.2.1 Report Organization

The report covers a large array of subjects in order to achieve the Objective and Scope for this project. The major sections of the report are as follows:

2. Introduction
3. Design Parameter Identification
4. Project Alternatives and Evaluations
5. Preliminary Design
6. Preliminary Project Cost Estimates
7. Benefit-Cost Analysis
8. Alternative Evaluations
9. Project Delivery and Financing
10. Conclusions and Recommendations

The report begins with discussion of hurricane impacts and history, identification of all design elements necessary to the protection system, and development of a series of alternates to be evaluated against an objective set of criteria. Preliminary design elements necessary for development of quantities and cost estimates were established and formed the basis for a preliminary Benefit-Cost Analysis and evaluation of the alternatives utilizing the developed grading system. Finally, potential project delivery and financing is discussed along with conclusions and recommendations.

Figures and tables are generally found in the body of the report unless specifically included in one of the appendices. Large sets of data and report material such as the geotechnical report and the environmental report support documentation are presented in separate appendices on compact disc.

2.3 Watershed Description

2.3.1 Topography

Orange County lies within the Gulf Coastal Plain in Texas. The topography is very flat with elevations in the study area ranging from 0 ft. to 20 ft. mean sea level. General land slope is 0.05% and less. The major drainage systems in Orange County are the Neches River in the western part and the Sabine River in the eastern part. These rivers, and other minor drainage systems, empty into the Gulf of Mexico at Sabine Lake.

2.3.2 Soil Characteristics

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

2.3.3 Climate

The climate in Orange County is subtropical humid with the highest annual rainfall in the state. The annual precipitation average is fifty-six inches, and the average humidity is 89 percent at 6:00 A.M. and 69 percent at 6:00 P.M. The annual average temperature is 68° F, with average temperatures ranging in January from a low of 42° F to a high of 61° F and in July from 74° F to 91° F. The growing season averages 240 days per year, with the last freeze in mid-March and the first freeze in early November. Although the average monthly rainfall is not excessive, concentrated rainfall of short duration from extreme meteorological storm events has been recorded.

2.4 History of Flooding

2.4.1 Southeast Texas Hurricane History

The following is a summary of tropical storms and hurricanes that had various levels of flooding impacts to the Orange County and Southeast Texas area.

Hurricane Ike: September12-13, 2008

A very large Category 2 hurricane that made landfall at Galveston Texas. Hurricane force winds were recorded over most of Southeast Texas. However, Ike will be remembered for the record storm surge values (NAVD88) from 14 feet near Sabine Pass with 11 to 12 feet across Sabine Lake, flooding most of Bridge City and portions of Orange. Port Arthur was spared the storm surge thanks to its 14-17 foot seawall. However, the remaining southern half of Jefferson County was inundated, with estimated high water marks reaching 18 to just over 19 feet to the south and east of High Island. This is the worst storm surge flooding recorded across this region during the last 150+ years of record keeping.

Hurricane Humberto: September12-13, 2007

A very small Category 1 hurricane that made landfall between High Island and Sea Rim State Park in Jefferson County, Texas. Due to the small size, storm surge values were 4 to 5 feet across Jefferson County, 3 to 4 feet across Sabine Lake.

Hurricane Rita: September 23-24, 2005

A very large Category 3 hurricane that made landfall between Johnson's Bayou and Sabine Pass, affecting the entire Louisiana and Southeast Texas coasts. Hurricane force winds were recorded from Jasper, Kountze, and High Island, Texas eastward into Louisiana. The storm generated a surge of 8 to 10 feet (NAVD 88) across eastern Jefferson and Orange Counties in Southeast Texas.

Tropical Storm Frances: September 9-12, 1998

A very large tropical storm that made landfall across the Central Texas coast, but the circulation covered the entire northwestern Gulf of Mexico. Every road in Sabine Pass was underwater, except Highway 87 right in front of the school. 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 under water. The extensive flooding was due to tides running between 3½ to near 5 feet for 2½ days.

Hurricane Chantal: August 1, 1989, Hurricane Jerry: October 15, 1989

Two very small Category 1 hurricanes that made landfall at High Island and Galveston respectively. Storm surge values were 4-5 feet across Jefferson County.

Hurricane Bonnie: June 26, 1986

A very small Category 1 hurricane that made landfall between High Island and Sea Rim State Park in Jefferson County. Storm surge values were 6-7 feet across Jefferson County.

Hurricane Alicia: August 17-18, 1983

A small Category 3 hurricane that made landfall across the Upper Texas coast just southwest of Galveston near Freeport. Storm surge values were just over 5 feet at Sabine Pass with higher values across Coastal Western Jefferson County.

Hurricane Carla: September 10-12, 1961

An extremely large Category 4 hurricane (circulation covered the entire Gulf of Mexico at one point) made landfall across the Central Texas coast. Due to the large size of the storm, storm surge values of 7 to 8 feet were common across coastal Jefferson and Orange Counties.

Hurricane Audrey: June 26-27, 1957

A very large Category 4 hurricane, with a 40 mile wide eye, made landfall from Sabine Pass to Cameron, Louisiana. Audrey affected the entire Louisiana and Southeast Texas coasts. Storm surge values of 8 to 10 feet were recorded across Eastern Jefferson and Orange Counties in Southeast Texas.

Storm #2: August 17, 1915

A very large Category 4 hurricane made landfall across western Galveston Island, Texas. Due to the large size of the storm, storm surge elevations of 9 to 11 feet were common across coastal areas of Jefferson and Orange Counties.

Storm #1: September 8-9, 1900

A Category 4 hurricane which made landfall across western Galveston Island, Texas. This was the deadliest storm in U.S. history with an estimated 6,000 to 8,000 lives lost. Storm surge for Jefferson and Orange Counties not available.

2.4.2 Response to Hurricane Carla

As described above, Hurricane Carla caused extensive flooding from Port O'Connor to the upper Texas coast. The cities of Orange, Bridge City, Groves, and the City of Pt. Arthur all experienced extensive flooding. According to the Report on Hurricane Carla, authored by the Corps of Engineers, Galveston District (1962), the existing piecemeal levee system in Pt. Arthur provided a low level of protection to the areas adjacent to Sabine Lake, but unprotected areas of Pt. Arthur and Groves experienced extensive flooding. In Orange County, the cities of Orange and Bridge City flooded to an elevation of about 7 feet. In Pt. Arthur, the response to this event was the design and construction of a consolidated levee system as a federal project through the Corps of Engineers which was cost shared by a local sponsor, Jefferson County Drainage District No. 7. The levee system was constructed in stages through the 1970's and completed in the early 1980's. The levee system effectively protected the Pt. Arthur and mid-Jefferson County area from the effects of Hurricane Ike.

2.5 Information Collection

2.5.1 General

The information used in the development of this study was collected from numerous areas. The following is a list of data sources utilized.

- Orange County Appraisal District aerial mapping utilized for base and detail maps
- FEMA LIDAR data acquired from TNRIS utilized for terrain modeling
- Surveying of a sample of ground elevations for development of benefit-cost elevation model
- City of Orange Flood Protection Study, Carter and Burgess, Inc., April 1994 report on drainage and levees
- ADCIRC computer model runs by ARCADIS to consider impacts of a shifted Ike track
- FEMA Draft DFIRMs and surge elevation mapping
- NRCS Soil Survey of Jefferson and Orange Counties
- Numerous meetings of the Orange County Levee Steering Committee consisting of members from governmental entities and private industry
- USGS Water Data for historical stage and discharge information

2.5.2 Public Meetings

Three Public Meetings were held in accordance with TWDB rules and procedures.

- 1st Public Meeting, January, 12, 2011– The meeting was held at the Bridge City Community Center. Presentation was made by Carroll & Blackman, Inc. to present the scope and work progress of the study. Public comments were solicited included concerns about environmental impacts and level of protection.
- 2nd Public Meeting, August 3, 2011 – The meeting was held at the Orange County Commissioners Court. Presentation by Carroll & Blackman, Inc. to present the scope and work progress of the study. Public comments included questions about the alignment alternatives.
- 3rd Public Meeting, September 12, 2012 – The preliminary study report was presented to the public focusing on the proposed protection system for the entire county and on alternatives considered.

2.5.3 Stakeholder Process

The project is supported by a steering committee (stakeholder group) consisting of Orange County municipalities, Orange County EDC, Port of Orange, Orange County Drainage District, and the Association of Plant Managers in Orange County. Numerous meetings of the steering committee were held during the study process. Subjects discussed at these meetings included:

- Study scope review
- Alignment alternatives
- Preliminary alignments
- Levels of protection
- Study progress

3. Design Parameter Identification

3.1 Surveying

All project horizontal and vertical control for this project has been established by utilizing GPS Static methods. The survey team began by setting four (4) control monuments and recovering one (1) NGS MonumentT1199 to utilize as the primary project control. These monuments were occupied and data collected utilizing static methods. Data for each control point was collected over multiple days and redundant ties were made to insure the highest accuracy possible. At least two (2) monuments were occupied in overlapping fashion in any one observation.

Once all data was collected, the network was post processed utilizing the CORS (Continuously Operating Reference Station) and referenced to the Texas State Plane Coordinate System, Central Zone. The CORS used for post processing for this project were:

DM7139	TXAC Anahuac ARP	N294640.059, W0944017.232
DM7838	TXPT Port Arthur ARP	N295650.701, W0935710.509
DL8633	DQCY DeQuincy ARP	N302704.235, W0932643.063
DK3579	CAMR Cameron CT ARP	N294754.577, W0931930.381
DE8095	MCNE McNeese St. ARP	N301050.022, W0931303.843

Once horizontal and vertical coordinates were established all topographic data was collected utilizing GPS RTK Methods. GPS base station was occupied on one of the known control points and a GPS rover was used to collect the necessary data. Check shots were taken multiple times daily to insure accuracy.

The control data sheets for the primary monuments are shown in Appendix A.

3.2 System-wide Level of Protection

One of the primary design parameters which need to be established for a system is the level of protection to which the system will be built. The level of protection includes a number of aspects of the design parameters and system life-span assumptions for the various components. The major parameters are discussed in the following sections.

3.2.1 Protection Level for Feasibility Study

A discussion of Level of Protection was held at a steering committee meeting during the study. At that meeting, the consensus was that an “Ike Level” event should be considered when evaluating the feasibility and cost of the various components of the proposed protection system. When considering this position, several conditions and factors were considered by the study team.

- The FEMA 100 year elevations should be considered the minimally accepted levels for system planning.

- The Jefferson County Drainage District No. 7 (DD 7) system which protects Port Arthur and other areas in southeast Jefferson County exists at an elevation of 16 ft. +/-, which apparently provides those communities with a level of protection slightly in excess of the FEMA 100-year surge event level.

- Major structural components of the proposed system should be designed at the Ike Level elevations with consideration of earthen embankments at both an elevation consistent with the DD7 system and at the Ike Level.

- The study recognizes the potential effects of sea level rise (discussed in detail in another report section) and that the impacts should be incorporated at least into the minimally accepted design level.

The following section describes the information collected and developed for the analysis of the level of protection to be used throughout this study.

3.2.2 Design Event for Storm Surge Protection

Three flooding events were investigated in order to determine the required protection system top elevations to be considered for the hurricane storm surge protection elements of the proposed system. The minimum level of protection to be considered with regard to hurricane surge events is the 100-year event which the Federal Emergency Management Agency (FEMA) mandates in order to be a participant in the National Flood Insurance Program (NFIP). Two conditions which considered Hurricane Ike-like storms were also investigated.

3.2.2.1 100-year FEMA Coastal Study

The minimum level of protection considered by the study team is the 100-year recurrence interval as defined and mapped by FEMA. It is the minimum level to which FEMA will accredit levee systems with regard to the NFIP and the Flood Insurance Rate Maps (FIRMs). In the wake of Hurricanes Rita and Ike, new models were developed and calibrated for the Gulf Coast of the United States. Draft Digital FIRMs (DFIRMs) for Orange and Jefferson Counties were presented to the local entities by FEMA in February and March, 2012, which provided needed flood elevation information, including still water elevations, wave heights and wave runup heights, and flood zone mapping (VE and AE) designations.

Table 3-1 represents the minimum levee height necessary at the location of peak surge and wave heights along the proposed protection system to meet the levee height requirements for FEMA accreditation.

3.2.2.2 Hurricane Ike and "Shifted Ike" Events

In addition to the FEMA mapping and elevation modeling, the study team retained ARCADIS to conduct modeling based on the updated and calibrated Advanced Circulation (ADCIRC) models. Results of model runs for this study are presented in Appendix B. The analysis of Hurricane Ike by ARCADIS included the calibrated Ike surge modeling as well as a "shifted" Ike track that would provide a more severe (than the FEMA 100 year event) scenario for Orange County if Ike or a similar storm had made landfall in southeastern Jefferson County. This series of models provided the study team with data along the proposed levee alignments using the case of a significant hurricane event in excess of the 100-year storm event. The following table represents the levee height necessary at the location of peak surge and wave heights along the proposed protection system based on the Ike and "Shifted Ike" scenario.

Table 3-1 Ike Surge and Wave Elevations

Ike and Shifted Ike Protection System Top Elevation Analysis			
Ike Condition	Elev.	"Shifted Ike Condition	Elev.
Ike Surge Elevation	15	Shifted Ike Surge Elevation	16.5
Ike Wave Height/Runup	2.3	Shifted Ike Wave Height/Runup	2.5
Peak elevation	17.3	Peak elevation	19

As indicated in the shifted Ike model runs, the most critical area for the combination of surge and wave generated elevations in Orange County is from the mouth of the Neches River to Adams Bayou, along the Sabine River. The models also indicate that the surge and wave height elevations drop as the surge moves up the Sabine River towards I.H. 10.

This information, combined with the draft DFIRM information, indicates that the storm surge influence on the potential flooding conditions along both the Sabine and Neches Rivers begins to diminish in the vicinity of the I.H. 10 crossings of both rivers. At those river stations the riverine flood levels begin to exceed the storm surge elevations, thus the hurricane flood protection system can be designed to tie into the appropriate natural ground elevations north of I.H. 10. These locations will be determined and described in subsequent sections of this report.

The following table shows the 100-year storm event, Hurricane Ike and "Shifted Ike" flood levels used to establish a potential flood profile along the Sabine and Neches Rivers in order to compare the level of protection provided and to aid the project team in establishing the level of protection parameter to be used throughout the study.

Table 3-2 Level of Protection

Level of Protection					
Location	100 year		Hurricane Ike	"Shifted" Ike	
	Flood Elev	With Freeboard	Flood Elev	Flood Elev	Proposed Protection Elevation
SABINE RIVER ALIGNMENT					
Neches River Crossing	13	14	17	19	19
Bridge City Area	13	14	16	17	18
Cow Bayou	13	14	15	16.5	18
Adams Bayou	11	12	13	13.5	16
Port of Orange	11	12	12	13.5	16
I.H. 10	11	12	11	11.5	14
NECHES RIVER ALIGNMENT					
Bridge City	13	14	n/a	n/a	n/a
Vidor	12	13	n/a	n/a	n/a
Downtown Beaumont	11	12	n/a	n/a	n/a
I.H. 10	11	12	n/a	n/a	n/a

The following graphs depict the protection elevations, including appropriate freeboard, along the Sabine and Neches River alignments from Table 3-2, with the natural ground elevations indicating the upstream extents of each alignment alternative. Note that the reference to "Preliminary FEMA 1% VE …" refers to the mapped elevations from the FEMA 100 year surge event.

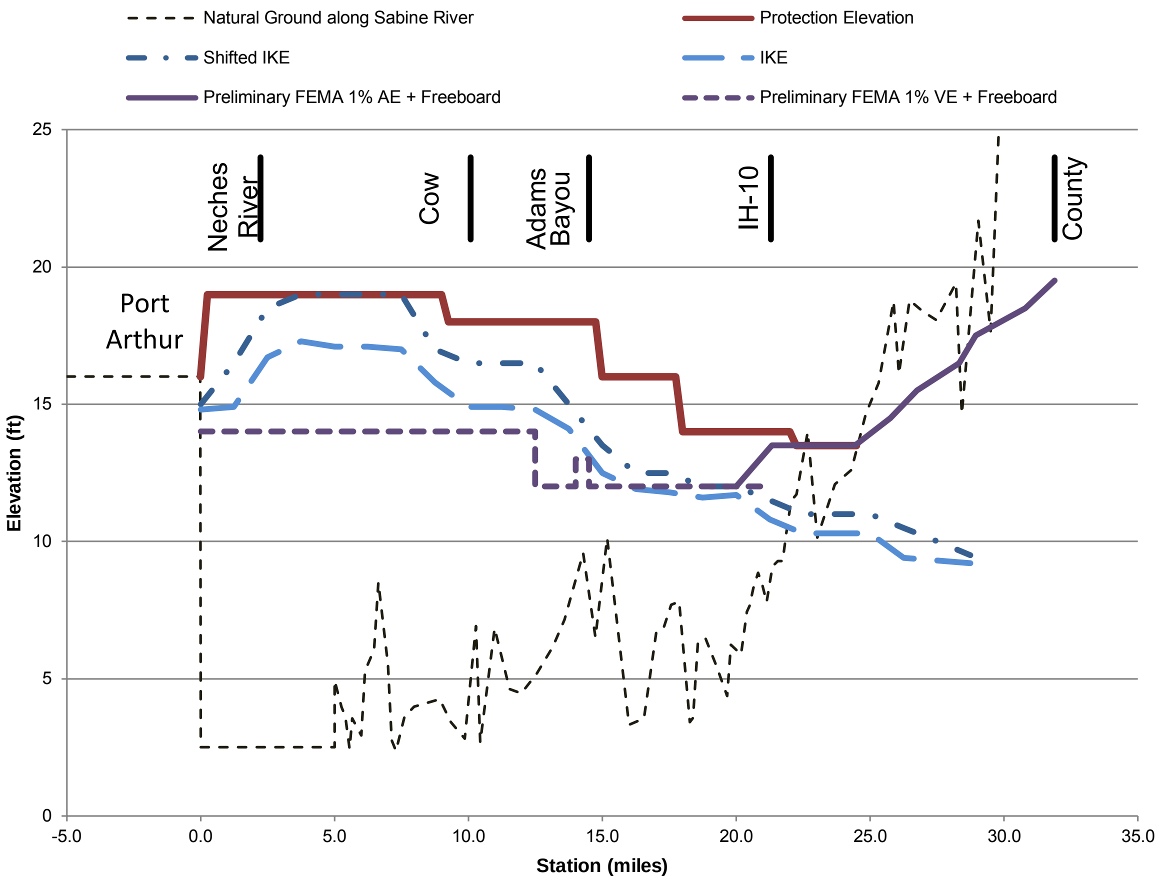

Figure 3-1 Profile of Protection Level Parameters along Sabine River Alignment

Station 0 on the X axis represents the location of a proposed tie-in to the Port Arthur levee system in southeastern Jefferson County. Other key locations, or Points of Interest, are shown along the top of the graph. The "Preliminary FEMA 1% + Freeboard" line represents the minimum top elevations, based on the preliminary DFIRMs, required to achieve FEMA accreditation of the selected protection system alignment. The proposed protection system top elevation, as represented by the top line on the graph, would provide protection from an Ike-level hurricane event, which is well in excess of the FEMA 100-year event.

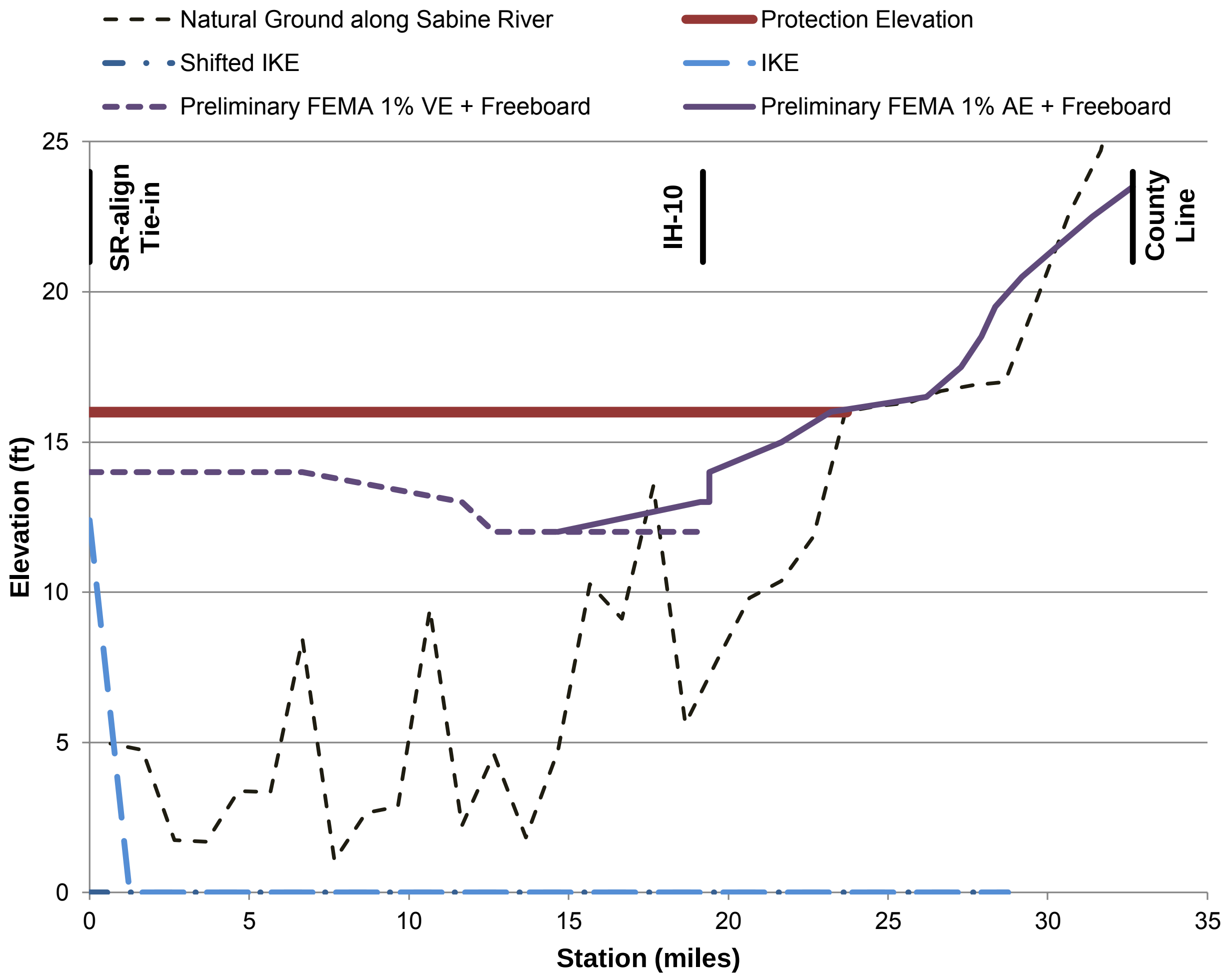

Figure 3-2 Profile of Protection Level Parameters along Neches River Alignment

3.2.3 Sea Level Rise

Sea level rise is a consideration when establishing a design top elevation for structural hurricane flood protection projects. The project's level of protection is effectively reduced over time due to the effects of relative sea level rise, which includes both the absolute rise in water level, as well as land subsidence. In the last century, sea level rise is a well-documented phenomenon and is expected to continue during this century. There are many studies that attempt to predict the magnitude of rise in sea level and consider the effects on coastal areas on a global basis.

The Intergovernmental Panel on Climate Change (IPCC) was established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) to provide the world with a clear scientific view on the current state of knowledge in climate change and its potential environmental and socio-economic impacts. The UN General Assembly endorsed the action by WMO and UNEP in jointly establishing the IPCC. It reviews and assesses the most recent scientific, technical and socio-economic information produced worldwide relevant to the understanding of climate change. It does not conduct any research, nor does it monitor climate related data or parameters.

According to the IPCC Fourth Assessment Report: Climate Change 2007; "The two major causes of global sea-level rise are thermal expansion caused by the warming of the oceans (since water expands as it warms) and the loss of land-based ice (such as glaciers and polar ice caps) due to increased melting. Records and research show that sea level has been steadily rising at a rate of 1 to 2.5 millimeters (0.04 to 0.1 inches) per year since 1900."

This equates to an elevation increase of about 9 inches from 1870 to 2000. For the century 2000 to 2100 the predicted range of sea level rise is from 7 to 19 inches. The majority of scientific literature and studies reviewed for this feasibility study support this range.

In addition to the potential rise in global sea level described above, ground subsidence is a known phenomenon along the upper Texas coast that is at least as significant. Tide station records dating back to 1958 in Sabine Pass and to 1908 in Galveston, document a relative sea level rise (including the effects of both absolute sea level rise and ground subsidence) of about 6 mm/yr (1.9 feet per century) (NOAA Tides & Currents), compared to worldwide sea level rise estimates (e.g., IPCC) of 1 to 2.5 mm/yr that do not include subsidence.

Upper Texas coastal subsidence over the past century has been correlated, in part, with extraction of subsurface water, oil, and gas as well as the more typical natural soil consolidation (compaction). In particular, gas extraction from shallow fields in western Orange County caused dramatic localized subsidence in the Bessie Heights marsh region in the mid-20th Century. The intensity of such extraction has been reduced or eliminated in recent decades, and relative sea level has not increased significantly in Sabine Pass or Galveston since about 1990 (TxBEG).

Amid the uncertainties associated with predictions of future accelerated sea level rise and reduced subsidence, this study will assume the continuation of the measured historical rate of relative sea level rise in the region of roughly 2 feet per century. Including an allowance for sea level rise into the protections system height calculations will be discussed in subsequent sections.

3.3 Hydrologic & Hydraulic Parameters for Internal Drainage Systems

The hydrologic and hydraulic design parameters which will be applied to this study were taken from a number of sources. There are numerous existing drainage systems within Orange County, including Adams and Cow Bayous and several other relatively large watersheds. The design and analysis criteria for these internal drainage systems were obtained from the existing Orange County Drainage District criteria and supplemented with criteria from similar riverine and coastal protection systems along the upper and middle Texas Gulf Coast.

3.3.1 Design rainfall

The design rainfall event utilized for analysis of the interior drainage system is the FEMA benchmark 100-year rainfall (1% probability of reccurrence). Peak flows were developed for point locations where the interior drainage channels would drain through the proposed structural system. At these locations proposed closure structures and, in some cases, pump stations, will concurrently provide protection against storm surges and pumping capacity adequate to convey the 100 year runoff that may be associated with a tropical storm or hurricane event. The interior drainage system was not analyzed for capacity and ability to convey flows through the system to the outlet points. The interior flood plain is based on the current conveyance system and analysis and improvements will have no impact on the system proposed in this study.

3.3.2 Coincidental rainfall

Rainfall quantity from hurricanes is very difficult to predict and does not generally coincide with typical design rainfall events such as the FEMA 100 year rainfall.

The following article is from the NOAA website.

Inland Flooding

"In the 1970s, '80s, and '90s, inland flooding was responsible for more than half of the deaths associated with tropical cyclones in the United States."

Consider the following:

When it comes to hurricanes, wind speeds do not tell the whole story. Hurricanes produce storm surges, tornadoes, and often the most deadly of all - inland flooding.

While storm surge is always a potential threat, more people have died from inland flooding from 1970 up to 2000. Intense rainfall is not directly related to the wind speed of tropical cyclones. In fact, some of the greatest rainfall amounts occur from weaker storms that drift slowly or stall over an area."

The following was written by Dr. Steve Lyons on The Weather Channel website at WeatherInsights®: The Weather Channel Blog.

"One of the most difficult tropical cyclone (tropical depression, tropical storm or hurricane) land impacts to forecast accurately is its rainfall. Because rain is highly variable in space and its patterns constantly change through time, forecasting where rain will fall, how fast it will fall, how much will fall and who will get flooded are very difficult forecasts indeed!"

For interior drainage at outlet locations along the proposed protection system, the study team selected the 100 yr. rainfall event. (discussed below) This level of rainfall event represents a standard that is accepted by regulatory, engineering and municipal communities and also represents a conservative approach to rainfall flood hydrograph prediction at outlet locations.

3.3.3 Drainage Analysis (large basins)

Hydrology for the large-scale drainage basins such as Cow and Adams Bayou was initially developed utilizing the Corps of Engineers HEC-1 and HEC-HMS computer programs. A regional regression analysis was then utilized to confirm and calibrate the flow data at downstream points of analysis at which pump stations are being proposed. Because the conveyance systems were not being specifically analyzed for capacity and planning purposes, channel hydraulics and backwater analyses were not performed or considered. This approach provides runoff flows at the selected points of analysis which will be slightly higher than expected if a routing step method had been utilized. For the purposes of preliminary pump station and gate structure sizing, this approach provides a "factor of safety" when considering the construction and operation of gate and pump systems that will provide drainage during a hurricane surge event.

3.3.4 Pump Stations

Construction of the levee system will impede the existing drainage patterns for most of the established drainage systems within the county. The majority of these systems drain by gravity. In order to be able to block these drainageways in the event of a storm surge, closure structures, generally consisting of gates, are proposed and will be accompanied by pump stations that would operate to discharge the internal system runoff during periods when the gate structures are closed. Based on the size of the contributing watersheds, some drainage systems can be combined to reduce the total number of pump stations.

3.3.5 Tidal Boundary Conditions

For purposes of analyzing the internal streams under normal localized rainfall events and under the coincidental (pumping) event, tidal boundary water surface elevations were obtained. The normal water levels in Sabine Lake, Neches River, Sabine River, Cow Bayou, and Adams Bayou are tidally influenced. These tidal influences on water levels in the lake and waterways vary in time and by location. In addition to establishing the actual water level in Sabine Lake and downstream reaches of the rivers and bayous to which storm surge is added during a design event, the tide level is the downstream boundary condition for calculating backwater conditions and water levels in upstream reaches of the rivers and bayous resulting from stream flows. Higher tidal boundary conditions result in higher water levels upstream for a given stream flow.

Astronomical tides cause predictable daily variations in water levels and monthly cycles associated with the earth’s rotation and the lunar orbit. Water levels also show seasonal trends related to variations in temperature, salinity, wind, atmospheric pressure, and ocean currents.

The diurnal range (daily differences in height between mean higher high water and mean lower low water) at the Rainbow Bridge tide gage (Station ID 8770520) is 0.93 ft, meaning that the effect of astronomical tides on downstream boundary water levels is typically no more than about a half-foot above or below mean sea level.

The average seasonal cycle of water levels in Sabine Pass (per NOAA, Station 8770570) shows seasonal maxima in May and September, and minima in January and July. Of significance to this study is the September average maxima of 0.43 ft. above mean sea level. Thus, initial tide conditions during late-season (September-October) hurricanes could be several tenths of a foot higher than in other months.

The Rainbow Bridge station adjacent to the project location has a current datum sheet published by the Texas Coastal Ocean Observation Network (TCOON) indicating that in 2003 mean sea level at that station was 1.02 ft. above NAVD88 datum. No further adjustment of this relationship was made for the current study.

3.4 Levee Cross Section Design

An earthen levee cross section is proposed to be the primary means by which protection will be provided. The typical levee cross section will include a 20 foot top width, 6:1 (H:V) side slopes on the seaward (flood) side, 4:1 side slopes on the landward (protected) side, a 50 foot wide maintenance area (berm) on the flood side toe of the levee, a 20 foot wide maintenance area (berm) on the landward toe of levee, and a 12 foot wide area for an interceptor swale along the landward berm, as depicted on Figure 3-3.

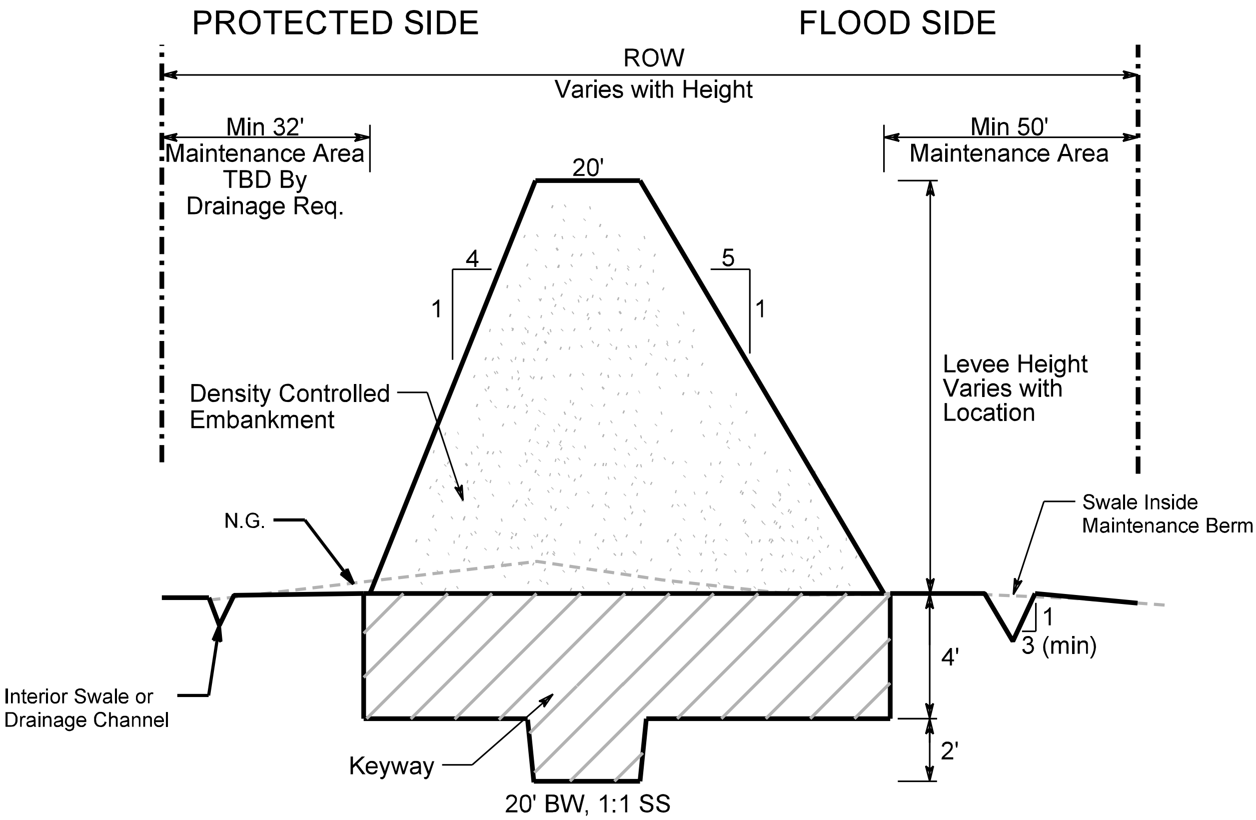

Figure 3-3 Earthen Levee Cross Section

In order to provide protection against vehicular damage (wheel rutting) on the levee tops and accommodate inspection and maintenance access along the levee, a 20-foot wide all-weather roadway surface will be provided along the top of the levee. In areas where public access or a higher level of transportation needs are identified, the levee top will be paved with either asphalt or concrete pavement, as determined by the local codes or other design considerations.

As shown on Figure 3-3, where necessary, interceptor swales will be located along the landward and seaward sides of the right of way. These swales are intended to intercept runoff from the levee and surrounding areas in order to prevent surface ponding within the right of way and on the adjacent properties.

Along certain reaches of the levee, an interior ditch will be proposed to convey interior runoff flows to the gravity outfall structures and/or pump stations. Such interior ditches will be used where interior drainage patterns and/or existing development dictates the need for one. The interior ditch right of way is established as 150 feet in width for all ditch sections. This assumed width will accommodate a 56-foot bottom width ditch, with an average depth of 8 feet, 4:1 side slopes and a 30-foot wide maintenance berm along the interior side. These ditches would share a maintenance berm and interceptor swale along the levee side of the ditches.

The detention pond/borrow pit right of way was computed based on an average assumed depth of the pond of 12 feet, with 4:1 side slopes and 30-foot wide maintenance berms, in order to provide the required volume for each pond location identified.

3.5 Flood Wall Design

Two typical sections were used to represent potential flood wall geometries for the purposes of this study. The larger section is intended for use in coastal areas, likely to experience highest surge elevations and energy was compiled from review of typical flood wall systems constructed in the vicinity of New Orleans, Louisiana as part of the post-Katrina improvements to the protection system there. This section was chosen for the development of probable cost for this study due to the likely similarities in topography and geotechnical conditions between the two regions as well as timeliness of available data from the recently constructed systems in Louisiana. This larger typical section was assumed to be applicable with wall heights from 8' to 20'. A second typical section for use in smaller walls (less than 8') in more upland areas that are not velocity zones was also developed. This smaller section was designed to approximate the required section based on the likely flood induced loads.

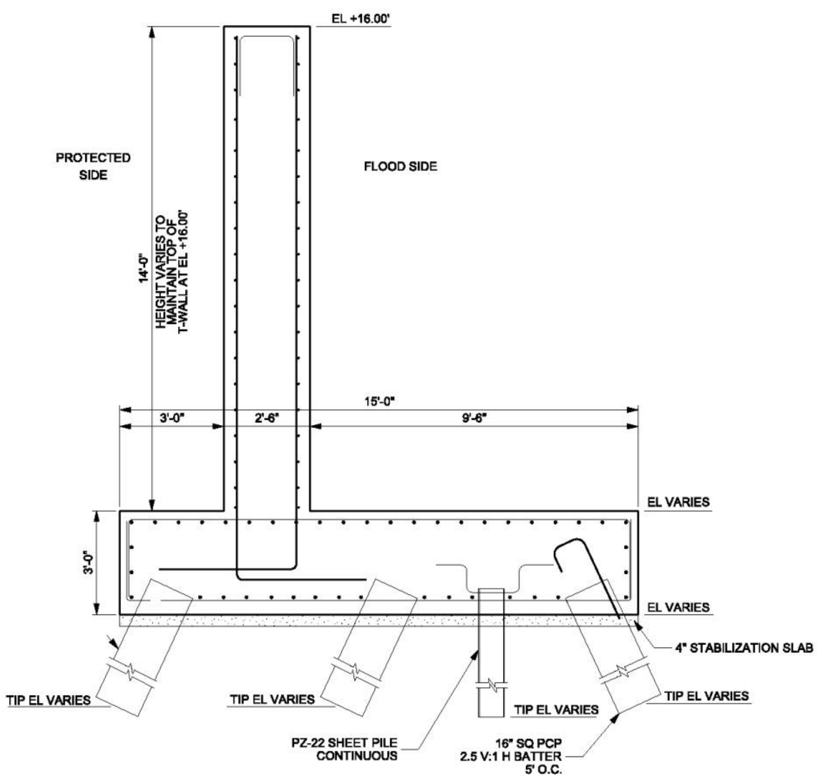

Figure 3-4 Typical Flood Wall Section

The two typical sections were used to represent the flood wall geometry throughout the proposed alignments for this study, with only the stem height varying to accommodate variations in natural ground elevations. Footing width, stem thickness, and pile arrangements for the floodwall typical section were based on a stem height of 14' for the larger typical section and 8' for the smaller typical section regardless of the actual stem height required at any given location within the alignments.

3.6 Transportation Considerations

Construction of a protection system will require that the system cross the transportation infrastructure in the project area. The various types of infrastructure and proposed crossing methods are discussed in the following sections. The types of transportation infrastructure crossings addressed in this section are: State and federal highways, county roads, local major thoroughfares, local streets, private driveways, and railroad corridors. The criteria for crossing these types of infrastructure include a number of considerations; availability of right of way, type of use of the infrastructure, and adjacent land uses among other considerations. Two main types of crossings will be considered for this study: raised-profile crossings and gated closures. Each is described in the following sections.

3.6.1 Raised-Profile Crossings

Raised-profile crossings consist of reconstructing a roadway over a proposed earthen levee section in order to accommodate access across the levee without interruption of traffic during normal use and in the times of an approaching storm. This type of crossing allows the movement of vehicles across the levee, up to the time external floodwaters cut off access, does not require manual operation to put into place, can provide easy maintenance and inspection access to the levee at all times, and has a much reduced risk of failure over operated gates. While this type of crossing may be more expensive to install in the initial construction of the system, due to greater right of way requirements, longer interruptions in traffic operations during construction, embankment fill material, roadway pavement construction, and possible utility reconstruction to eliminate conflicts, the long term benefits and reduced operations costs can be significant. Additionally, raised-profile crossings will require much fewer maintenance activities during normal operations than will gated closures.

The major highways in the vicinity of the proposed project are typically Hurricane Evacuation Routes, used in advance of approaching tropical events and for general mobility and commerce in the region. It will be advantageous to have these major facilities open to traffic at all times, without the need for the protection system operators to close gates or otherwise monitor these crossings. On major thoroughfares, which may also need uninterrupted access across the levee, up to the time of the approaching storm event, raised-profile crossings will be utilized.

A typical roadway cross section with the pertinent design parameters for 2 and 4-lane roads is shown on Figure 3-5 below**.**

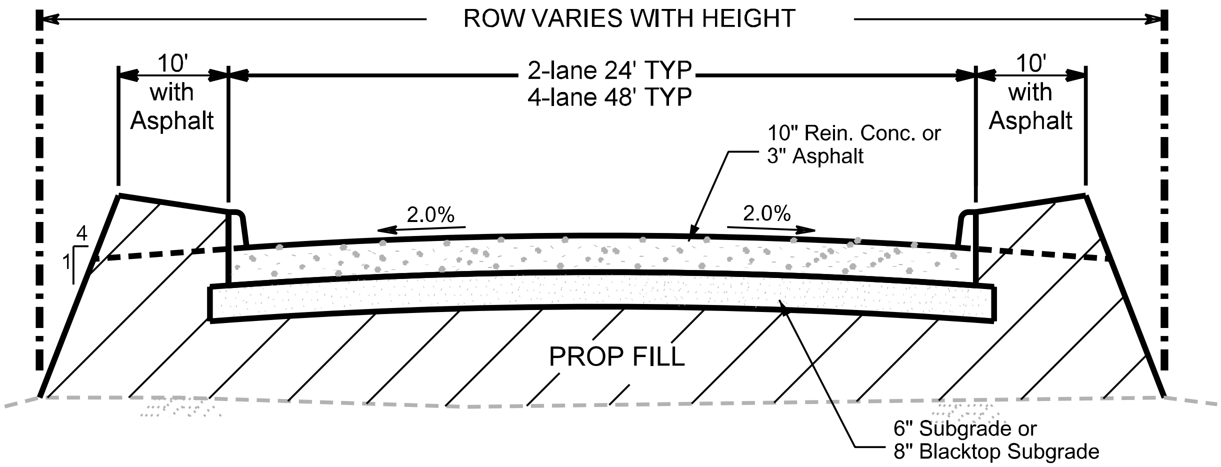

Figure 3-5 Typical roadway cross section for concrete and asphalt pavement sections

A typical profile for a raised-profile levee crossing is shown on **Exhibit 5.5c** for roadways of various design speeds. Vertical profile design data was developed from the TxDOT's *"Roadway Design Manual"* and the ASSTHO publication *"A Policy on the Geometric Design of Highways and Streets."*

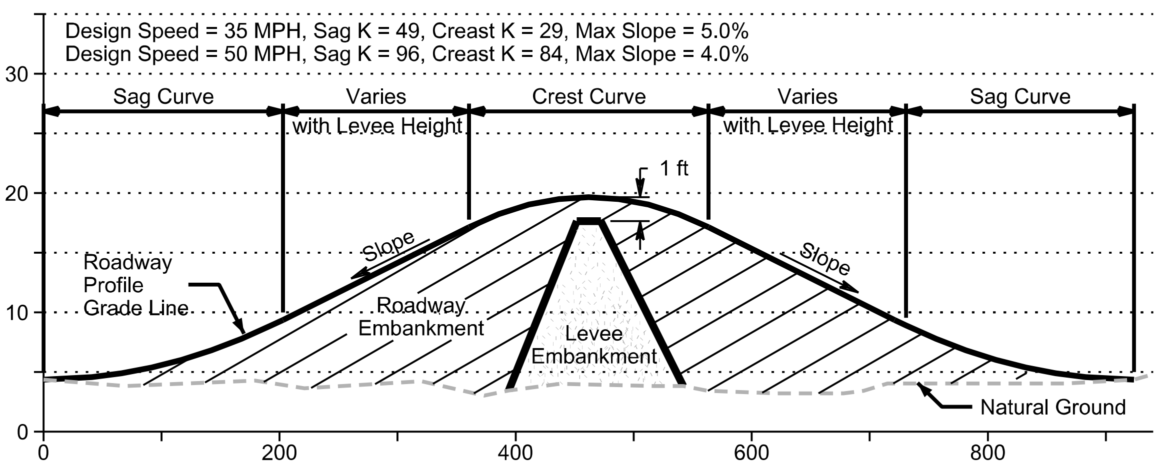

Figure 3-6 Typical raised-profile roadway levee crossing

3.6.2 Gated Closures

Gated closures may be required on some roadway crossings due to limited right of way availability, restrictive access geometry, such as within existing industrial areas, and locations which may require at-grade roadway access through the levee. Gated closure will also be necessary in locations where floodwalls are to be utilized. These gated closures will need to be closed by operations personnel during the mobilization phase of a flooding event. An emergency operations plan will be developed which will identify detailed closure procedures, key times, related to approaching storms, at which gates must be closed, and the personnel responsible for closure of each location.

There are five commonly used types of closure structures that can be used for transportation crossings: stop logs, swing gates, miter gates, rolling gates, and trolley gates. Three types of gates are anticipated being used for this project: swing gate, miter gate and rolling gate types, as described in USACE Engineering Manual 1110-2-2705, due to the relative advantages of these gate types over the other types. Swing gates will be used in those locations where a single leaf gate will span the opening and provide adequate strength against the static hydraulic and wave action loading computed for those locations. Miter gates will be used where double-leaf gates are required to span the opening, since these gates will provide better closure performance against static hydraulic and wave action loadings. Rolling gates will be used in locations of restricted clearances for swing-type gates are found, typically within industrial facilities and rail yards.

3.6.3 TxDOT Coordination

Construction of the proposed levee protection system will require crossing of several state and federal highways maintained by the Texas Department of Transportation (TxDOT). These crossings will be designed using the latest TxDOT highway design manual and applicable Federal Highway Administration (FHWA) standards and criteria. The design, construction plans, and construction contracts will all be prepared in accordance with TxDOT standards and criteria. It can be anticipated that the construction contracts for each roadway improvement project will be administered and overseen by TxDOT, with all costs of such projects being paid by the sponsoring agency.

The construction of these highway improvements will be closely coordinated with TxDOT in order to facilitate the timely construction of the facilities and minimize the disruption to local and through-traffic during construction. Any right of way expansions required to accommodate the roadway crossings will be required to be deeded to TxDOT, with the acquisition of same being the responsibility of the levee agency. An inter-local agreement between TxDOT and the local levee agency may be required to identify the rights and responsibilities of each agency regarding future improvements, utilities and maintenance of these crossings

3.6.4 County and City Coordination

The preliminary alignments of the various protection levee alternatives will cross many county roads and city streets. In order to maintain access across or through the proposed levee or floodwall, either flood gates or raised-profile roadway crossings will be utilized. The type of closures at thoroughfare and street crossings will be determined by the availability of right-of-way, the level of service required for the street and the surrounding land uses.

The construction of these roadway and street improvements will be closely coordinated with the respective owning agency (county or city), in order to facilitate the timely construction of the facilities and minimize the disruption to local and through-traffic during construction. It is recommended that any right of way expansions required to accommodate the crossings be deeded to the respective agencies to facilitate their maintenance of the roadway components, with the acquisition of the right of way being the responsibility of the levee agency. An inter-local agreement between each of the respective agencies and the levee agency is recommended in order to identify the rights and responsibilities of each agency regarding future improvements, utilities and maintenance of these crossings.

3.6.5 Private Street and Driveway Owner Coordination

The preliminary alignments of the various protection levee alternatives will cross a number of private streets and driveways. In order to maintain access across or through the proposed levee or floodwall, either flood gates or raised-profile roadway crossings will be utilized. The type of closures at private street and driveway crossings will be determined by the availability of right-of-way, the level of service required for access and the surrounding land uses.

The construction of these roadway and street improvements will be closely coordinated with the respective owning agency (county or city), in order to facilitate the timely construction of the facilities and minimize the disruption to traffic and plant operations during construction. It is recommended that any right of way expansions required to accommodate the crossings be deeded to or remain with the respective owners to facilitate their maintenance of the street and driveway components. Easements to the levee agency should be acquired in these locations, with adequate language included in order to identify the rights and responsibilities of each entity regarding future improvements, utilities and maintenance of these crossings.

3.6.6 Railroad Coordination

The preliminary alignments of the various protection levee alternatives will cross several rail lines in the project area. In order to maintain access through the proposed levee or floodwall, gated closures will be utilized in order to avoid raising the rail lines. The type of gate at each rail crossings will be determined by the availability of right of way and the width of the rail corridor at the crossing location.

The design and construction of these railroad closure gates will be closely coordinated with the respective owning agency (major rail company or industry), in order to facilitate the timely construction of the facilities and minimize the disruption to traffic and plant operations during construction. It is recommended that any right of way expansions required to accommodate the crossings be deeded to or remain with the respective owners to facilitate their maintenance of the rail components. Easements to the levee agency should be acquired in these locations, with adequate language included in order to identify the rights and responsibilities of each entity regarding future improvements, utilities and maintenance of these crossings.

3.7 Right-of-Way Considerations

It is proposed that all right of way for permanent drainage and levee protection features be obtained as fee simple acquisitions by the public entity responsible for the levee. Such acquisitions allow for easier control of access, more consistent maintenance activities throughout the system and other intangible advantages. In some instances or locations, it may not be possible to acquire fee simple right of way. In those areas, easements must be obtained to allow for the construction and maintenance of the protection system. The rights of the levee owner within such easements should include the ability to control or limit the access to the facilities; maintain the vegetation in a manner consistent with accepted local and federal criteria; set design and construction standards for utility, roadway, pipeline and other infrastructure crossings, review and approve such crossings prior to construction; and have unlimited access to the protection facilities by maintenance and inspection personnel, through adjoining property if necessary, by agreed upon means and access points.

3.8 Geotechnical

In order to assess the geotechnical feasibility of the proposed storm protection system, a study was conducted consisting of the following scope:

- Review of available public information and data from in-house files relative to the general geology and soil conditions along the proposed alignments;
- Identification of possible geotechnical concerns for the proposed alignments;
- Preliminary assessment of possible levee and flood-wall cross-sections; and
- Preparation of a discussion and considerations for additional study for the preliminary and final design.

Levee embankments can be constructed of materials which vary from sand materials to highly plastic clay materials. The choice of materials for a levee is typically based on the availability of a particular soil type near the area of construction. Levees constructed of sandy materials require larger cross sectional areas in order to control through-embankment seepage and to satisfy stability requirements, among other considerations. Levees constructed of clay materials can be built with smaller cross sections, however the compaction requirements are more intensive and the control of the material composition, typically CL to CH classifications with Plasticity Indexes (PI) within controlled ranges, is more critical. Details of soil material properties for levee construction are discussed in the Geotechnical Report in Appendix C.

Given the general availability of clays in this area and the associated ability to utilize smaller cross sectional areas, it will be proposed that the earthen levee segments will be constructed of clay materials, obtained from local sources.

The details of the preliminary geotechnical study are presented in Appendix C.

3.9 Coastal Processes

The primary focus of the present study is to determine the feasibility and cost of protecting Orange County interests from damage caused by hurricane storm surge. Protective measures must prevent or reduce to an acceptable level the amount of sea water entering the area to be protected.

Wind, waves, currents, and their interactions with the coast and coastal structures affect the required crest elevation of protective measures. The levee crest elevation necessary to achieve such protection is discussed elsewhere in this report. Relative sea level rise, the combination of rising global sea water levels and local land subsidence, is also discussed elsewhere.

In addition to storm surge itself, coastal processes relevant to the study include the effects of wind, waves, sea water level, tidal currents, wind-driven currents, sediment transport, and scour. To be effective, protective measures must not only be capable of surviving the hurricane event that would cause the design level of storm surge, but must also remain serviceable through years or decades of lesser events that could precede a design event.

The relevance of these coastal processes to the present feasibility-level study of surge protection options relates primarily to their influence on protection system components and resulting alternative costs. Cost elements are included in alternative costs to account for protection against direct wave impacts where protective measures are exposed to a long fetch (near Sabine Lake), and for scour protection at other locations.

Sea water level in advance of the design storm could significantly influence alternative measures of handling internal drainage and various operations activities. Accordingly, the study team spent considerable effort on determining the possible combined probabilities of storm surge and rainfall flooding in the preparation of alternatives and their analysis. The results showed that the combined probability of inland flooding contemporaneous with design surge is quite low and is not a determining factor in the analysis.

3.9.1 Coastal Design Parameters

Coastal engineering design parameters for Orange County storm surge protection alternatives include the following:

- Crest elevation (levee or floodwall)
- Armor stone
- General scour
- Local scour
- Overtopping scour

A brief discussion of each parameter and considerations that should be made during later design stages of the project are presented below. For cost estimation purposes, a percentage factor is included in the levee construction costs presented in this report to account for design elements needed to address coastal processes. More detailed design effort in later stages will be necessary to allow refinement of cost estimates once location-specific needs can be identified.

Crest elevation

As discussed previously in this report, the crest elevation of the primary protective measures (earthen levees and floodwalls) is a fundamental project parameter. The appropriate crest elevation in this case is a function of the following:

- tide or background water level (feet above project datum)
- storm surge (feet above tide or background water level)
- wave setup (feet above still water level)
- wave runup (feet above still water level)
- localized two-dimensional effects on each of the above
- assumed future relative sea level rise (feet per unit time)
- freeboard (feet)
- desired level of protection (percent chance of exceedance)
- resilience to overtopping
- tolerable overtopping rate (cfs per foot of levee or wall)
- operation, maintenance, and repair program

- system redundancy, if any

Overall system level of protection can be maximized by varying the crest elevation along the project length as cumulative changes to the above inputs vary. A constant crest elevation along the entire project length would be wasteful and would reduce the benefit/cost ratio of any alternative. The variable crest elevations presented in the descriptions of alternatives generally account for the inputs listed above to allow feasibility-level planning and cost estimation.

Armor stone

Performance of the storm surge protection system depends, in part, on the resilience of the system under attack by the design event (or larger event). In turn, the condition of the system at the time of the design event depends upon the system's performance during preceding lesser events and implementation of associated maintenance and repairs.

Later design stages of the project should consider: (1) the effects of day-to-day conditions where project elements are in regular contact with the marine environment; (2) minor and major storm conditions that do not reach design conditions but will physically affect the system; (3) the design condition; and, not to be overlooked, (4) conditions exceeding the design event in order to determine resilience, system survival, and protective performance under those conditions.

Trade-offs must be made during the design phase among first cost, maintenance/repair cost, and resilience/risk that will influence the degree to which portions of the system should be armored against wave attack, overtopping, and scour.

To the extent wave attack on the system is possible or likely, especially from breaking waves, flexible and resilient armor such as rock revetment should be considered as part of the local typical section. As critical locations are identified, appropriate armor systems can be designed to suit the needs. While rock armor is far from the only possible approach, it is typically useful to identify a suitable rock design to which other means may be compared.

In addition to wave attack, three primary processes requiring the designers' attention include general scour, local scour, and overtopping scour. Note that scour could occur on either side of the levee or floodwall.

General scour

General scour can be viewed as a a relatively one-dimensional condition expected to prevail over relatively long portions of the system in a similar way, such as where waves impact the toe of a levee or floodwall. Evaluation methods for general scour can be more simplistic. Typical responses to potential general scour at a structure toe can be a scour apron or additional toe armor stone. Floodwalls should either provide for protection against general scour or assume an appropriately-reduced soil surface elevation for passive resistance calculations.

Local scour

Local scour can be viewed as a more location-specific condition that may develop due to two-dimensional flow effects. Local scour can occur, for example, at system transitions, structure ends, angle points, flow constrictions, or at any point where flow velocities are high.

Overtopping scour

Overtopping scour can occur on the protected side of a levee or floodwall where significant overtopping flow contacts inadequately-protected soil. If the levee crest is unprotected, overtopping scour can lead to progressive downcutting and catastrophic reduction of system crest elevation, such as occurred in post-Katrina New Orleans. Overtopping scour at floodwalls can result in overturning failure of the wall.

3.10 Environmental Considerations

The construction of a flood protection system in the vicinity of Orange County will have a high potential of impacting jurisdictional wetlands, waters of the U.S., archaeological resources, historical resources, and hazardous waste sites. The guidelines used for these preliminary investigations are described in the individual reports presented in subsequent sections. The depth of these investigations was intended to be data collection level with minimal analysis of the data or field reconnaissance performed. This "desk-top" type of analysis will aid in the evaluation of each alternative alignment and provide comparative data in order to assess the relative advantages or disadvantages of each alternative.

3.11 System Design Life

The protection system design life is 100 years and is dependent on many factors related to the operation and maintenance of the system. Certain components of the system, such as pump stations will require more frequent maintenance and replacement due to the nature of those mechanical systems. Factors that will need to be considered within the framework of an Operations and Maintenance system (O & M) include:

- Maintenance of earthen levee systems according to state and national standards including vegetation management, roadway maintenance, regular inspection
- Jurisdictional control of all property within the system right-of-way with regard to potential access and crossing needs of the surrounding communities
- Regular inspection and maintenance of all structural sections including concrete and steel wall sections, gated closure structures, and other appurtenances
- Regular inspection and maintenance of pump stations
- Sea level rise monitoring on a periodic basis to consider protection level impacts and mitigation strategy

It is the opinion of the study team that the life of the protection system can be extended significantly by strict adherence to all operation and maintenance policies and activities.

3.12 Navigation Considerations

Orange County is bounded on the west and southwest by the Neches River, on the east by the Sabine River and to the south by Sabine Lake and the Sabine-Neches Canal. Both rivers serve as critical infrastructure for the area's extensive maritime industry. As a result, the potential impact to the maritime industry must be considered in the evaluation of feasibility of a hurricane flood protection system for the county.

Neches River

The Neches River currently has a project depth of 40 feet from the mouth to the turning basin at the Port of Beaumont and a planned deepening project would take the project depth for this reach to 48 feet. The Neches serves several large petro-chemical, refining, and terminal facilities including ExxonMobil, Oil Tanking, Sun Oil, Chevron, Huntsman, and Total as well as numerous other industrial users. The Neches also serves as one of three anchorages for the U.S. Ready Reserve Fleet. Additionally, The Port of Beaumont is located on the Neches River. In 2010, the American Association of Port Authorities ranked the Port of Beaumont as the fourth largest U.S. port by gross tonnage and the Port is clearly an important asset to local commerce.

Sabine River

The Sabine River has a project depth of 30 feet from its mouth to the old US 90 bridge approximately 2 miles north of the Port of Orange Alabama Street Terminal. In addition to the Port of Orange the Sabine River serves several shipyards including Orange Shipbuilding and Signal International as well as several other industrial users. Additionally, the Sabine River allows navigation to navigable channels at Cow and Adams Bayou.

Cow Bayou

A navigable channel improvement resulting in a 100 feet wide, 13 feet deep channel was approved by Congress in 1963 and constructed thereafter for approximately 7 miles from its mouth at the Sabine River to near Orangefield, TX. Current NOAA navigation maps report that the channel is only 7 feet deep in places but the channel still supports barge traffic and small vessel traffic to several small shipyards on the channel as well as to the Knife River bulk material terminal at SH87 in Bridge City, TX. The existing barge traffic on the channel indicates that depths reported in current navigational charts may understate the current channel depth.

Adams Bayou

Adams Bayou is navigable by barge and shallow draft vessel from its mouth at the Sabine River to approximately 1.5 miles upstream. This length of channel has been improved and channelized to a width of at least 100 feet. Current NOAA charts report the depth to be as little as 3 feet in places but recreational users report the draft through this section of channel to be approximately 10 to 11 feet. Navigation further upstream is limited by a fixed bridge at FM 1006 with a reported vertical clearance of 11 feet. The lower Navigable portion of the channel serves Sneed Shipbuilding at its northern limit as well as supporting barge traffic to the DuPont Sabine River Works Dock located approximately three quarters of a mile upstream of the bayou’s confluence with the Sabine River.

Little Cypress Bayou

Little Cypress Bayou is navigable by small boat for approximately 1.7 miles upstream of its mouth at the Sabine River which is just down river from the Interstate 10 bridge. This bayou serves a small recreational craft ramp as well as American Airboat Corporation.

3.13 Potential Floodplain Fill and Floodway Encroachments

The analysis of the various alignment alternatives also included an evaluation of potential encroachments into effective 100-year floodplains and floodways along the channels proposed to be crossed. The two types of encroachments to be addressed are floodplain fill and floodway encroachments.

3.13.1 Floodplain Fill

The proposed design of each of the alternative alignments will require that some encroachment into the 100-year or regulatory floodplains be made. Two conditions of floodplain encroachment are anticipated with each alternative; displacement of volume by the entire levee system during a tropical event, and displacement of floodplain volume in each drainage stream during normal localized rainfall events. Each is addressed below.

3.13.1.1 Tropical Events

The construction of a levee system in a coastal region to protect against storm surge intrusion will cause the displacement of some volume of the storm surge back into the coastal waters, in this case Sabine Lake. In order to identify the potential impacts of such an encroachment, storm surge modeling was performed for both the pre-levee and post-levee conditions, as described in Section 3.2.2. The results of that modeling indicates that only minute changes in the computed surge elevations would be caused by the proposed project alternatives, therefore no mitigation for these potential affects is proposed.

3.13.1.2 Localized Rainfall Events

The proposed levees and the integral stream closure structures will encroach into the regulatory 100-year floodplains of the streams listed above. Current FEMA floodplain management criteria require that any potential adverse impacts to the regulatory 100-year floodplain elevation, or Base Flood Elevation (BFE), be mitigated to prevent adverse flooding impacts along the stream. In order to prevent adverse impacts to the 100-year floodplain elevations, mitigating improvements in the vicinity of these structures is proposed. These mitigating improvements may include channel improvements or internal detention improvements incorporated into the closure structure design or pump station design and operations, as determined on a case-by-case basis.

3.13.2 Floodway Encroachments

Floodway encroachments are unavoidable due to the need to build closure structures within the channels in order to cross the major streams. In order to minimize the impacts of these encroachments, the proposed levees, floodwalls and closure structure designs will be designed to minimize the encroachment into the floodways, however some encroachment is anticipated. Current FEMA floodplain management criteria requirements state that when a floodway encroachment is planned, no increases in the BFE greater than 0.000 feet is allowed, nor can any increase in the floodway elevation occur. In order to accommodate the proposed channel crossings/closure structures, mitigating improvements will be necessary to offset the potential effects to the floodway.

These mitigating improvements may include channel improvements or internal detention improvements incorporated into the closure structure design or pump station design and operations, as determined on a case-by-case basis. For the purposes of this preliminary analysis, it was assumed that the mitigating improvements for the floodway encroachments will be accommodated in the interior drainage improvements already necessary to accommodate the detention and conveyance requirements of the interior drainage systems and pump stations.

3.13.3 Impact Analysis

Implementation of a storm surge protection project can result in off-site impacts at locations outside of the protected area. The primary impacts considered are increased 100 year flood event water surface elevations, increased velocities of flow, and redirection of wave energy at off-site locations near the project. The study team considered scenarios that may lead to such impacts, and commissioned a series of numerical simulations of hurricane storm surge to facilitate the comparison of results, both with and without an Orange County protection system in place.

As part of this comparative analysis, a comparison was made of a calibrated numerical model of the actual Hurricane Ike with a simulation of Hurricane Ike with the Port Arthur Hurricane Levee Protection System removed from the model domain. This comparison supported the conclusion that the implementation of the Port Arthur levee system had a negligible effect on water levels in Orange County during Hurricane Ike.

As with the simulations of Hurricane Ike, with and without the Port Arthur levee system, the analysis of a simulated large storm surge event, with and without a proposed Orange County levee system, showed negligible effects on peak storm surge water levels at locations east and west of the protected area. While these effects should continue to be considered during later study phases, the impact to the alternatives analysis and feasibility determination does not appear to be a critical factor.

Additionally, impact analyses will be performed on each of the streams and drainage channels crossed by the selected alignment alternative. These impact analyses will identify potential adverse impacts to the flooding levels caused during the 100 year rainfall event, independent of a tropical system or storm surge event, and investigate mitigating improvements to offset those potential impacts to the interior drainage systems.

3.13.4 CLOMR/LOMR

In accordance with FEMA requirements and local floodplain management regulations, the changes to the regulatory floodplain created by the selected alignment alternative will require that a Conditional Letter of Map Revision (CLOMR) be submitted to FEMA. The impact analyses, performed on the interior drainage systems will be submitted to FEMA as part of the CLOMR request. FEMA will review such a request and issue its findings on the potential impact of the project on the 100-year floodplain and floodway. The CLOMR would be prepared concurrently with the Preliminary Engineering Report (PER) for the design alternative selected then submitted to FEMA for review and comment. It can be expected that a CLOMR for such a large project would take a significant amount of time for FEMA to review and provide comments, and for the engineering team to provide the associated responses to achieve an acceptable outcome. This time should be planned to run concurrently with the final design efforts of the design team. While the receipt of an approved CLOMR prior to the start of construction is ideal, with regard to identifying the proposed floodplain and floodway delineations and regulatory Base Flood Elevations (BFEs), it is not mandatory that a CLOMR be issued prior to construction.

Upon the completion of the construction of the project, the certification by the owning or managing agency and the certification by a registered professional engineer that the project meets all of the requirements of FEMA for their accreditation/recognition (44CFR §65.10) that the levee and its associated flood protection components provide reasonable assurance that protection from flooding caused by the occurrence of the base flood is provided, a Letter of Map Revision (LOMR) application must be submitted to FEMA. Upon approval of such a LOMR, the leveed area can be delineated on the FIRMs and denoted as being protected from the 100 year flood by levee dike or other structure subject to possible failure during larger floods.

4. Project Alternatives and Evaluations

The project is being considered as a series of alternatives to be evaluated on an essentially objective basis. Each alternative considered provides a different protection plan, but they will be evaluated on a similar set of criteria in order to provide an objective as possible basis for comparison and consideration of the alternative. In addition to the areas protected, factors considered will include benefits vs. costs, environmental impacts, major transportation and utility impacts.

4.1 Preliminary Considerations

4.1.1 Alternatives

Five alternatives were considered which would provide a look at scenarios offering various levels of protection to Orange County. These alternatives are not necessarily directly comparable, but represent a range of solutions for protection to all or parts of the County.

These five alternatives are:

1. A no-action category as a baseline for evaluation of structural alternatives.
2. Orange County Protection Only with Sabine River Alignment and East Bank of the Neches River
3. As an alternative to a Neches River crossing, a protection system on the east and west bank of the Neches River has been evaluated.
4. The broadest alternative is represented by the county-wide protection system with tie-in across the Neches River to the DD7 protection system.
5. A final alternative consists of consolidation of a protection system with a salt water barrier on the Sabine River which would provide protection to fresh water supplies managed by the Sabine River Authority of Texas.
6. As a possible "first phase" of a county-wide protection system, a ring levee protecting the "chemical row" area is an alternative which could provide an initial level of protection to critical economic infrastructure in Orange County.

4.1.2 Protection System Features/Strategies

In addition to evaluation of a no-action alternative, the various structural solutions evaluated will consist of combinations of the following features.

- Earthen Levees
- Concrete Floodwall (T-Wall)
- Closure Gate Structures – Navigable
- Closure Structures – Non-Navigable
- Highway and Roadway Crossings - Non-Gated
- Pump Stations

4.2 Description of Alternatives Investigated

4.2.1 No-Action Alternative

The no-action alternative will evaluate potential damage and economic losses of the selected design storm. It will form the basis for the final Benefit-Cost Analysis and the basis for comparison and evaluation of the structural protection alternatives. It will also provide the basis for evaluation of environmental impacts resulting from proposed structural solutions. Appendix J depicts the 100-year floodplain obtained from the draft Preliminary Flood Insurance Rate Maps of Orange County, the approximate inundation limits caused by Hurricane Ike and the assumed inundation limits of an Ike-like hurricane, shifted to impact the Sabine Lake area, as described in Section 3.2.2.2.

4.2.2 County-Wide Protection Sabine River and East Bank of Neches River

Protection system on the east bank of the Neches River would close the protection system within Orange County instead of a closure structure on the Neches River. This system would provide full protection to Orange County but would not offer the protection to areas within eastern Jefferson County not protected by the Pt. Arthur levee system

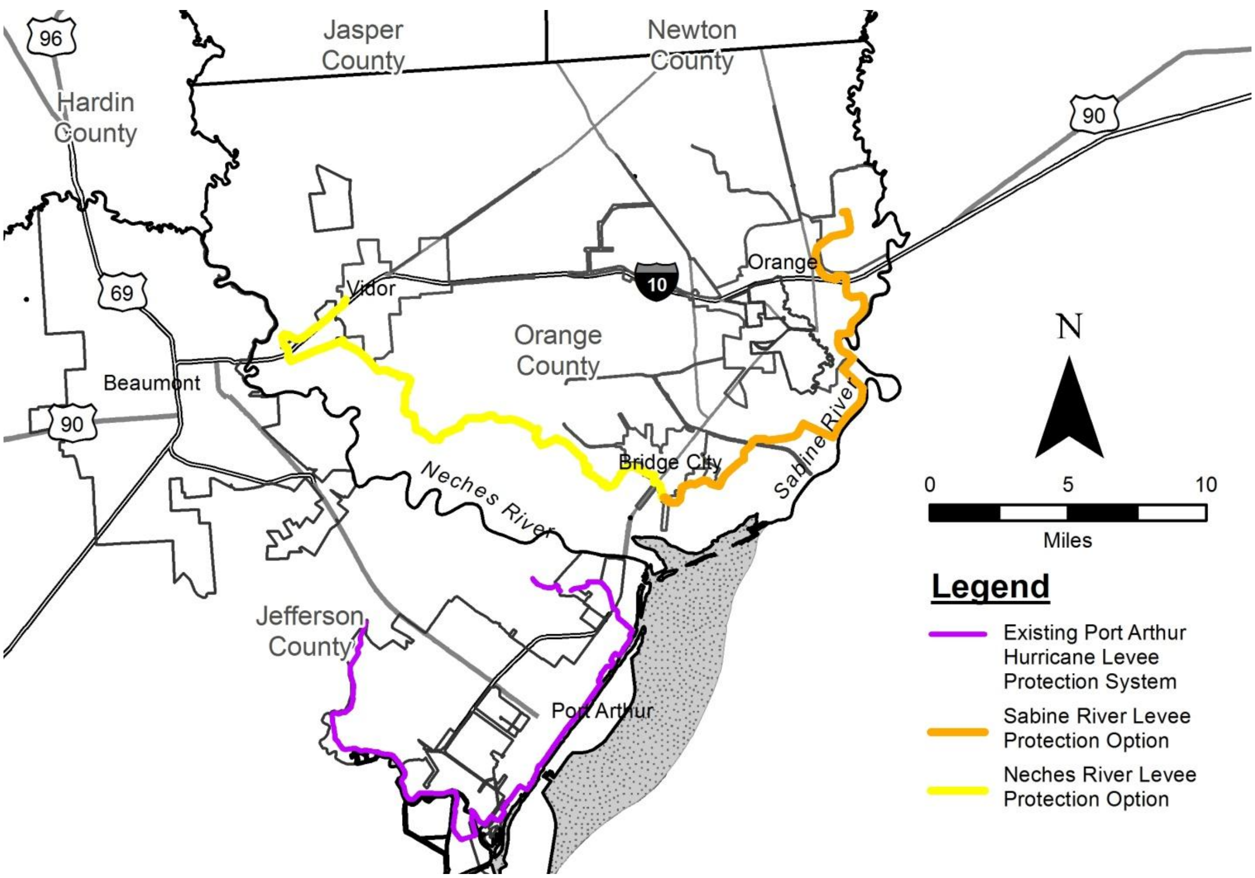

Figure 4-1 Levee alignment alternative to provided full protection to Orange County only

4.2.3 Protection System on the East and West Bank of the Neches River

Protection system on the east bank of the Neches River would close the protection system within Orange County instead of a closure structure on the Neches River. This system would provide full protection to both Orange County and offer protection to areas within eastern Jefferson County not protected by the Pt. Arthur levee system.

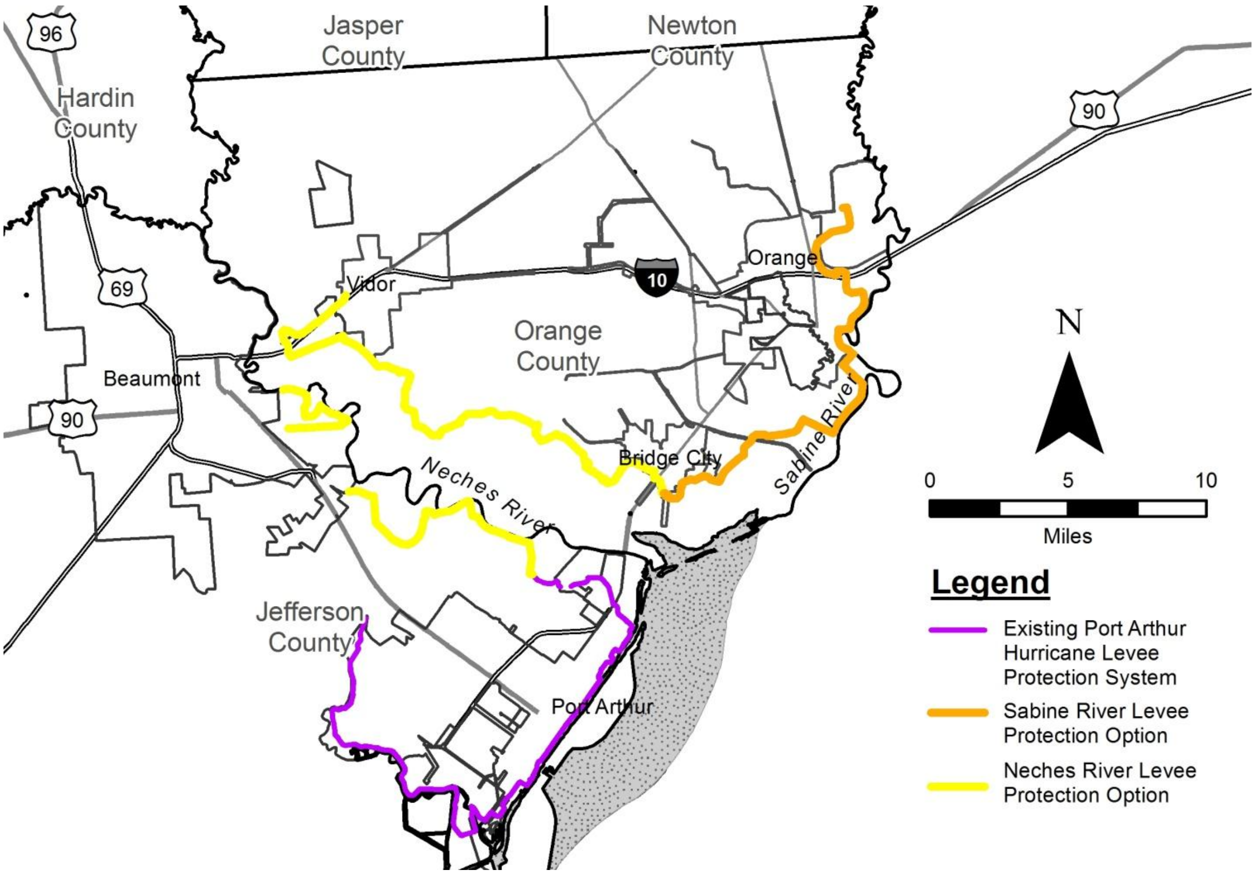

Figure 4-2 Levee Alignment to Provide Full County Protection-Levee on East and West Bank of Neches River

4.2.4 County-Wide Protection with DD7 System Tie-in

County-wide protection with DD7 System tie-in across Neches River is the "big picture" level of protection consisting of evaluation of a system tying into the Pt. Arthur protection system on the west bank of the Neches River, continuing east through a closure structure on the Neches River with the alignment to the east generally inland from the marsh area along the north coast of Sabine Lake to the Sabine River. The system continues generally along the west bank of the Sabine River to just north of IH 10. In addition to complete protection of Orange County, this approach would offer protection to eastern Jefferson County, particularly along the Neches River up to the City of Beaumont area.

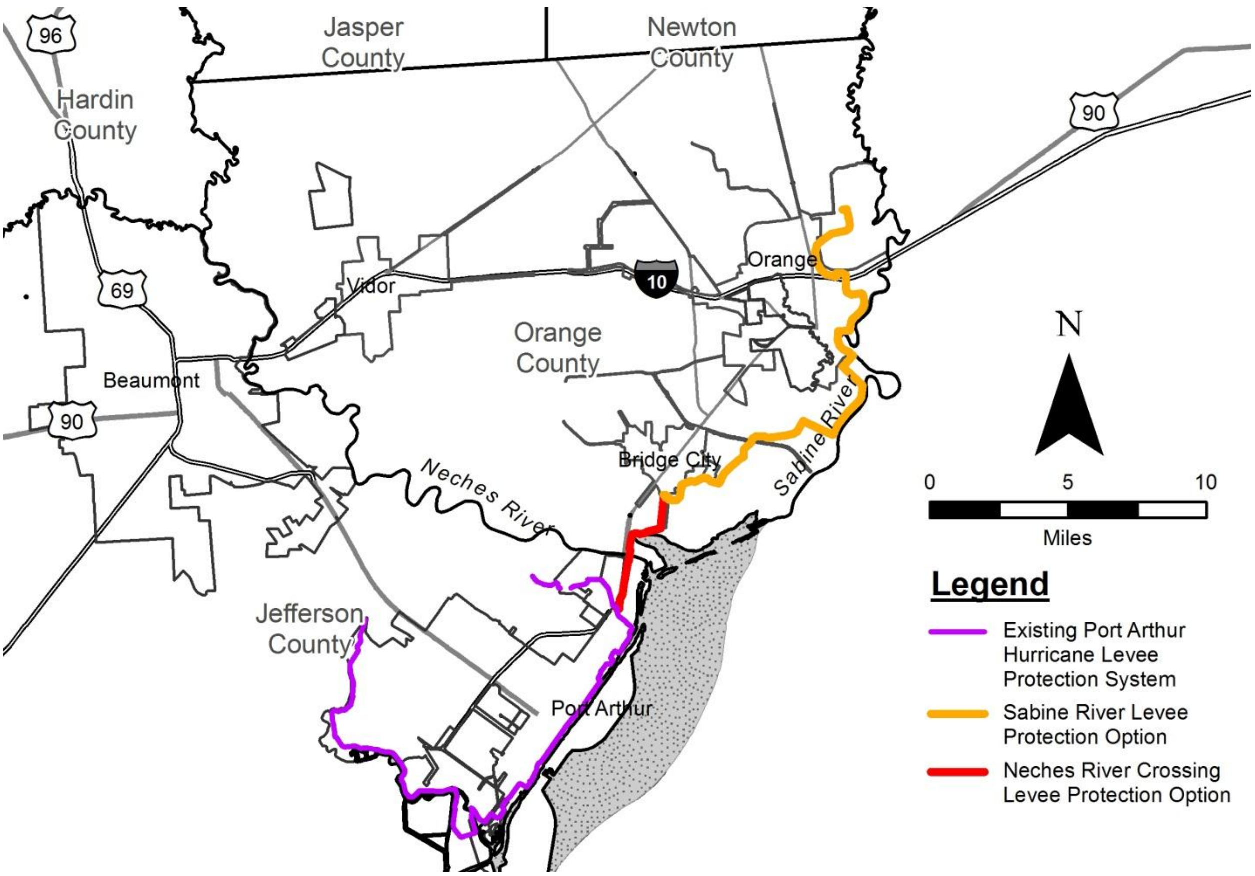

Figure 4-3 Levee Alignment Location to provide full protection to Orange County and eastern Jefferson County

4.2.5 Sabine River Crossing

Sabine River crossing would consist of a structure on the Sabine River which would also serve as a salt water barrier which would provide protection to fresh water supplies managed by the Sabine River Authority of Texas.

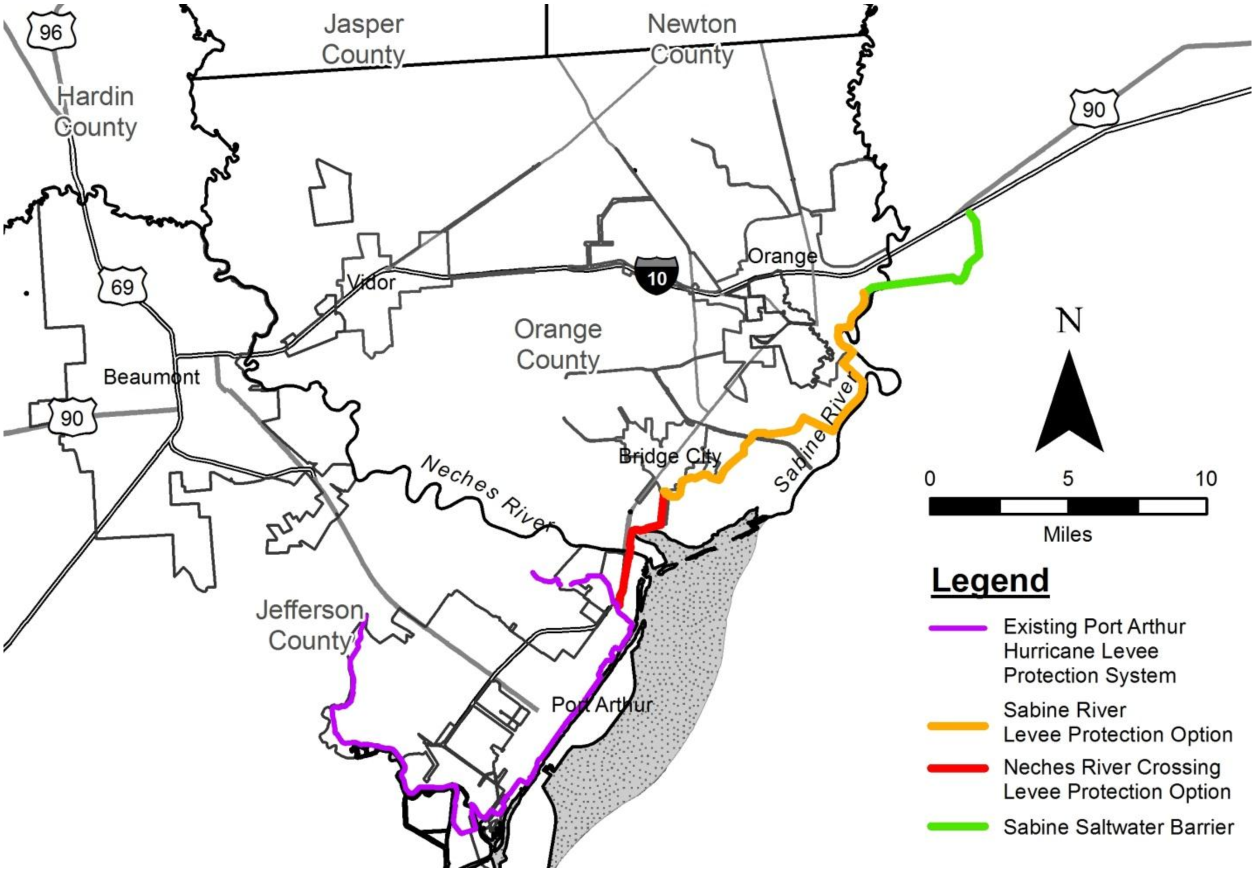

Figure 4-4 Levee Alignment location to Provide Full County Protection Supporting Location for Sabine River Authority of Texas Salt Water Barrier

4.2.6 Industrial Complex Protection System

The Industrial Complex Ring System is being evaluated as a protection measure protecting the "chemical row" area which would provide an initial level of protection to critical economic infrastructure in Orange County. As a possible "first phase" of a county-wide protection system, a ring system would also comprise a smaller, less expensive project that would become the first phase of the ultimate goal of a county-wide protection system.

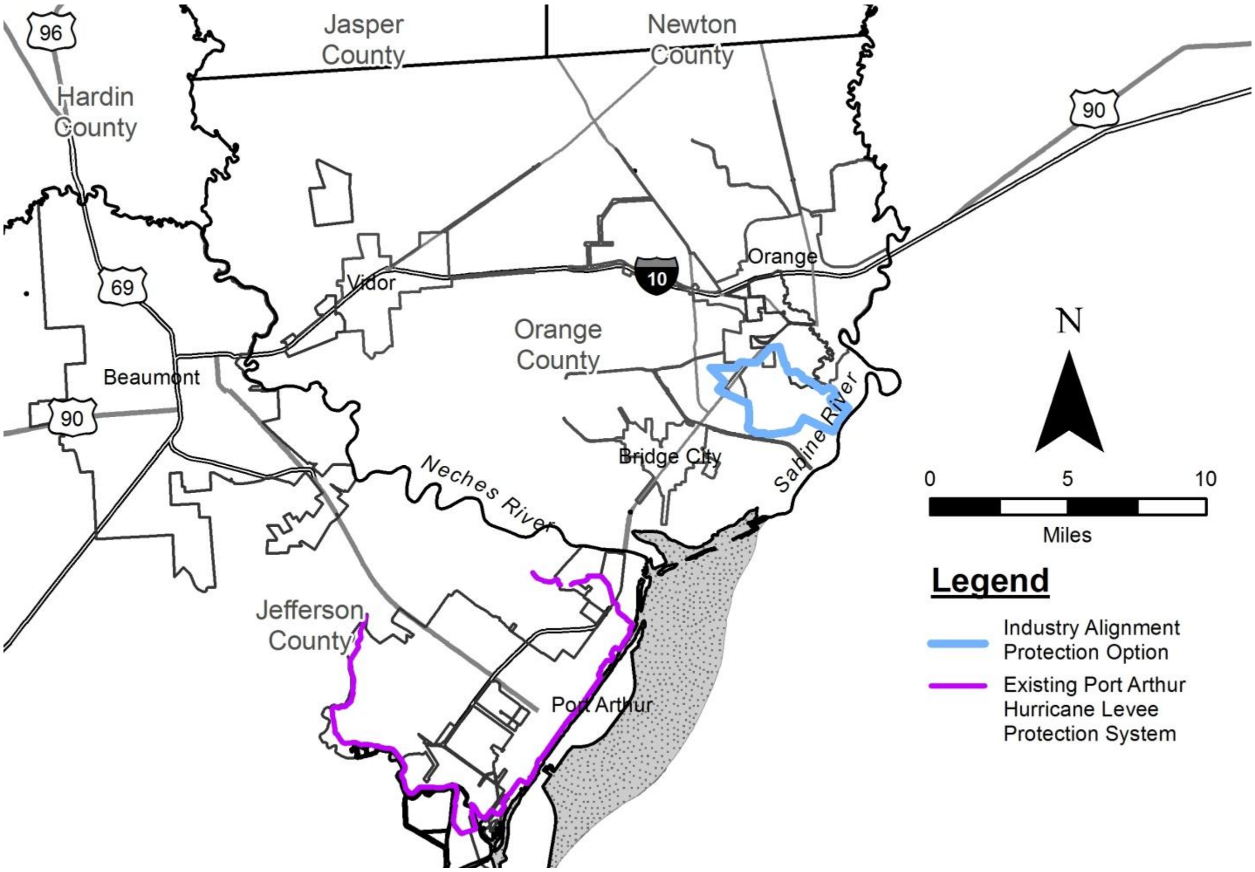

Figure 4-5 Levee Alignment Location to Provide Industrial Complex Protection

4.3 Description and discussion of Alternatives Evaluation Process

A method for evaluating the benefits and drawbacks of each alternative in order to determine which alternative is the best selection for further analysis and implementation is critical to this feasibility study. Several methods were investigated during this study and no one method presented a comprehensive evaluation of costs, benefits, constructability, long-term performance, innovation, and other intangible aspects that would make a project desirable and achievable, therefore a number of criteria were combined which address various aspects of the projects and a grading system was developed to aid in the evaluation of each alternative. The grading system is based on the relative ranking of each alternative for each criterion. This system would then allow for a summary rank to be assigned to each alternative which should guide the decision process for selecting an alternative for further design.

Twenty-one criteria were selected to evaluate each alternative alignment. These are listed in Section 8.1. These criteria were selected to represent several standard evaluation procedures and metrics (i.e.: USACE Benefit-Cost Ratio) and also to include other evaluation metrics which reflect a common sense approach to the evaluation process (i.e.: number of tracts to be taken for right-of-way acquisition).

Each alternative is assigned a rank for the specific criterion considered. This rank, 1 through 5, is based on the relative position each alternative holds when comparing the alternatives to each other. An example would be ranking the alternatives based on the number of tracts to be taken to provide the required right-of-way. The alternative with the fewest tracts to be acquired would be assigned the lowest numerical rank. The ranks of each criterion would be added together, then divided by the total number of criteria, yielding an average overall rank, with the lowest overall rank indicating the alternative which satisfied the most individual criteria.

A "No Action" alternative is also presented in this feasibility study, as it is required in several other selection criteria. In this feasibility, the No Action alternative identifies the potential damages which will be caused by another storm, similar to Hurricane Ike, hitting the Sabine/Neches River vicinity. This No Action alternative was not included in the Alternative Grading System Evaluation since it does not fulfill the most fundamental of the criteria established for this study, which is to provide protection from a storm surge caused by a tropical event hitting the Upper Texas Gulf Coast.

5. Preliminary Design

The Preliminary Design process for the purposes of this study consists of utilization of design parameters described in Section 3 to develop preliminary designs to address the various alternative protection plans. The designs presented are schematic in character and represent systems and components that are currently in use in the United States and globally. The level of detail of the schematic designs is sufficient to develop costs estimates suitable for budget and funding development as well as for benefit-cost analyses. To aid in tracking the cost for different alignment alternatives, each alignment alternative was divided into alignment segments based on the major sections of each alignment as shown on below.

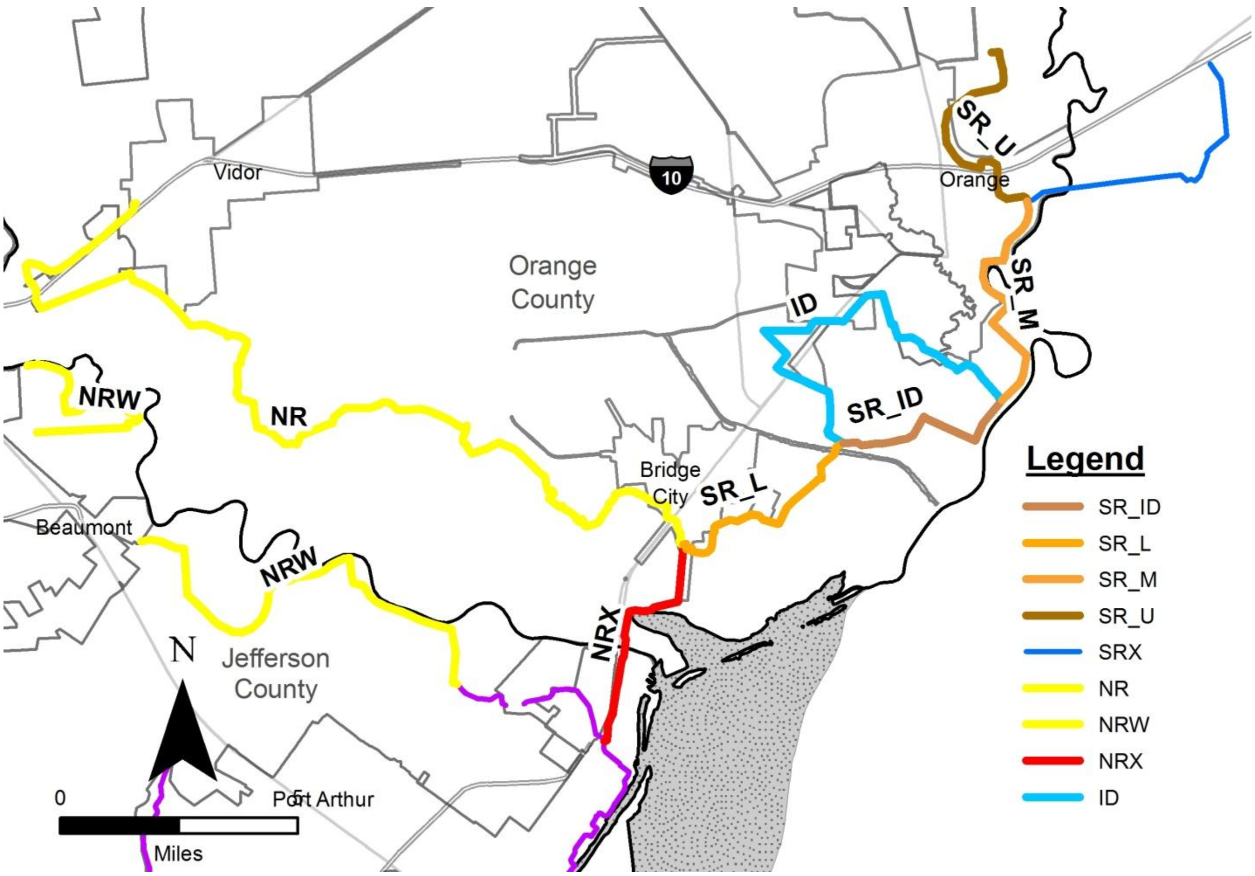

Figure 5-1 Alignment Segments

5.1 Levee and Floodwall Design

5.1.1 Height Determination

The levee and floodwall heights along each alternative alignment are a function of the top elevation established in Section 3.2.1 and the average natural ground elevation along any particular segment of the individual alignments.

The earthen levee height is used to compute the quantities of right of way required, keyway and foundation excavation, and embankment fill for use in computing cost estimates for the project. The floodwall height is used as the basis for floodwall cost estimates for the project.

In order to provide reasonably accurate levee height calculations along each alignment alternative, each alignment was divided into individual segments. Each segment was defined based on changes in levee top elevation, average natural ground elevation, levee cross section dimensions, the type of protection component proposed (levee, floodwall or closure structure) and land use of the surrounding area. The segments vary from approximately 100 to 6,000 feet in length. Each segment was assigned the computed average natural ground (+/- 1 foot) computed from the Orange County LiDAR and the top elevation defined in Section 3.2.1.

5.1.2 Earthen Levee Locations and Design

Locations of earthen levee segments of the proposed protection system alternative alignments were determined by desktop analysis of the data obtained. This information included input from the stakeholders, knowledge of the project team of the general area and region, knowledge of the project team on design of similar facilities along the upper and middle Texas Gulf Coast, and literature review of numerous design guidelines and manuals for similar facilities. Earthen levees will be the main protection system used in each alternative alignment, since earthen levee costs per linear foot are significantly less than structural wall or other means and earthen levees provide an effective, lower maintenance alternative to other systems. A typical cross section of the earthen levee proposed is shown on Figure 3-3, Section 3.4. Detailed design of each segment of levee will be addressed in subsequent phases of the project development.

5.1.3 Flood Wall Locations and Design

Locations for flood walls were determined by desktop analysis of the various proposed protection system alignments. Because of the higher cost of construction of flood walls when compared to earthen levees, flood walls are only used where necessary to limit impacts to adjacent facilities or existing development, thus efforts were made to limit the length of proposed flood wall reaches to the extent feasible. A typical floodwall design is shown on Figure 3-4, Section 3.5. Detailed design of specific segments will be addressed in subsequent phases of the project development and will include considerations of existing natural grades, required flood protection elevations, and site specific geotechnical considerations. The location of flood wall reaches along each of the alignment alternatives are shown in Drawings 420-1001-EX-1001 through EX-1003 included in Appendix H.

5.1.4 Right of Way Requirements

The right-of-way requirements for this project were computed using the typical levee cross sections for earthen levee segments, the typical interior ditch cross sections and lengths, and the interior detention ponds, as identified in 5.1.2 and the typical sections of floodwall segments, as identified in Section 5.1.3. All of the right of way calculations, described below, are provided in Appendix E1. More precise right of way dimensions and acreages will be determined in the design phase of the selected alternative.

The total acreages of right of way required for each alternative alignment investigated is the sum of the computed levee, interior ditch and borrow pit top areas, with appropriate maintenance/access berms, as shown in Appendix E.

The earthen levee right of way width was computed based on the average height of the levee for each segment computed, using the typical earthen levee cross section information shown in Figure 3-3. An allowance of 2 additional feet of height, above that computed in Section 3.2.1

above, was included to account for potential sea level rise. This additional allowance will help to eliminate future right of way purchases in areas of limited availability.

The floodwall right of way width was computed based on the width of the foundation, including batter pile encroachment widths, using the typical wall cross section information shown in Figure 3-4. It is also assumed that the right of way would accommodate inspection access roads along the wall alignments where access from adjacent property is not available. It is not anticipated that any additional right of way would be required to raise these walls in the future since such an effort would be within the right of way computed for this analysis.

The right of way computations for detention ponds/borrow pits were performed in order to determine approximate areas required to provide the excavation volumes needed for the project. It can be assumed that the ownership of such borrow pits will remain in or revert back to the original owners once the borrow pits are no longer needed for the project construction.

5.2 Major channel / river crossings

Six major channel crossings have been identified during the course of this study. While there are other channels that will need to be crossed, these six represent the ones that are either intended to remain navigable by commercial vessels or that represent some other level of technical complexity not expected in smaller drainage channel crossings.

5.2.1 Neches River

Clearly the largest and busiest channel within the project, the Neches River crossing allows the proposed Sabine River alignment to tie in to the existing Port Arthur protection system, providing protection for all of Orange County as well as a substantial portion of Jefferson County along the west bank of the Neches River. Proposed to be located just downstream of the Veteran's Memorial Bridge (see Drawing 420-1001-C-1006 in Appendix H) the crossing would be accomplished with a navigable closure structure that would allow the river to be closed prior to hurricane landfall but open for navigation and normal flow at all other times. For the purposes of considering feasibility, the Maeslant Barrier in Hoek van Holland, The Netherlands was considered as the model for this closure structure. Constructed in the 1990's, this structure serves to close the entrance to the Port of Rotterdam, the New Waterway, during times of high tides in the North Sea.

The Maeslant Barrier is simply a very large sector gate. Each of the two leaves of the system float and is stored in dry dock alongside the channel when not deployed for flood protection. This dry storage of the gate's moveable components is advantageous in terms of access for inspection and regular maintenance as well as reducing the systems exposure to environmental degradation that is common with submerged metallic structures. When deployment is required by storm events or for system testing, the dry docks are flooded, the gate leaves are moved into the channel and ballasted, causing them to sink and effecting closure of the waterway.

The Neches River Closure Structure is required to provide protection for surge elevations to a minimum elevation 20.0 feet and a sill elevation of approximately -50.00 feet to accommodate the proposed deepening of the Neches River. The Maeslant barrier as constructed utilizes gates that are approximately 72 feet tall and are comparable to the height that would be required by the Neches River Closure Structure. In the event that this alternative is selected for further development, consideration should be given to the provision of additional elevation against surges and for the potential for the use of a deeper sill to accommodate future channel deepening projects.

The existence of a structure of similar size serving a similar function is indicative of the feasibility of the endeavor. However, a significant effort to evaluate other potential types of closure structures should be undertaken if the option to construct the Neches River Closure Structure is selected for further consideration.

5.2.1.1 Cost of Neches River Closure Structure

The proposed closure structure at the Neches River is assumed to be similar to the Maeslant Barrier for the purpose of determining cost. For the Neches River closing, a structure about 80% of the size of the Maeslant barrier would be required. Assuming that the cost of the Neches River structure would be similar to the Maeslant Barrier when adjusted for the smaller size and for inflation, the cost of the Neches River Closure structure is expected to be approximately $475 million in 2012 dollars. This figure is estimated as follows. The reported cost of the Maeslant Barrier was €450 million and it was completed in 1997. The Euro wasn't issued until 1999, so the exchange rate for dollars to Euros in 1999 was used to determine the 1999 cost in US dollars. The exchange rate varied over the course of 1999 between 0.85 USD/EUR and 0.99 USD/EUR. For the purpose of this estimate, a rate of 0.95 USD/EUR was used. The Bureau of Labor Statistics CPI inflation calculator was then applied to the 1999 cost to determine the 2012 cost.

5.2.2 Cow Bayou

A sector gate with a navigable opening of 56' was selected to represent the navigable structure at Cow Bayou. This structure is large enough to accommodate single barges and other moderate draft vessels that are likely to use the waterway. Similar structures are in use in the region at the Lower Neches Valley Authority saltwater barrier facility on the Neches River in Beaumont, TX as well as at the USACE Wallisville Lake Project on the Trinity River. The model structure used specifically for consideration of the navigable closure structure at Cow Bayou was the sector gate that was recently completed at the Caernarvon Canal as part of the New Orleans Hurricane Protection Project Work, Lake Pontchartrain and Vicinity, Reach 149. Additionally, due to the width of the floodway at the proposed crossing, an additional series of non-navigable flood gates are proposed to mitigate impacts to channel flow during regular upland rainfall events. Two 160 feet wide vertical lift flood gates would flank the sector gate and an additional vertical lift flood gate would be provided in an adjacent oxbow to the south to maximize the flow area available for the passage of flood flows during times of high runoff not associated with a concurrent storm surge. The geometry of the channel and proposed closure structures is shown in Drawing 488-1001-G-1001 in Appendix H. Estimated cost for the sector gate structure is $21 million and each flood gate is estimated to cost $6 million. Details of the cost estimates are included in Appendix E. Total structure cost for the Cow Bayou closure is estimated to be $39 million exclusive of flood wall cost which are accounted for elsewhere.

5.2.3 Adams Bayou

The same sector gate proposed at Cow Bayou is proposed for the navigable structure at Adams Bayou and the cost for the sector gate portion of the Adams closure should be the same at $21 million. A pair of smaller non-navigable vertical lift flood gates is proposed to flank the navigable sector gate. Each vertical lift flood gate at Adams Bayou is estimated to cost $4 million. Total structure cost for the Adams Bayou closure is estimated to be $29 million exclusive of flood wall cost which are accounted for elsewhere.

5.2.4 Little Cypress Bayou

The proposed closure structure for this channel is a bulkhead closure structure. The general arrangement of this closure is shown in Drawing 420-1001-G-1005 and a preliminary concept of the closure structure is presented in Drawing 420-1001-C-1003. Both drawings can be found in Appendix H. The bulkhead closure structure was chosen for its simplicity and lower cost relative to a typical sector gate. The bulkhead closure structure proposed for this closure was modeled on a similar but larger structure that was recently installed in the Hero Canal in Plaquemines Parrish, Louisiana. The estimated cost for this closure structure is $8 million and details of the cost estimate are included in Appendix E.

5.2.5 Sabine Station Intake Canal

This closure is not intended to be navigable but is included here due to the complexity of the potential operational requirements of the system. Entergy's Sabine Station is a 1,960 MW Natural Gas Fired power plant located approximately 2 miles west of Bridge City, TX. At peak production, the facility requires 884,000 gpm (1970 cfs) of intake water through its intake canal that draws water from Old River Cove at the north end of Sabine Lake. This water is circulated through condensers and discharged through the discharge canal that runs southwest from the facility to the Neches River. This system of cooling water supply and discharge serves Units 1 through 4. Unit 5 receives cooling water from the Sabine River Authority (SRA) from a canal that bisects Orange County and approaches the facility from the north along Powerhouse Road. Refer to Drawing 420-1001-EX-1001 for facility location.

The intake canal is essential to continued generation during an event that would require closure of the flood protection system. A system is proposed that would allow modulation of flows of intake water through the structure in the event of ongoing generation activities during a hurricane event. A typical flood gate structure is proposed to affect closure of the canal. Six 84" diameter bypass pipes with redundant valves on each would allow flow through the levee system to be controlled as head increased on the outside of the structure during a storm surge. For the 1970 CFS of required flow through the canal, two feet of differential head across the bypass pipes would be required. Entergy's minimum allowable water surface elevation (WSE) at their pump suction basin is reported to be -5 MSL, indicating that even at the beginning of a storm event before large increases in WSE due to surge, this head loss can likely be tolerated in the intake canal. As WSE increases outside the canal closure due to increased storm surge, one of the two valves on each bypass could be modulated to control WSE in the intake canal with the other valve acting as a redundant closure valve. In the event of a failure of the control valve, the control valve should fail closed and should also trigger the closure of the redundant closure valve on that pipe. As part of follow up work if this closure structure is to be pursued, further consideration will need to be given to the potential impacts to Sabine Station operations in response to conditions in each bypass line as well as the details of the redundant systems to ensure suitability for flood protection. Clearly, the design of this portion of the system will have to be closely coordinated with Entergy.

Estimated cost of this closure structure for the Entergy Sabine Station intake canal is $19.5 million. Details of the estimated cost are included in Appendix E and a general plan layout of the closure is included in Drawing 420-1001-C-1008.

5.2.6 Sabine Station Discharge Canal

The discharge canal must convey discharge at the same rates that the intake canal conveys water to the facility. For the purpose of this study, it is assumed that an additional pump station will be required in the event that the Neches River alignment is chosen for further development. Using the project standard cost of $25/ gpm of pumping, the cost of a pump station to pump this discharge over the levee when the discharge canal flood gate is closed would be $22.1 million. Additionally, the expected cost of the required 180' wide flood gate is $9.5 million, leading to a total cost of $31.6 million to affect a closure of the discharge canal. While it is beyond the scope of this study, consideration should be given to the fact that Entergy is already pumping this water and perhaps a modification to their discharge configuration may eliminate the need for both the flood gate and the additional pump station.

5.3 Preliminary pump station sizes and locations

5.3.1 Pump Stations

To facilitate the removal of water inside the proposed levee system while the gate structures are closed, numerous storm water pump stations will need to be constructed. The pumping capacity for these pump stations will range in size from 100,000 gallons per minute to 2,500,000 gallons per minute. To maximize efficiency, vertical axial flow pumps with diesel engines or electric motors will be used to move the water across or through the levee. The pumps stations will be concrete structures which will provide protection of the equipment during major storm events and will provide for easier operation and maintenance. Additional appurtenances which will be needed as part of each pump station will include: generators, bar screens with rakes, fuel storage and transfer, and station heating and ventilation.

Each of the pump stations will be sized according to the amount of runoff that will be delivered to it by the interior drainage system. During the design phase, sizing of the pump forebays and available storage in the interior drainage system will need to be closely analyzed to determine the exact pumping requirements. In general, increased storage reduces the amount of pumping required, but will never eliminate the need for some level of pumping. This study accounts for available storage in the larger watersheds. For smaller (minor) watersheds, the assumption is that all flows would need to be pumped in order to provide a conservative estimate of pumping needs.

A closure structure and pump station on the Neches River presents a unique design problem with regard to a number of issues which are discussed in various sections of the report. For this study, a basin storage approach was taken wherein the available volume of the Lower Neches basin was calculated based on available LiDAR data. A simple correlation of daily flow volumes vs. available volume based on several scenarios of gate closure and maximum allowable water surface elevation was developed to both determine how long a gate could remain closed and what a pump station would need to discharge to maintain the available volume as long as possible. Monthly and annual flows as published by the USGS were also examined to develop a base flow rate. The results of this analysis revealed that the basin can store a significant amount of volume in the event of a gate closure, but that in order to insure that the storage remains available in the face of heavy rainfall during a storm event, a significant pumping capacity needs to be available to continue to move the expected base flow into Sabine Lake.

Tables showing the volume vs. flow analysis and the USGS average flow are shown below.

Project design will need to include the development and calibration of a hydrologic and hydraulic model of the Neches River which would allow development of various hydrographs at the location of the proposed Neches River gate structure. This model would also allow for simulation of gate closure, various rainfall events which may be anticipated during a hurricane event and the interaction of a pumping system to maintain base flow through the closed gate system.

NECHES RIVER STAGE STORAGE VOLUME		
ELEVATION	VOLUME	
Ft.	C.F.	AC-FT
0	1,693,320	39
1	135,564,998	3,113
2	643,500,923	14,776
3	1,522,640,925	34,962
4	2,863,390,887	65,748
5	4,494,000,397	103,189
6	6,312,547,777	144,946
7	8,285,359,829	190,245
8	10,397,378,351	238,740
9	12,642,849,602	290,300
10	15,011,977,140	344,699

Table 5-1 Neches River Stage-Storage Table

Table 5-2 Neches River Flow Analysis

FLOW ANALYSIS			
Elev. 4-8 Volume - C.F.	cfs/24 hr.	cfs/48 hr.	cfs/72 hr.
7,533,987,464	87,199	43,599	29,066

Table 5-3 Neches River USGS Monthly Mean Flow

YEAR	Discharge, tidally filtered, cubic feet per second, Monthly mean in cfs (Calculation Period: 2003-07-01 -> 2011-09-30)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2003							2,978			4,794	8,526	4,408
2004		23,390		11,154								
2005	11,720	23,755	20,674		3,140	2,044	2,396	2,260		3,083	1,165	2,538
2006	1,065	5,035	2,119	1,802	3,490	2,078	4,726	4,352	1,238	27,208	10,446	3,329
2007	24,529	23,700	8,774	8,087	5,955	5,293	14,785	13,149	5,321	2,247	1,416	2,748
2008	4,500	10,972	9,163	7,991	3,599	2,397	1,995	3,861	6,107	2,552	6,063	4,050
2009	2,438	2,487	5,807	13,103	10,516	1,329	1,000	2,254	1,844	4,803	13,823	11,608
2010	10,660	16,163	11,549	4,196	2,241	2,981	4,772	3,011	3,447	1,096	706	572
2011	1,237	1,645	748	486	391	252	1,129	1,095	480			
Monthly Mean	8,021	13,393	8,405	6,688	4,190	2,339	4,223	4,283	3,073	6,540	6,021	4,179
						Mean Flow June -October				4,530		
						Annual Mean Flow				5,946		

5.3.2 Gravity Drainage Analysis

Analysis of the interior drainage for the various alternates considered was conducted on a regional basis, looking at mainly watershed-level drainage areas, except for tributaries that would become isolated based on a particular alternate alignment. Appendix F contains a discussion of the criteria and methodology utilized for this study

Construction of the levee system will impede the existing drainage patterns for many of the smaller interior drainage systems within the county. Based on the size and the relative location of the contributing watersheds, some interior drainage systems can be combined to reduce the total number of outfall structures and pump stations required. Drainage areas were delineated and outfall locations were identified along the reach of the proposed levee using aerial photography and LiDAR data as shown on Appendix F.

5.4 Major utility conflicts

5.4.1 Municipal utilities

5.4.1.1 Power

Two alignments cross under existing power transmission infrastructure. The Neches Crossing (NX) alignment crosses a transmission line approximately 500 feet south of its intersection with the Sabine River Alignment. The Sabine River (SR) alignment crosses under existing transmission infrastructure in two places, one at the substation near the south end of Plant Reservoir (Ref Dwg 420-1001-G-1032, App I) and one about 350 feet north of the intersection of Simmons Drive and North Farragut Ave. The proposed section at each of these crossing points is earthen levee and the existence of the transmission infrastructure is not expected to impose an impediment to construction. The design of the levee at these intersections should be detailed to avoid the creation of intrusions into the required clearance below the transmission lines, particularly with respect to access roads that may run along the levee. In these areas, it may be necessary to route the access road off of the levee top to avoid clearance issues.

Smaller distribution lines were not individually considered. However, it is reasonable to assume that many of the roads crossed by the proposed levee alignments will also have electrical distribution along the road right away. For the purposes of estimating the cost of these smaller potential relocations, each road crossing is assumed to require a minor electrical utility relocation at the cost of $60,000 per relocation. These costs are accounted for in the road crossing estimates in Appendix E.

5.4.1.2 Potable Water & Sanitary Sewer

Specific information regarding the presence of large diameter water and sewer mains was not available to the study team, however, further detailed engineering is almost certain to result in the discovery of water and sewer infrastructure that will require relocation, particularly in the northern reaches of the proposed industries (ID) alignment as this portion of the proposed alignment crosses areas between existing areas of relatively dense development. Because specific information was not available, it is assumed that two large diameter water mains and two large diameter sanitary sewer force mains will have to be relocated. It is assumed that each of these relocations will be accomplished by boring to an acceptable depth below the protection system and that the total length of each relocation segment will be 1000' long and will cost $3,000,000 each.

5.4.1.3 Fresh water canals

Fresh water canals are important infrastructure items that provide irrigation water to local agricultural users as well as providing large volumes of fresh water to industrial users for various uses that are critical to their operations. The Sabine River (SR) alignment crosses an irrigation lateral of the SRA system just south of the proposed Cow Bayou System. Proposed Flood Gate # 9 (Ref Drawing 420-1001-G-1038) closes this canal. This canal serves agricultural lands outside the proposed protection system and short term closure of this canal segment during a storm event is not expected to be problematic to the canal system or its users.

5.4.2 Pipelines

Due to the prevalence of the petrochemical industry in the vicinity of Orange County, the area is crossed by numerous pipelines carrying various petroleum products. The Railroad Commission of Texas Pipeline Master data set was used to determine the location of pipelines that cross the various proposed alignments. The pipelines were then classified as major (diameter greater than 12 inches), moderate (diameter less than 12 inches but greater than 8 inches) or minor (diameter less than 8 inches) with respect to the complexity of pipeline modifications required due to the installation of the proposed protection elements. The location and classification of the individual crossings are shown in drawings 420-1001-G-1014 through 420-1001-G-1041 which are included in Appendix I. Pipelines under flood wall were assumed to be accommodated by changes to floodwall foundations to avoid conflict with pipelines. Pipelines that occurred under levee sections were assumed to be relocated by boring new pipeline such that the depth of the relocated line was a minimum of 20' deep at the levee right of way boundaries. The length of each boring was determined using an entry and exit vertical angle of 10 degrees and evaluating the radius of vertical curvature for the boring based on an assumed radius of vertical curvature of 100 pipe diameters. On smaller diameter pipes where the horizontal distance required to achieve the curvature was less than the length of the pipeline skew as it crossed the levee right of way, the distance along the pipeline from right of way to right of way was used to calculate the total boring length. This length was used in conjunction with an estimated relocation cost of $30 per inch of pipe diameter per foot of pipe to calculate the total crossing relocation cost. In some areas, pipe lines cross the proposed right of way but do not encroach beneath the footprint of the levee proper. These pipelines were ignored in the cost calculation as it will be possible to avoid them during future detailed engineering.

The estimated cost of the pipeline relocations are summarized below and the estimated length and cost of each crossing is tabulated in the detailed pipeline crossing sheets in Appendix E

Table 5-4 Summary of pipeline relocations

Alignment	Classification	Number of Crossings	Cost
Sabine River (SR)	Major	17	$10,816,000
Sabine River (SR)	Moderate	12	$1,852,000
Sabine River (SR)	Minor	11	$829,000
		Alignment Subtotal	**$13,497,000**
Industry (ID)	Major	12	$9,305,000
Industry (ID)	Moderate	8	$1,076,000
Industry (ID)	Minor	17	$1,393,000
		Alignment Subtotal	**$11,774,000**
Neches Crossing (NX)	Major	1	$437,000
Neches Crossing (NX)	Moderate	3	$433,000
Neches Crossing (NX)	Minor	3	$230,000
		Alignment Subtotal	**$1,100,000**
Neches River (NR)	Major	40	$31,318,000
Neches River (NR)	Moderate	16	$2,411,000
Neches River (NR)	Minor	19	$1,655,000
		Alignment Subtotal	**$35,384,000**
Neches River West (NRW)	Major	23	$14,530,000
	Moderate	17	$1,806,000
	Minor	20	$1,254,000
		Alignment Subtotal	**$17,590,000**

5.5 Transportation Crossings

In the design of a levee protection system, the existing transportation infrastructure network will need to be considered at the points of intersection with the proposed levee alignment. The two means of transportation corridor crossings investigated in this study included a raised-profile crossing, where the road is elevated above the levee top, or a structural gate closure that is controlled by the levee system operator as a flooding event approaches. Crossings along the each of the alignments identified within this report are categorized by the transportation mode and the roadway classification of the transportation facility, as described below.

Table 5-5 Transportation corridor categories

Transportation Category	Description
Railroad	Local and interstate rail lines
Vehicular Major	Interstates, US Highways, State Highways
Vehicular Minor	Farm to Market (FM), County Road (CR), Local Streets
Private	Residential/Commercial Driveways, Industrial Facility Driveways/Access Streets

Transportation data for Orange County was obtained from Geographical Information Systems (GIS) shapefiles provided by Orange County Appraisal District, Texas Natural Resource Information Systems (TNRIS) databases and field reconnaissance data. This data was compiled into GIS shapefiles for use throughout the study. Crossing locations were identified along each of the alternative levee alignments, as shown on Appendix G1 and each crossing was assigned a category as described above. The type of traffic and surrounding land uses that would utilize the crossings were analyzed to determine whether a raised-profile or a gated closure would be used. Cost estimate summaries for each crossing were developed using the classification, road height, and closure type, as presented in Section 6.

5.5.1 Railroad Crossings

At all railroad crossings, gated closure structures will be used due to the long profile grades on either side of the levee which would be required to raise the rail lines over the levee tops. Raising the rail lines would require significant right-of-way acquisitions, re-construction costs of the rail lines, and difficulty in the normal operations of the rail lines on relatively steep grades. Gated closure structures avoid these difficulties, however they will require close cooperation of the rail line owners/operators, the end users of the rail services and the levee operators/district to ensure that the closure of the gates occurs at appropriate times in advance of an approaching storm and the re-opening of the gates after an event occurs, as soon as is practicable, to ensure proper flood protection is maintained.

5.5.2 Major Highway Crossings

Five potential major highway crossings were identified in this investigation: one on State Highway 73 (SH 73), two on State Highway 87 (SH 87) and two along Interstate Highway 10 (IH-10), as shown on Appendix G1, dependent upon the alignment alternative chosen.

A preliminary investigation of the existing roadway elevations of SH 73 indicated that the existing roadway is at approximately elevation 7.9, below the required elevation of 19 at this location. Based on this information SH 73 would need to be raised approximately 11.1 feet, should the Neches River alignment be selected. A raised-profile type of crossing was the only option considered, as this highway is a major evacuation route and is a heavily traveled roadway at all times, therefore the use of operated gates would cause undue traffic disruptions as a storm approaches the region. The estimated construction costs for raising SH 73 to cross the proposed levee are shown in Appendix E.

A preliminary investigation of the existing roadway elevations of SH 87 indicated that the existing roadway is at approximately elevation 7 on the west crossing and elevation 13.7 on the east crossing, with a the required elevation of 13 at these locations. Based on this information SH 87 would need to be raised approximately 6 feet on the west end and no raising required on the east end, should the Industries alignment be selected. Raised-profile type of crossings were the only option considered, as this highway is a major evacuation route and is a heavily traveled roadway at all times, therefore the use of operated gates would cause undue traffic disruptions as a storm approaches the region. The estimated construction costs for raising SH 87 to cross the proposed levee are shown in Appendix E.

A preliminary investigation of the existing roadway embankment heights at the two IH-10 crossings (West Crossing near Vidor; East Crossing in City of Orange) revealed that the existing roadway embankment heights are sufficient to accommodate the proposed levee heights required at these two locations.

Two major concerns of tying into or using an existing roadway embankment as part of a flood protection system are the adequacy of the existing embankment material and the potential permeability of the embankment. The typical roadway embankment materials used by the Texas Department of Transportation (TxDOT) and the compaction requirements of the TxDOT engineering technical specifications are similar to those proposed to be used for the construction of this levee system, therefore no significant roadway improvements are expected along the IH-10 corridor. Some additional erosion protection measures may be required at the levee-highway crossing locations to ensure that proper protection of the levee and roadway embankment slopes is maintained. A more detailed investigation of the as-built conditions at the location of a potential tie-in of the proposed levee into the existing highway embankments is recommended during the detailed design phase of the selected alignment alternative. Estimated construction costs of embankment erosion protection measures are provided in Appendix E.

5.5.3 Minor Highway, County Road, Local Street and Private Driveway Crossings

Two types of crossings were considered for minor highway, county roadway, local street and private driveways and industrial access crossings of the proposed levee system: 1) raised-profile crossings and 2) gated closures. Raised-profile crossings were used in areas where sufficient right-of-way was determined to be available and potential conflicts with existing infrastructure of private facilities were minimal. Gated closure structures were used where existing facilities or development would preclude the acquisition of right-of-way or would require relocation of existing major industrial infrastructure.

5.5.3.1 Raised-Profile Roadway Crossings

In those locations where sufficient additional right-of-way for widening to accommodate the raised roadway was determined to be available, a raised-profile grade of the roadway was proposed. Preliminary costs of each size and type of crossing were developed as shown in Appendix E.

5.5.3.2 Gated Closure Structures

Potential locations of gated closure structures are shown on Appendix G**.** The levee height and average natural ground elevation were estimated for each location and the existing roadway width was estimated from aerial photography, then adjusted for standard roadway widths and side clearance requirements, based on TxDOT design manual standards for each roadway use type. This data was used to assign each gate location a width and height, which would then be used to determine an estimated construction cost for each location. Final design parameters and dimensions will be determined for each location along the selected alternative alignment during the detailed design phase.

5.5.3.3 Street/Driveway Terminations

In some instances streets, private driveways and access roads will be terminated at the proposed levee right of way. These will occur at locations where access across, over or through the levee is not necessary, based on the land uses in the vicinity of the facility. These locations are shown on Appendix G.

5.5.4 Interior and Exterior Ditch Crossing of Roadways

Where proposed interior or exterior drainage systems will cross existing transportation systems, culvert structures are proposed. These crossing structures were classified by the drainage area size upstream of the crossing location in order to determine an approximate 100-year flood event for each location. Each location's upstream drainage area was determined using LiDAR data, local knowledge, and preliminary design of interior drainage systems, described in Section 5.5. All of the crossings were assumed to be accomplished with concrete box culvert structures, with appropriate sizes determined for each drainage classification based on drainage area size and type of transportation infrastructure the crossing structure would impact, as described in Table 5-6, below. Preliminary construction costs estimates were developed for each location as shown in Appendix E.

Table 5-6 Listing of Roadway drainage crossings

Drainage Classification	Description	Exterior Crossing Culvert Sizes	Interior Crossing Culvert Sizes
Super-Regional	Greater than 640 ac Major Transportation Classification	1 – 8x8 Box	2 – 12x10 Box
Regional	Greater than 640 ac	1 – 8x8 Box	2 – 10x10 Box
Semi-Regional	200 ac to 640 ac	1 – 72" RCP	2 – 10x8 Box
Localized	Less than 200 ac	1 – 60" RCP	2 – 72" RCP

5.6 Navigation considerations

5.6.1 Operational Considerations for Proposed Channel Closure Structures

Neches River Closure Structure

Traffic on the Neches River is directed by the United States Coast Guard (USCG) Captain of the Port COTP aided by the Vessel Traffic Service (VTS) Port Arthur. According to " Hurricane Planning Information for the Maritime Industry" published by COTP Port Arthur on May 9, 2012 there are currently no "safe havens" within the Port Arthur zone and as such, COTP believes that evasion at sea for seaworthy deep draft vessels represents the safest course of action in response to hurricanes.

The current schedule for preparing vessel's and the waterway for the impact of a hurricane is as follows:

- Condition Whiskey - Alert at 72 hours prior to expected gale force winds – Vessels should make all preparations for getting underway
- Condition X-Ray – Readiness at 48 hours prior to expected gale force winds – Vessels should complete cargo operations and depart port within 24 hours or when condition Yankee is set.
- Condition Yankee – Warning at 24 hours prior to expected gale force winds – The port is closed to incoming traffic without specific approval of COTP. All vessels are encouraged to put to sea.
- Condition Zulu – Danger at 12 hours prior to expected gale force winds - Port is closed and no vessel, terminal or facility operations are permitted.

It should be noted that the closure of a structure at the Neches River will have to be closely coordinated with this schedule and may result in modification to the operational approach of the waterway. It is unclear as of this writing whether the installation of a structure that closes the waterway for protection from storm surge would create a “safe haven”. Even with protection from surge, vessels berthed during storms are still exposed to the strong winds and wave action that are associated with hurricanes and could represent a substantial risk to the facilities at which they might be berthed if allowed to stay in port. It is likely that COTP will continue to require the port to be cleared when threatened with an approaching hurricane. This situation would indicate that, operationally, the Neches River closure structure would remain open until Condition Zulu was declared at 12 hours prior to expected gale force winds. It is expected that the time to close a structure on the Neches similar to the Maeslant Barrier would take approximately two hours to close, so waiting until 12 hours until gale force winds is not expected to create a problem from a structure closure standpoint.

However, because of the base flow in the Neches River it would be desirable to close the structure much earlier than Condition Zulu to prevent the inflow of storm surge that precedes hurricanes and to allow the additional storage volume within the portion of the Neches River floodway inside the flood protection system that is created by closing the gates before significantly elevated tides. For instance, during Hurricane Ike, surge elevation at the proposed location of the Neches closure structure was approximately 0.8 feet above the predicted tide level at the time of condition Yankee and 1.6 feet above predicted tide at the time of condition Zulu.

5.7 Geotechnical / structural stability considerations

The details of the preliminary geotechnical study are presented in a separate report by Fugro Consultants in Appendix C.

5.8 Wetlands / Environmental Considerations

5.8.1 General Constraints Mapping - aerials, historical information

The potential impacts to three types of natural and cultural resources were investigated for each of the alternative alignments described above. These include wetlands and waters of the U.S. impacts, hazardous waste and environmental health locations, and historical, archeological and cultural resource locations.

5.8.1.1 Wetlands and Waters of the U.S.

In order to determine potential wetlands and waters of the U.S. issues within each alternative levee alignment, ArcGIS was used to project the preliminary alignments onto TXDOQQ 2010, true color, digital aerial photography. TXDOQQ 1995 infrared aerial imagery was also analyzed.

A 500-foot buffer was then used to create approximate project boundaries based on each alignment alternative. Digital National Wetland Inventory (NWI) Maps were then used to project the approximate locations of wetlands and waters of the U.S. within each of the alignment boundaries. GIS shapefiles were created to estimate the acreages of wetlands and waters of the U.S. within the boundaries of each preliminary alignment alternative. Exhibits D-1 through D-4 depict each of the alternative alignments and the approximate locations and sizes of wetlands and waters of the U.S. within each boundary. The table below lists the acreages for total right-of-way, wetlands areas and waters of the U.S. areas for each of the major segments of the alignment alternatives investigated. This preliminary analysis of potential impacts is based solely on an analysis of the available GIS data. A wetlands delineation, in accordance with the USACE standards, has not been conducted. A complete study of the selected alternative alignment will be required in the next phase of the project development to fully evaluate the potential impacts associated with that alignment.

Table 5-7 Summary of Potential Impacts to Wetlands/Waters of the U.S. by Segment

Alignment Segments	Approximate Acreage	Potential Wetland Acreage	Potential Waters of the U.S. Acreage
Sabine River Lower (SR_L)	312	186	18
Sabine River Industrial (SR_ID)	256	189	15
Sabine River Middle (SR_M)	344	105	42
Sabine River Upper (SR_U)	307	173	25
Sabine River Crossing (SRX)	397	312	10
Neches River East Bank (NR)	1,791	1,055	105
Neches Rier West Bank (NRW)	652	143	70
Neches Crossing (NX)	314	211	56
Industrial District Backside (ID)	313	36	33

5.8.1.2 Hazardous Waste and Environmental Health

In order to determine any potential issues regarding potential hazardous waste and environmental health concern locations within or adjacent to each alignment alternative, a regulatory data search using the ASTM 1527 standard was performed by Banks Environmental Data. The regulatory data search identified potential locations of hazardous waste sites and sites with potential environmental health and safety concerns within a one (1) mile radius of each of the preliminary alignment alternatives, specifically regulated under CERCLA and RCRA. The potential areas of concern were then mapped by Banks and explanations of the concerns provided in **Appendix D**. This appendix is divided into sections, each which includes the data for individual segments. Each appendix section includes a summary of the potentially impacted sites which is summarized in the table below. **Appendix D-1** includes the data for the segment along the Sabine River alignment alternative from Bridge City to the Port of Orange, **Appendix D-2** for the segment along the Sabine River from the Port of Orange to north of IH-10, **Appendix D-3** for the segment along the Neches River from north of IH-10 to just south of the City of Rose City, **Appendix D-4** for the segment along the Neches River from just south of Rose City to Bridge City, **Appendix D-5** for the Neches River Crossing segment, and **Appendix D-6** for the segments of the Industries alignment which are not included in the Sabine alignment.

Table 5-8 Summary of Potentially Impacted Hazardous Waste and Environmental Health Sites by Segment

Alignment Segments	Mapped Sites	Unmapped Sites	Total Sites
Sabine River	172	186	358
Neches River East Bank	25	69	94
Neches Crossing	8	63	71
Industrial District Backside	203	171	374

5.8.1.3 Archeological and Cultural Resources

In order to determine the potential archeological and cultural resource concerns associated with each alignment, HRA Gray & Pape, LLC was contracted to conduct a desktop archaeological and historic records review for each alignment alternative. Site file research was initiated by reviewing records maintained by the Texas Archeological Research Laboratory (TARL) in Austin, Texas, and by consulting on-line research archives maintained by the THC. Site file research resulted in a listing of all cultural resources and previously conducted surveys within ½ mile of the project area. Cultural resources identified include previously recorded archeological sites, cemeteries, shipwrecks, National Register properties, historic districts, and historical markers. Documentary research was conducted in order to provide an understanding of the development and history of the project location, the surrounding area, and southeast Texas in general. This research then was used to prepare an overview history of the area and to provide an understanding of the contextual framework of Orange County prehistory and history.

A series of tables are presented in **Appendix D-7** which show the data collected for this study. The data includes the number of all cultural resources identified within and immediately adjacent to a 500 foot wide corridor, identified as the approximate project width, along each alignment segment. In an effort to provide the most accurate risk assessment for known cultural resource impacts for each segment, each segment was divided into mileposts, as shown on the exhibits provided in **Appendix D-7**. The alignment segments that indicate a potential impact risk to known cultural resources were color coded as red sections, and the segments located near cultural resources located outside of the 500-foot corridor were color coded as orange sections to signify the potential impact risk to known cultural resources for which defined boundaries are unavailable, as shown on **Figures 2-5 of Appendix D-7**. In addition, modeling of each alignment segment was undertaken to assess the impact risk to areas with a high probability for impacting previously unrecorded cultural resources. The table below summarizes the results of the findings presented in **Tables 3-6 of Appendix D-7**.

Table 5-9 Summary of Potentially Impacted Cultural Resources Sites by Segment

Alignment Segments	Known Sites	Nearby Known Sites	Total Sites
Sabine River	6	1	7
Neches River East Bank	2	0	2
Neches Crossing	1	1	2
Industrial District Backside	0	2	2

5.8.2 Mitigation Considerations

Each preliminary alignment alternative will potentially impact a considerable amount of wetlands and waters of the U.S., also referred to as jurisdictional areas. Compensatory mitigation will be required for impacts to all jurisdictional areas over 0.10 acres. The exact type and method of mitigation should be determined at the time of application for permits, based on the regulations in effect at that time and specific mitigation methods that may be negotiated with the USACE and other resource agencies. Typically, in-kind mitigation is required, meaning creation of new wetlands for wetlands impacts, and stream mitigation for impacted waters of U.S. determined to be streams. Additionally, impacts to tidally influenced areas would most likely require mitigation with tidally influenced wetlands.

It can be anticipated that in order to mitigate the potential impact to cultural resources those segments of a particular alignment alternative would be realigned to avoid the resource or the resource would be removed or relocated. A final determination of actual impacts cannot be assessed at this level of investigation, but should be conducted during the next phase of project development for the specific alignment alternative selected.

5.8.3 Preliminary Investigations - "Fatal Flaw Analysis"

In order to determine the relative ranking of each alignment alternative considered in this study, with respect to the potential environmental, historical and cultural impacts, the potential for impacts to these types of resources are discussed below.

5.8.3.1 Wetlands and Waters of the U.S.

The areas of the total right-of-way and potential wetlands and waters of the U.S. are shown in the table below. Review of this information indicates that a significant percentage of each of the alternative alignments will potentially impact existing wetlands and waters of the U.S., thus requiring an investigation into possible mitigation measures needs to be included in the next phase of the project development. It is recommended that a more detailed investigation be performed on the selected alternative alignment, which would include an investigation into realignment of certain sections of the protection system to avoid impacts to existing wetlands and waters of the U.S., where practical, and to identify mitigation measures and locations for the remainder of the selected project.

Table 5-10 Summary of Potential Impacts to Wetlands/Waters of the U.S. by Alignment Alternative

Alignment Alternatives	Approximate Acreage	Potential Wetland Acreage	Potential Waters of the U.S. Acreage	Percent of Total Acreage
Protection of Industrial Complex (ID + SR_ID)	569	255	48	48%
Orange County Protection - East Bank of Neches River (SR + NR)	3,010	1,708	205	64%
Protection System on East & West Bank of Neches River (SR + NR + NRW)	3,662	1,851	275	58%
County-Wide Protection with Neches River Crossing (SR + NX)	1,533	864	156	67%
County-Wide Protection with Neches River Crossing and Sabine River Crossing (SR + NX + SRX)	1,623	1,003	141	70%

5.8.3.2 Hazardous Waste and Environmental Health

The results of the regulatory data search along each alternative alignment segment indicates that there are significant potential impacts to known CERCLA and RCRA facilities due to the preliminary locations of each of the alignments. The table below shows the summary of the data collected by Banks Environmental Data, as presented in **Appendices D-1 through D-6**. Review of the results indicates that the Industries Alignment (ID) has the fewest potential sites impacted. The second fewest potentially impacted sites are along the County-wide Protection with DD7 Tie-in (Sabine River with Neches River Crossing). It is recommended that a more detailed investigation of the potential impacts and locations of possible conflicts be performed for the selected alignment alternative as part of the next phase of project development.

Table 5-11 Summary of Potential Hazardous Waste and Environmental Health Sites within 1-Mile Corridor by Alignment Alternative

Alignment Alternatives	Mapped Sites	Unmapped Sites	Total Sites
Protection of Industrial Complex (ID + SR_ID)	203	171	374
Orange County Protection - East Bank of Neches River (SR + NR)	197	255	452
Protection System on East & West Bank of Neches River (SR + NR + NRW)	197	255	452
County-Wide Protection with Neches River Crossing (SR + NX)	180	249	429
County-Wide Protection with Neches River Crossing and Sabine River Crossing (SR + NX + SRX)	180	249	429

5.8.3.3 Archaeological and Cultural Resources

The results of the archaeological and cultural resources investigation indicates that each of the protection system alignment alternatives has the potential to impact either known cultural resource sites or known cultural resource sites within close proximity to the preliminary alignments shown on the exhibits in **Appendix D-7**. The table below summarizes the potential number of impacted sites based on each alignment alternative investigated. Review of the results indicates that the Industries Alignment (ID) has the fewest potential sites impacted. The second fewest potentially impacted sites are along the County-wide Protection with DD7 Tie-in (Sabine River with Neches River Crossing) and the Neches River East Bank alignment (Sabine River and Neches East Bank). It is recommended that a more detailed investigation of the potential impacts and locations of possible conflicts be performed for the selected alignment alternative as part of the next phase of project development.

Table 5-12 Summary of Potentially Impacted Cultural Resources Sites by Alignment Alternative

Alignment Alternatives	Mapped Sites	Unmapped Sites	Total Sites
Protection of Industrial Complex (ID + SR_ID)	0	2	2
Orange County Protection - East Bank of Neches River (SR + NR)	8	1	9
Protection System on East & West Bank of Neches River (SR + NR + NRW)	8	1	9
County-Wide Protection with Neches River Crossing (SR + NX)	7	2	9
County-Wide Protection with Neches River Crossing and Sabine River Crossing (SR + NX + SRX)	7	2	9

5.9 Protected Area Damage Reduction/Prevention

In determining the feasibility of a levee protection system, the cost of the system must be compared to the economic and societal benefits of the protection provided. Recent storm events, as described previously in Section 2, have caused large amounts of economic loss and property damage throughout the southern half of Orange County. The area protected for each alignment segment was calculated by taking the protection elevation of each segment and intersecting that elevation with the LiDAR data as shown on Figure 5-2 below.

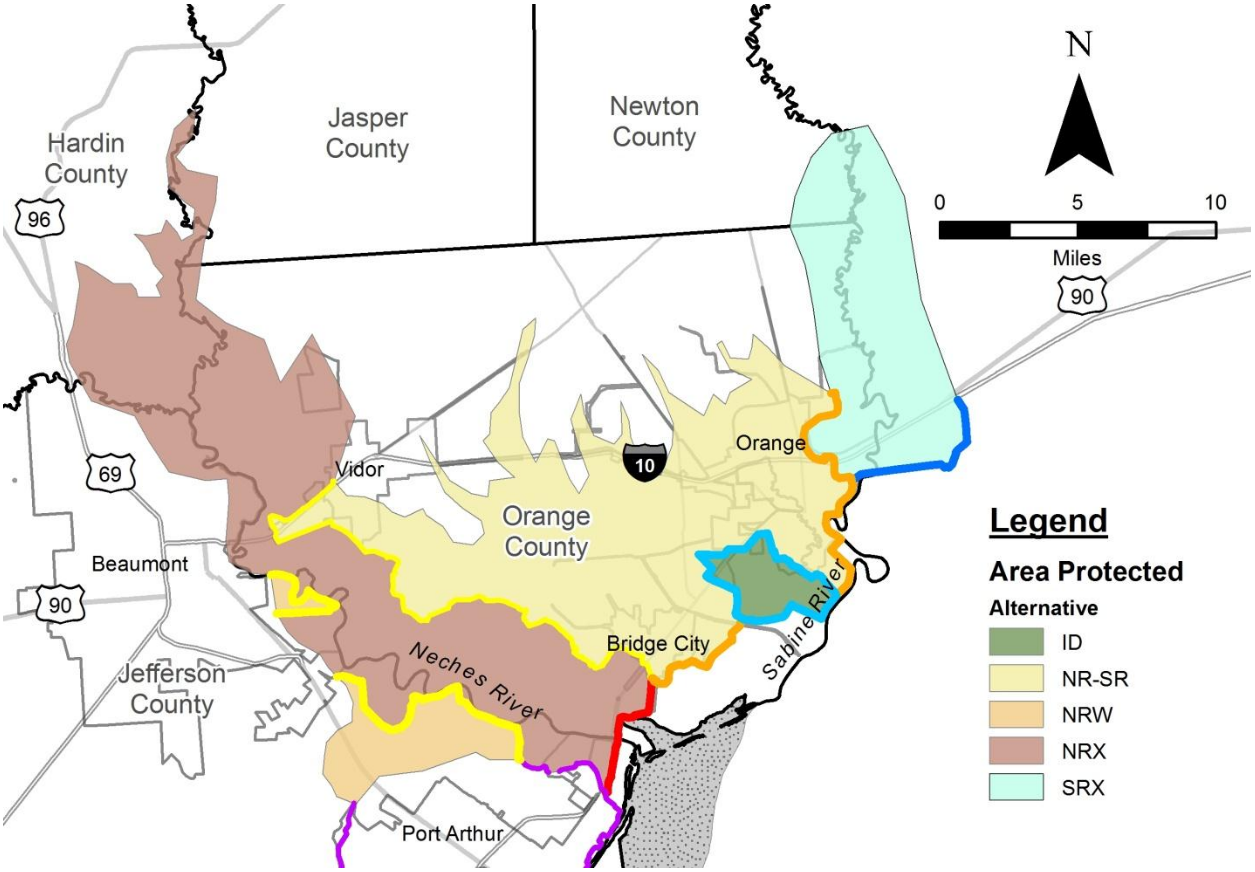

Figure 5-2 Area protected based on levee protection elevation and LiDAR data

Four metrics were developed to identify the effects of the alignment alternatives at the established protection elevations as described below:

- Population Protected – based on 2010 census TIGER data (**TIGER** = **T**opologically **I**ntegrated **G**eographic **E**ncoding and **R**eferencing)
- Area Protected – from Figure 5-2 above for Orange & Jefferson Counties
- Structures protected – from the 2010 census TIGER Housing Units data
- Assessed Value – property valued identified in the 2010 Orange County appraisal district and Jefferson County Appraisal District parcel shapefiles.

In order to determine the possible protection that could be provided, the area protected shapefile was overlaid within GIS with the county appraisal district information and the 2010 census TIGER data for each alignment segment. A summary of the results of the protection analysis for each levee segment is listed in **Table 5-13** below.

Table 5-13 Summary of Protection Metrics

Alignment	Area Protected (ac)	Residential Structures Protected	Population Protected	Assessed Value Protected
ID	5,276	114	236	$22,741,622
SRX	29,052	449	916	$7,220,784
SR-NR	71,436	21,183	47,410	$2,121,107,223
NRX	60,744	1,877	4,448	$219,196,026
NRW	10,888	9,341	21,642	$1,218,818,959

This analysis is used within the Alternate Grading Analysis to aid in determining the preferred levee alignment.

6. Preliminary Project Cost Estimates

The following paragraphs describe the major items considered in the construction cost estimates performed for this feasibility study.

6.1 Standard Unit Items and Prices

The different components required for each section of the levee system were determined to develop an engineer's estimate of the probable construction costs of each alignment alternative. These include the earthen levee sections, floodwall sections, right-of-way acquisition, pump stations, interior drainage, transportation crossings, utility crossings and relocations, and non-construction costs. These cost figures are used within the Benefit-Cost analysis calculation and within the alignment grading system to help identify an alignment to further investigate and proceed with preliminary design analyses. The following sections describe the items, units of measurement, and unit prices for each component of the levee system. Quantities and unit costs were obtained from representative projects from 2010 to 2012. Detailed cost estimates for each major item are shown in Appendix E. A summary of each alignment alternative is shown in the tables below along with Total Cost comparisons for each alternative.

6.2 Right-of-Way Acquisition Cost Estimates

In order to construct the levees, sufficient right-of-way or easements must be acquired to provide an area to construct and maintain the levee and to intercept runoff to accommodate altered drainage patterns. The proposed alignment alternatives traverse many different property types, including residential, high density commercial, industrial facilities and undeveloped land. When computing land acquisition costs for large projects, two major factors affect the total right-of-way costs: land area to be acquired and the existing uses of the land to be acquired. The land area to be acquired for each alternative alignment was determined by the top area of the levee, floodwall and interior drainage facilities, as described in Sections 5.1 and shown in Appendix E1.

Land values for each land use type must be determined for use in the preliminary cost estimates. Four approximate land values per acre of property acquired were developed from the Orange County Appraisal District data currently available. An average value of undeveloped property in the vicinity of the levee alignments investigated was computed from the available data. A typical value of residential property was computed using the average costs of residential properties within the areas generally surrounding the proposed levee alignments. A similar value was computed for commercial properties in the Port of Orange and the City of Orange waterfront areas. An average value of property within the existing industrial complex was also computed using this methodology. These values were applied to the individual segments of right-of-way based on the predominant land use within each segment computed. It should be noted that this methodology is only an estimation of the land values in any given area and that detailed appraisals of any property or easements to be acquired will be required prior to purchase. Average land costs per acre, for each land use type considered, were computed as shown in Table 6-1.

Table 6-1 Average land value cost per acre

Row Types	Cost /ac
Commercial	$115,000.00
Industrial	$5,000.00
Residential	$60,000.00
Undeveloped	$1,500.00

In any project which requires the acquisition of large amounts of land, it can be expected that some land owners will not willingly sell their property or will protest the values established by the required land appraisals. In those instances, property condemnation proceedings may become necessary. It was assumed that 10% of the total number of affected tracts will need to be acquired through the condemnation process with an average cost of $70,000 per tract. An allowance for condemnation costs, for the number of tracts assumed to be condemned is included in the cost estimates, as shown in Table 6-2.

The total number of tracts potentially affected or acquired for each alternative was determined by establishing a 500-foot wide buffer zone along each alignment, in order to allow for variations in the actual alignment, then intersecting this buffer zone with the 2010 Orange County Appraisal District (OCAD) parcel data shapefile.

Table 6-2 Number of Potentially Affected Properties

Alignment Segments	Number of Potentially Affected Properties	Number of Condemned Properties (10%)	Condemnation Cost
Sabine River Lower (SR_L)	63	7	$490,000
Sabine River Industrial (SR_ID)	16	2	$140,000
Sabine River Middle (SR_M)	64	7	$490,000
Sabine River Upper (SR_U)	91	10	$700,000
Sabine River Crossing (SRX)	33	4	$280,000
Neches River East Bank (NR)	302	31	$2,170,000
Neches Rier West Bank (NRW)	252	26	$1,820,000
Neches Crossing (NX)	12	2	$140,000
Industrial District Backside (ID)	174	18	$1,260,000

6.3 Earthen Levee Construction Cost Estimates

The earthen levee costs were calculated by determining quantities for each levee alternative using the alignments depicted on Figure 5-1 and the levee heights discussed in Section 3.4. Each alignment alternative was divided into segments to more closely represent the natural ground elevation and required top elevation along the alignment. Preliminary cost estimates were developed for each segment, using the unit cost identified in Table 6-3 below. Summaries of the segments to be included into each alignment alternative are also presented in Appendix E.

Table 6-3 Earthen Levee Unit Cost

Earthen Levee Construction Cost		Unit	Unit Cost
1	Levee ROW Clearing and Grubbing	AC	$3,000.00
2	Stripping, Stockpiling Topsoil	AC	$3,000.00
3	Levee Embankment (material having a PI of 15 or greater) Spreading & Compacting	CY	$2.00
4	Borrow Site Clearing	AC	$3,000.00
5	Borrow Pit Excavation & Loading & Hauling	CY	$15.00
6	Interior Ditch Clearing & Grubbing	AC	$3,000.00
7	Interior Ditch Excavation & Loading & Hauling	CY	$5.00
8	Turf Establishment	AC	$2,500.00
9	Exterior Backslope Swales	LF	$2.00
10	Backslope Inlets (includes 24" CGMP)	EA	$3,500.00

6.3.1 Fill Computations

All levee embankment fill volumes are computed using the typical levee cross sections and levee heights identified in Sections 5.1.1 and 5.1.2. The volume of fill material required includes the embankment and keyway volumes, computed for each segment of earthen levee. The average end area method was used to compute the required material volumes for each segment of earthen levee.

6.3.2 Excavation Computations

The volume of clay material required to construct the earthen levees is proposed to be provided from excavation projects in the general vicinity of the project. These projects would be constructed in conjunction with the levee construction and may be components of the interior drainage requirements of the levee system. Three potential types of projects are described which could provide the required material volumes for the proposed earthen levee segments:

- Excavation of interior drainage ditch improvements;
- Excavation of internal detention ponds;
- Excavation from borrow pits.

The computations of the excavation required to provide the computed embankment volumes include a compaction and loss factor of 15% added to the computed volume of embankment. These assumed losses account for losses encountered between the excavation sites and the levee locations and for the inherent differences between in-situ soil densities and the design densities of the levee embankment.

The excavated materials must be tested during construction to ensure that the soil materials used to construct the levee embankments meet the project technical specifications.

6.3.2.1 Interior Drainage Ditch Improvements

Interior drainage ditches will be required to connect the numerous natural channels and other drainage ditches within the project area to the proposed pumps stations. Use of this excavated material, assuming the soil types are within the project specifications, is one of the preferred means of obtaining embankment fill material, since it is likely that a significant amount of interior channel will be required to direct the interior drainage to the desired locations. This method may greatly reduce haul distances, thus reducing construction costs. The location and sizes of individual ditches will be determined in the Preliminary Engineering phase of the selected project.

6.3.2.2 Internal Detention Ponds

Internal detention ponds may be utilized as part of the internal drainage system to mitigate the potential effects of the levees on local stream hydraulics and to provide stormwater runoff storage as part of the proposed pump station operations. Use of this excavated material, assuming the soil types are within the project specifications, is another one of the preferred means of obtaining embankment fill material, since it is likely that a significant amount of internal detention volume will be required as part of the proposed pump station sizing and operations. This method may greatly reduce haul distances, thus reducing construction costs.

Typical ponds may be located along existing drainage channels or in conjunction with proposed drainage channels. The location and sizes of individual ponds will be determined in the Preliminary Engineering phase of the selected project. It is assumed that all detention pond locations will be located on undeveloped lands and use the undeveloped land value for cost estimation purposes.

6.3.2.3 Borrow Pit Excavation

Additional excavation volume requirements which cannot be met by the above two potential sources will be supplemented by excavation from borrow pits. The actual location of borrow pits will be established during the Preliminary Design phase by geotechnical investigations and acquisition of the necessary properties or easements.

6.3.2.4 Other Material Sources

Other sources of suitable materials for levee embankment construction may be identified during the Preliminary and Final Design phases of the selected project. These may include:

- Spoil materials from floodwall and other structural foundation excavations. This potential source of materials could reduce overall projects costs by reducing the need for disposal of excess materials. The potential suitability of this material will be evaluated by geotechnical investigations at the time of final design and verified by materials testing during the construction of the various project components.

- Spoil material from local channel dredging operations within the adjacent waterways. At the time of construction, the availability of suitable dredge material from maintenance dredging or deepening/widening projects in the area should be investigated. Geotechnical analyses will be required to determine soil suitability and any spoil preparation requirements, such as dewatering.

6.4 Floodwall Construction Cost Estimates

As described in Section 3.5, two floodwall sections were utilized to develop cost estimates for the project. An algorithm was developed to automate the estimation process that would take into account the numerous dimensional characteristics of each floodwall section. The parameter list consists of:

- Length of section
- Natural ground elevation
- Wall top elevation
- Wall thickness
- Footing top elevation
- Footing thickness and width
- Batter pile top and tip elevations
- Number of batter piles per row
- Row spacing
- Steel sheet pile top and tip elevation

Detailed quantity take-offs and cost estimates are included in Appendix E.

6.5 Pumping /Interior Drainage Cost Estimates

6.5.1 Pump Cost Estimates

Based on recent and current projects developed and managed by the team, pump station cost estimates have been consolidated into a single cost factor which is dollars per GPM (gallons per minute). The range of pump station sizes is large, from 100,000 GPM to 2,500,000 GPM. Cost estimates were developed which represent groups of pump station facilities that correspond to the three alternatives being considered by this study. Because the pump station facilities will only be utilized during gate closures for predicted surge events, available storage has been estimated and utilized in storage routing calculations in an effort to minimize the size of the pumping facilities. The detailed estimates are included in Appendix E.

6.5.2 Levee Closure Structures

Each closure structure was assign a cost based on the structure type assigned to it in Section 5. Detail cost estimates for each structure can be seen in Appendix E.

6.5.2.1 Box Culverts

Quantities and unit cost for all box culvert crossings are identified in the Table 6-4 below. These values were used to develop a cost curve for box culverts ranging from 1 – 10x10 box culvert to 10 – 10x10 box culverts. Each structure was sized as shown in Appendix F and the required number of culverts was input into the cost curve shown in Figure 6-1 below.

Table 6-4 Levee closure structures – Box Culverts unit cost

Item	Unit	Cost
Mobilization	EA	$5,000.00
Channel Regrading	LF	$150.00
ROW Clearing & Grubbing	AC	$3,000.00
10"x10' RCB	LF	$700.00
Levee Control Structure Headwalls	EA	$200,000.00
10'x10' Flap Gates	EA	$60,000.00
10x10 Sluice Gates	EA	$80,000.00

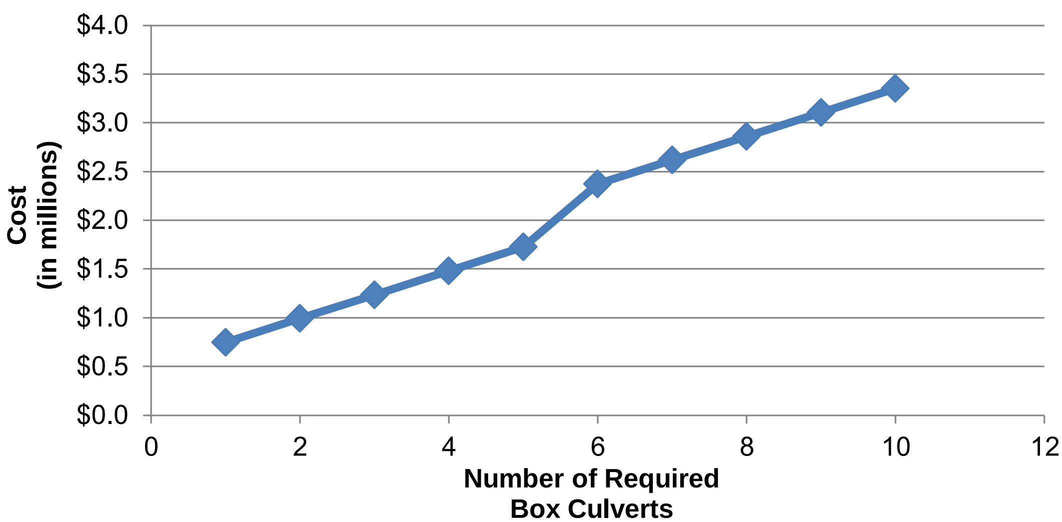

Figure 6-1 Box Culvert cost curve

6.6 Transportation Crossing Cost Estimates

Preliminary construction cost estimates for each of the transportation crossing types were developed. These estimates used the average height of the crossing, the size and type of closure structure, and the size and type of transportation crossing as described in the following paragraphs. The cost estimates for gates closure structures was developed using the quantities and unit cost shown in below.

Table 6-5 Gate closure structure unit cost

Item	Unit	Unit Cost
Steel	TON	$6,000
Structural Concrete	CY	$700
Sheet Pile	SF	$73
Batter Pile	LF	$36

To develop the cost for raised profile roadway crossings, a series of cost curves were developed for a range of levee heights, road widths, and pavement types. For purposes of this study, all minor roads were assumed to use the asphalt pavement section and all local, county, or other roads used the concrete roadway section. Quantities and unit cost used for asphalt pavement sections are shown in Table 6-6 below.

Table 6-6 Asphalt pavement quantities and unit cost

Item Description	Unit	Unit Cost
Preparing ROW	STA	$ 3,000.00
Excavation	CY	$ 5.00
Embankment (minus Levee)	CY	$ 10.00
Lime Treatment (6" EXST Material)	SY	$ 4.00
Lime (6% volume)	TON	$ 150.00
8" Asphalt Base	TON	$ 75.00
3" Asphalt Surface	TON	$ 100.00
Swale	LF	$ 2.50
Signing/Paving Marking	LF	$ 15.00
Seeding/Sodding	AC	$ 700.00
(Mobilization Approx 10%)	LS	$ 51,000.00
Additional ROW	AC	$ 35,000.00

A range of levee heights was used from 1-ft to 20-ft to develop the cost curves for asphalt roadways shown on Figure 6-2 below.

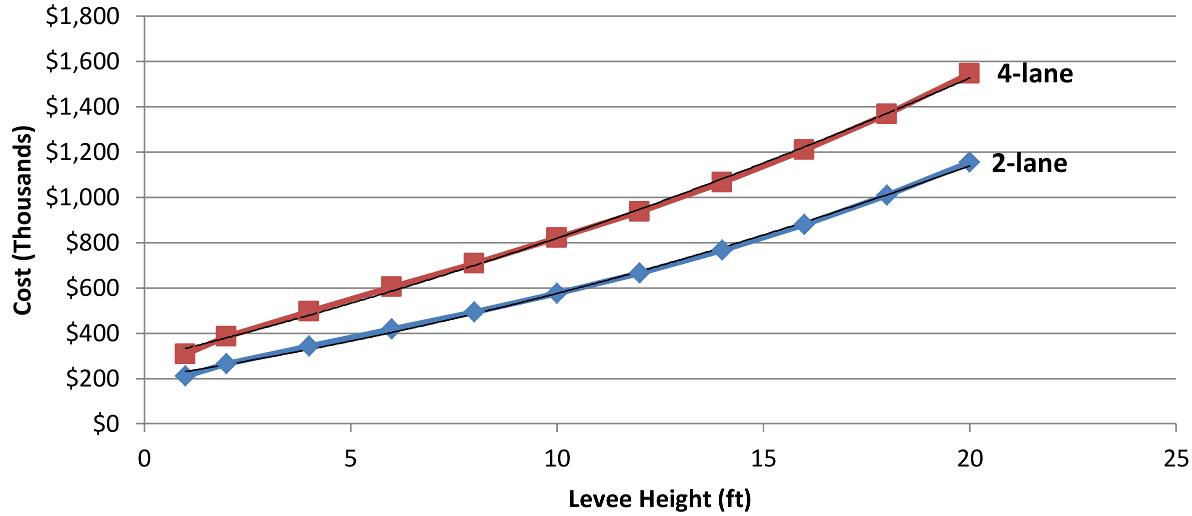

Figure 6-2 Asphalt road cost curves for 2-lane and 4-lane sections

Quantities and cost used for the concrete pavement section are shown in Table 6-7 below.

Table 6-7 Concrete pavement section quantities and unit cost

Item Description	Unit	Unit Cost
Preparing Right-of-Way	STA	$ 3,000.00
Excavation	CY	$ 5.00
Embankment (minus Levee)	CY	$ 10.00
Lime Treatment for Subgrade	SY	$ 4.00
Lime (6% volume)	TON	$ 150.00
10" Concrete Pavement	SY	$ 65.00
6" Concrete Curb	LF	$ 10.00
Swale	LF	$ 2.50
Signing/Paving Marking	LF	$ 15.00
Seeding/Sodding	AC	$ 700.00
Mobilizatoin (Approx 10%)	LS	$ 46,000.00
Additional ROW	AC	$ 35,000.00

A range of levee heights was used from 1-ft to 20-ft to develop the cost curves for concrete pavement roadways shown on below.

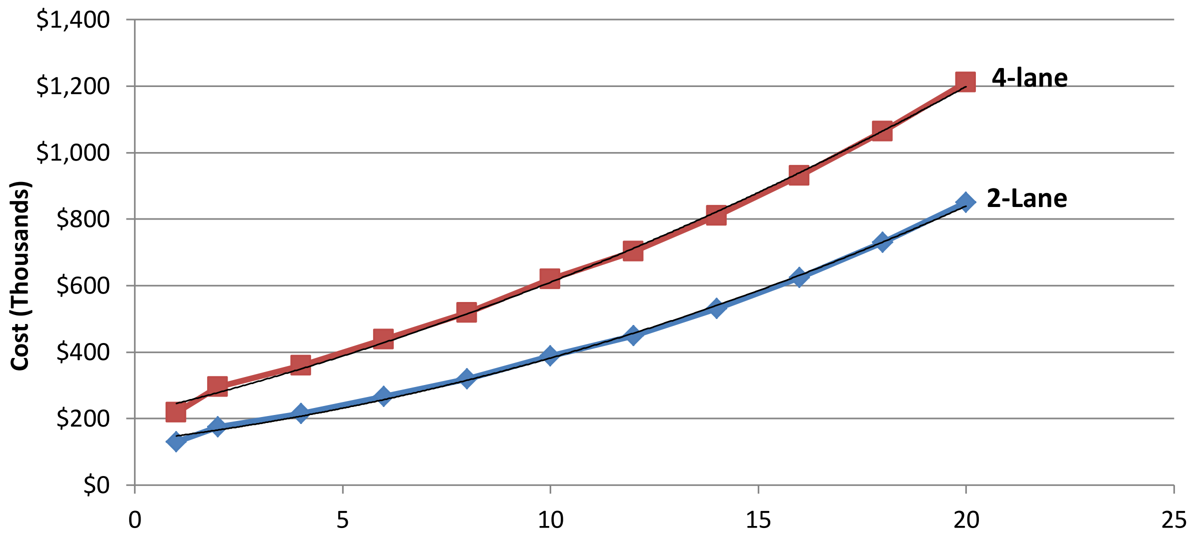

Figure 6-3 Concrete road cost curves for 2-lane and 4-lane sections

6.6.1 Railroad Crossings

Preliminary construction cost estimates for each of the various rail crossing locations for each alignment alternative are presented in Appendix E. At each crossing location the width of the railroad right-of-way which will be spanned by the proposed closure gate and the type of gate proposed are identified. The major items included in the preliminary gate costs are welded structural steel plate and supporting beams, and structural concrete for the supporting wing structures, sill and tie-in walls at the interface with the adjacent earthen levee. Minor costs will include preparation and painting of the steel components, signage to indicate contact numbers of operations personnel, general site preparation and restoration, and contingencies to cover other minor items.

6.6.2 Major Highway Crossings

The two crossings of IH-10 are not anticipated to require major highway modifications to accommodate the proposed levee embankment tie-ins. It is anticipated that some erosion protection measures at the tie-in locations will be necessary to protect the earthen slopes. Preliminary cost estimates for these locations are shown in Appendix E.

The three potential crossings of SH 73 will require the roadway to be modified using raised-profile crossings. A preliminary cost estimate for these locations is shown in Appendix E.

6.6.3 Minor Highway, County Road, Local Street and Private Driveway Crossings

The majority of the transportation crossings consist of minor highways, county roads, local streets, and private or industrial driveways and access roads. These crossings will be accomplished either by raised-grade crossings where right-of-way is easily available or gated closures where right-of-way or physical clearances are limited. Preliminary costs estimates for each potential location are shown in Appendix E.

6.6.4 Interior and Exterior Ditch Crossings of Roadways

Preliminary construction cost estimates for each drainage classification were developed, as presented in Appendix E. These estimates were developed using the culvert sizes associated with the required interior and exterior drainage infrastructure. Quantities and unit cost for each drainage structure are shown Table 6-8 below.

Table 6-8 Roadway crossing ditch crossings Quantities and Unit Cost

Item Description	Unit	Unit Cost
12x10 Box Culvert Crossings	LF	$900.00
12x10 Headwall	EA	$75,000.00
Exterior 8x8 Road Crossings	LF	$600.00
Exterior 8x8 Headwall	EA	$35,000.00
10x10 Box Culvert Crossings	LF	$750.00
10x10 Headwall	EA	$60,000.00
10x8 Box Culverts	LF	$750.00
10x8 Headwalls	EA	$60,000.00
Exterior 72" RCP	LF	$450.00
Exterior 72" RCP Headwalls	EA	$15,000.00
Exterior 60" RCP	LF	$350.00
Exterior 60" RCP Headwalls	EA	$15,000.00

The unit costs were used to develop the total drainage cost for each drainage classification selected for the roadway crossing as shown in Table 6-9 below.

Table 6-9 Drainage classification total cost

Drainage Classification	Total Cost
None	0
Local	$300,000.00
Semi-Regional	$480,000.00
Regional	$1,190,000.00
Super-Regional	$1,520,000.00

Preliminary costs estimates assigned for each potential roadway crossing is shown in Appendix E.

6.7 Wetlands and Environmental Mitigation Costs

Mitigation costs for impacts to wetlands and water of the U.S. are difficult to determine at this phase of project development, given the fluctuating nature of costs for the various components and the variability of USACE mitigation requirements at any given time. It is estimated, based on current mitigation prices within the USACE Galveston District, that mitigation for impacts to wetlands would cost approximately $80,000.00 per acre of impact, if credits were purchased from an approved mitigation bank. It is also estimated, based on current mitigation prices within the USACE Galveston District, that mitigation for impacts to waters of the U.S. determined to be streams would cost approximately $250 per linear foot of impact, if credits were purchased from an approved mitigation bank. These unit costs were applied to the total impacted area quantities identified in previous sections and in the preliminary cost estimates presented in Appendix E.

6.8 Non-Construction Costs

Non-construction costs associated with the construction of a project include an allowance for unforeseen contingencies in the construction costs, the engineering fees, project management fees and administrative fees, as described below:

6.8.1 Contingencies

A percentage of the total construction costs for the project, summarized above, is included in the costs estimate summaries below to cover incidental items, variability in unit price changes over the period of time between the feasibility study and actual bidding, and unforeseen design elements which are included into the project costs during final design. For this project, a 20% contingency cost has been added.

6.8.2 Engineering Fees

Engineering fees for this project are estimated to be 15% of the total construction costs plus contingencies. These fees include the final detailed design of the project components, including civil, structural, mechanical and electrical elements; development of construction plans and technical specifications; geotechnical investigations; environmental engineering to prepare applications and obtain the necessary permits; preparation, coordination and receipt of bids for the project; the engineer’s construction phase services, including the processing of shop drawings and pay applications; periodic field visits to the project; and certification that the project was constructed and completed in general compliance with the construction documents and design concepts.

6.9 Alignment Alternatives Cost Summaries

A summary of all computed construction costs and non-construction costs for each alignment alternative was developed as shown in the paragraphs below. It should be noted that the individual categories of cost were rounded up to the nearest $10,000 prior to summation of the Project Total Cost.

6.9.1 No-Action Alternative

While there are no direct construction or administrative costs associated with a no-action alternative, the costs associated with no action can be associated with the loss of property, life, and production capacity due to a major flooding event. This has been demonstrated in recent events during Hurricane Ike, with a storm surge peaking above elevation 11 ft. and total estimated damages of $800 million. This amount does not take into account the social impacts to area residents and business due to such an event. In excess of 3000 structures within Bridge City were inundated by storm surge during Hurricane Ike. The occurrence of future flooding events with similar or greater impacts would cause significant and lasting economic impacts to Orange County and the industries located within the study area.

6.9.2 Alignment Alternative Cost Summaries

Table 6-10 Protection System on East Bank of Neches and Sabine Alignment

Items	Sabine River Alignment Cost ($)	Neches River East Bank Alignment Cost ($)	Total Cost ($)
ROW Land Acquisition	$23,578,000	$17,878,000	$41,456,000
Earthen Levee	$112,965,000	$117,000,000	$229,965,000
Floodwall	$76,458,000	$53,992,000	$130,450,000
Pumping Cost	$182,000,000	$137,500,000	$319,500,000
Channel Closure Structures	$96,272,000	$23,059,000	$119,331,000
Pipeline and Utility Crossings	$23,272,000	$35,384,000	$58,656,000
Transportation Crossings/Structures	$13,830,000	$23,691,000	$37,521,000
Environmental Impacts Mitigation	$60,240,000	$92,800,000	$153,040,000
Sub Total	$588,615,000	$501,304,000	$1,089,919,000
Engineering (15%)	$88,292,000	$75,196,000	$163,488,000
Contingency (20%)	$117,723,000	$100,261,000	$217,984,000
Total	**$794,630,000**	**$676,761,000**	**$1,471,391,000**

Table 6-11 Protection System on East and West Bank of Neches and Sabine Alignment

Items	Sabine River Alignment Cost ($)	Neches River East Bank Alignment Cost ($)	Neches River West Bank Alignment Cost ($)	Total Cost ($)
ROW Land Acquisition	$23,578,000	$17,878,000	$7,258,000	$48,714,000
Earthen Levee	$112,965,000	$117,000,000	$39,693,000	$269,658,000
Floodwall	$76,458,000	$53,992,000	$64,656,000	$195,106,000
Pumping Cost	$182,000,000	$137,500,000	$17,500,000	$337,000,000
Channel Closure Structures	$96,272,000	$23,059,000	$14,018,000	$133,349,000
Pipeline and Utility Crossings	$23,272,000	$35,384,000	$17,590,000	$76,246,000
Transportation Crossings/Structures	$13,830,000	$23,691,000	$19,441,000	$56,962,000
Environmental Impacts Mitigation	$60,240,000	$92,800,000	$17,040,000	$170,080,000
Sub Total	$588,615,000	$501,304,000	$197,196,000	$1,287,115,000
Engineering (15%)	$88,292,000	$75,196,000	$29,579,000	$193,067,000
Contingency (20%)	$117,723,000	$100,261,000	$39,439,000	$257,423,000
Total	**$794,630,000**	**$676,761,000**	**$266,214,000**	**$1,737,605,000**

Table 6-12 County-Wide Protection with DD7 System Tie-in Alignment

Items	Sabine River Alignment Cost ($)	Neches River Crossing Alignment Cost ($)	Total Cost ($)
ROW Land Acquisition	$23,578,000	$603,000	$24,181,000
Earthen Levee	$112,965,000	$47,739,000	$160,704,000
Floodwall	$76,458,000	$1,587,000	$78,045,000
Pumping Cost	$182,000,000	$62,500,000	$244,500,000
Channel Closure Structures	$96,272,000	$496,001,000	$592,273,000
Pipeline and Utility Crossings	$23,272,000	$1,100,000	$24,372,000
Transportation Crossings/Structures	$13,830,000	$2,737,000	$16,567,000
Environmental Impacts Mitigation	$60,240,000	$21,360,000	$81,600,000
Sub Total	$588,615,000	$612,267,000	$1,140,642,000
Engineering (15%)	$88,292,000	$91,840,000	$171,096,000
Contingency (20%)	$117,723,000	$122,453,000	$228,128,000
Total	**$794,630,000**	**$826,560,000**	**$1,539,866,000**

Table 6-13 County-Wide Protection with Neches River Crossing and Sabine River Crossing

Items	Sabine River Alignment Cost ($)	Neches River Crossing Alignment Cost ($)	Sabine River Crossing Alignment Cost ($)	Total Cost ($)
ROW Land Acquisition	$13,719,000	$603,000	$859,000	$15,181,000
Earthen Levee	$87,981,000	$47,739,000	$51,753,000	$187,473,000
Floodwall	$76,458,000	$1,587,000	$0	$78,045,000
Pumping Cost	$182,000,000	$62,500,000	$137,500,000	$382,000,000
Channel Closure Structures	$96,272,000	$496,001,000	$85,492,000	$677,765,000
Pipeline and Utility Crossings	$10,604,000	$1,100,000	$0	$11,704,000
Transportation Crossings/Structures	$13,830,000	$2,737,000	$1,366,000	$17,933,000
Environmental Impacts Mitigation	$60,240,000	$21,360,000	$25,760,000	$107,360,000
Sub Total	$527,385,000	$611,664,000	$276,111,000	$1,354,920,000
Engineering (15%)	$79,108,000	$91,750,000	$41,417,000	$203,238,000
Contingency (20%)	$105,477,000	$122,333,000	$55,222,000	$270,984,000
Total	**$711,970,000**	**$825,747,000**	**$372,750,000**	**$1,829,142,000**

Table 6-14 Industrial Complex Protection System Alignment

Items	Industry Front Side Cost ($)	Industry Back Side Cost ($)	Total Cost ($)
ROW Land Acquisition	$1,108,000	$5,091,000	$6,199,000
Earthen Levee	$28,863,000	$26,202,000	$55,065,000
Floodwall	$0	$11,423,000	$11,423,000
Pumping Cost	$7,000,000	$10,500,000	$17,500,000
Channel Closure Structures	$6,079,000	$6,692,000	$12,771,000
Pipeline and Utility Crossings	$9,677,000	$11,774,000	$21,451,000
Transportation Crossings/Structures	$3,113,000	$7,576,000	$10,689,000
Environmental Impacts Mitigation	$16,320,000	$5,520,000	$21,840,000
Sub Total	$72,160,000	$84,778,000	$156,938,000
Engineering (15%)	$10,824,000	$12,717,000	$23,541,000
Contingency (20%)	$14,432,000	$16,956,000	$31,388,000
Total	**$97,416,000**	**$114,451,000**	**$211,867,000**

6.10 Total Cost Summary Comparisons

The table below shows the construction cost summaries for each alignment alternative. These values will be used in the Alternative Evaluations Grading System described in Section 8, below.

Table 6-15 Total Cost Summary

Alignment Alternative	Total Cost ($)
No-Action	$0
Orange County Protection - East Bank of Neches River (SR + NR)	$1,472,000,000
Protection System on East & West Bank of Neches River (SR + NR + NRW)	$1,738,000,000
County-Wide Protection with Neches River Crossing (SR + NX)	$1,540,000,000
County-Wide Protection with Neches River Crossing and Sabine River Crossing (SR + NX + SRX)	$1,830,000,000
Protection of Industrial Complex (ID)	$212,000,000

7. Supplementary Notes on Benefit Cost Analysis (BCA)

7.1 Project Description

The proposed project is comprised of a Levee system to control flooding in Orange County Texas. The project area is located at the northern end of Sabine Lake along the border between Texas and Louisiana. The project will protect a large area of Southern Orange County, Texas. Analysis of the project area current FIS Data, proposed BFEs and elevation data from the National Elevation Data Set determined that the proposed Levee system would benefit an area of Southern Orange County, Texas which extends north from the Northern tip of Sabine Lake to the man-made flood barrier/boundary created by Interstate-10. Interstate 10 is and elevated highway running east west through the county. The project area includes thousands of residential properties, hundreds of commercial properties, and some industrial and agricultural properties as well as all the infrastructure and roads related to the sites and population.

7.2 BCA Methodology

Because of the nature of the project, the Benefit Analysis was completed using the FEMA BCA 4.5.5 software. After defining the project area, the first element needed to complete the benefit analysis was collection of parcel specific data using the Orange County Central Appraisal District (CAD) database to determine the size and quality of improvements within the benefit/project area. GIS shape files, segment files containing detailed parcel data, and associated descriptive files were obtained from CAD. This data was used to determine the geographic location for each improved parcel within the project area as well as the size and class of each improvement.

A summary of this data is as follows:

Table 7-1 Summary of Orange County CAD data

Property Type	Property Count	Total Area	Average SqFt	Average BRV
Residential	15,226	22,966,709	1,508	$74.90
Commercial	1,514	8,888,984	5,871	$31.72
Mobile Home	1,152	1,377,499	1,196	$69.61
Total	17,892	33,233,192	1,857	$67.62

Due to the extensive time and cost associated with getting specific replacement cost data for each commercial building, and given the relatively small number of commercial buildings in the benefit area, for this analysis, we used $75/sqft for all commercial buildings to determine commercial building replacement cost value (dollar value of at risk commercial structures). In addition, for these commercial buildings we used the residential default depth/damage curves in the BCA module to predict avoided damages. Using this approach did not have a material effect on the overall Benefit Assessment, if anything, if actual use and type of construction for each commercial building were gathered; the benefits to these commercial structures would increase above what is indicated in this assessment. We consider this a conservative approach for these commercial structures. All other structures (Mobile Homes and Residential homes) were evaluated using the actual replacement cost value (further described below) and FEMAs default residential depth/damage curves.

For all residential structures, we used the current Marshall and Swift construction cost estimation tool to determine the dollar per square foot to determine Building Replacement Values (BRV). BRV equates to the dollar value of properties at risk within the benefit area. Marshall and Swift has varying dollar per sqft for ranges for properties, based on the type, size, and quality of construction. The information from the CAD tax database was used to determine the sqft, type, and quality of construction. The resultant dollar per sqft times the number of sqft for each building equals the building's replacement value. CAD reports for each parcel in the benefit area and Marshall and Swift tables are available upon request. Benefits Results are located in Appendix K, including a hyperlink to each of the 17,892 CAD records. The Marshall and Swift table summary for $/sqft ranges is included is also included in Appendix K.

The second element required to determine benefits is the Elevation of each structure. Collecting individual elevation on all 17,892 properties in the project area would be both time and cost prohibitive for this analysis. Many options for obtaining this data were reviewed including LIDAR data and topo maps. The National Elevation Dataset (NED) maintained by the US Geological Survey (USGS) was determined to be the most accurate and time / cost effective source for the elevation data required to perform the benefit analysis. The following two paragraphs are taken from the USGS website for NED:

The National Elevation Dataset (NED) is the primary elevation data product of the USGS. The NED is a seamless dataset with the best available raster elevation data of the conterminous United States, Alaska, Hawaii, and territorial islands. The NED is updated on a nominal two month cycle to integrate newly available, improved elevation source data. All NED data are public domain. The NED is derived from diverse source data that are processed to a common coordinate system and unit of vertical measure. NED data are distributed in geographic coordinates in units of decimal degrees, and in conformance with the North American Datum of 1983 (NAD 83). All elevation values are in meters and, over the conterminous United States, are referenced to the North American Vertical Datum of 1988 (NAVD 88).

The NED serves as the elevation layer of The National Map, and provides basic elevation information for earth science studies and mapping applications in the United States. Scientists and resource managers use NED data for global change research, hydrologic modeling, resource monitoring, mapping and visualization, and many other applications.

NED provides elevations based on Latitude and Longitude (Lat/Long). The parcel data provided gave us an address which could be Geocoded to obtain a parcel by parcel corresponding Lat/Long. The other way to obtain Latitude and Longitude was to query the GIS shape files for the Latitude and Longitude of the center of each parcel. Since Geocoding in most cases provides the Lat/Long of a point at curbside, it was determined that the more accurate elevation, for the improvements, would be at the center of the parcel. A software script was developed to query NED for elevation for each improved parcel in the project benefit area. LJA Engineering provided 100 ground truthed elevation points, randomly spread across the project area. This ground truthing was used to determine the accuracy of and required adjustment to the NED elevations. Analysis of these data points showed an average difference between the NED provided elevations and the ground truthed, surveyed elevations of approximately .32 feet. After analysis and review it was determined that an adjustment of .5 ft would be added to the NED elevations to obtain bare earth elevations.

Improvements in the county are not typically located at grade, but are more typically built slab on grade, on piers or posts. Since there are relatively few pier and post foundations in comparison to the slab on grade it was determined that all properties would be considered slab on grade and an additional adjustment factor of .5 ft was added to the elevation data obtained from NED. With the NED data, a .5' adder for the ground truth/NED adjustment, and a .5' adder for slabs, we had what is a fairly accurate estimated first for elevation for all 17,892 structures within the benefit area. With elevations determined we moved to the third element required to complete the analysis.

The third element needed to determine benefits for the project is the hydrology. As we are completing this analysis using FEMA's BCA Flood Model and the fact that all properties are located in the SHFA in Coastal Flood Zones we needed the Stillwater elevations for the 10, 50, 100 and 500 year storm events. The Current FIS data and revised data from the recently release preliminary maps were reviewed to obtain the Stillwater elevations (SWEL) affecting the structures within the project area. The Stillwater elevations from the current FIS were adjusted by the increase indicated on the preliminary maps to determine the inputs required to complete the analysis. The adjusted SWEL data was applied to the project parcels based on their location within three transects identified in the project area.

Table 7-2 Stillwater Elevations

Area 1	10	50	100	500
Current FIS Data	5.2	7	7.8	10
Adjusted FIS Data	9.4	11.2	12	14.2

Area 2	10	50	100	500
Current FIS Data	5	6.8	7.6	9.8
Adjusted FIS Data	8.4	10.2	11	13.2

Area 3	10	50	100	500
Current FIS Data	5.2	7	7.8	10
Adjusted FIS Data	6.6	8.4	9.2	11.4

Benefit calculations were performed on all improved properties within the project area using the FEMA BCA 4.5.5 software. The parcel specific data relative to replacement cost value, the First Floor Elevation for each structure, and the corresponding Stillwater elevation data for each 17,892 improved parcels were input into the Flood Module and benefits were calculated on a parcel by parcel basis. As this levee is proposed to fully protect all structures, we did not reintroduce damages a future theoretical storm event size. The FIS data was Coastal A, in the SHFA, with FFE and 10, 50 100 and 500 yr SWELs.

Building damages (avoided damages) were calculated by the software by using:

- Adjusted Stillwater elevation data from the current FEMA FIS studies, adjusted elevation data from NED with adjustments based on 100 'truthing' points throughout the planning area
- Building values (value of at risk structures) were determined using Marshal and Swift residential construction cost estimation tool dated 12/31/2011, applied to improvement data from Orange County Appraisal District.
- Contents damages were based on the FEMA default values of, 50% of the building value, as calculated by the FEMA BCA software.
- Displacement benefits were calculated by the BCA software and based on FEMA default value of $1.44 per Square Foot of space per month of displacement time.

In the FEMA BCA methodology, displacement times and values account for certain additional costs of flooding other than direct damages to structures and contents. These include renting alternative living or work space, extra commuting timing, storage, etc. Current FEMA guidance provides recommended values for these costs, and the FD software provides defaults for displacement times for residential uses.

The table below results of the risk assessment, which calculates expected future damages to improved parcels in the project area, over a 100-year horizon. The proposed project benefits an area of structures with a total at risk value of conservatively $2.3 billion and avoided damages of $798,742,851.52. As noted elsewhere in this summary, these results should be considered lower-bound. The risk calculation includes only future damages to improved parcels. It does not include many benefits afforded to non-residential properties or infrastructure in the same project area, or any risk related to properties or infrastructure outside the project area. Furthermore, there are likely significant benefits related to avoided loss of road and utility function that are not counted in the analysis.

Table 7-3 Results of Risk Assessment using BCA Software

Property Type	Property Count	Total At Risk Structure Value	Total Benefits	Average Benefit
Residential	15,226	$1,630,537,527.70	$551,486,367.89	$36,220.04
Mobile Home	1,152	$45,666,160.00	$19,291,938.39	$16,746.47
Commercial	1,514	$666,273,800.00	$227,964,545.24	$150,571.03
Total	17,892	$2,342,477,487.70	$798,742,851.52	$44,642.46

7.3 Additional Potential Benefits

For the purpose of the in-depth BC analysis completed (as discussed above), we looked at all improved parcels in the benefit area. It was outside the scope of this project, and/or very expensive and time consuming to collect all needed data for the additional benefit categories listed below. However, it is important to note that there are significant additional benefits that can and will be calculated when further analyses for this potential project are undertaken. The categories of these potential benefits and a brief explanation of each follows.

Road Damages and closures

Road damages and closures can be calculated based road elevations relative to water surface elevations pre- and post-project for a range of flood frequencies, with the miles of road that are inundated by floods at various levels.

The damages related to road inundation can be calculated based on $300,000 per road mile of repair costs, as per historical experience, engineering judgment, and Data from TXDOT.

Avoided damages associated with road closures can be calculated using estimated closure time, TXDOT cost per hour of time to detour, and detour length in miles.

Crop Damages

Crop damages can be calculated based on water surface elevations pre- and post-project for a range of flood frequencies, with the crops acreages that are inundated by floods in various frequencies.

Based on similar prior analysis in the Project area:

- Crop damages are estimated at $500 per acre.
- Crops are rotated every three years, so each year 33% of the acreage is subject to inundation
- Significant rainfall occurs only during about half of each year, so the damages are further reduced by half annually in the analysis.

Using FEMA's DFA BCA module we can calculate the net present value of the avoided damages by determining ground elevation with farming portions of the benefit area, flood depths in various recurrence intervals, and duration of surface water.

Damages Related to Loss of Feed for Livestock

Portions of the project area are used to graze livestock. When the land is flooded, the livestock lose their source of food, at an expense to the farmers, who must provide alternative feed sources. The estimated losses can be derived based on interviews with ranchers/farmers in the, and data from prior similar BCA work done in the project area for other FEMA funded mitigation projects.

FEMA's DFA BCA module can be used to calculate the net present value of the avoided damages.

Direct Damages to Refineries (equipment, facilities, and operations)

The potential interrupted function at several large refineries in the project area can be calculated using historical loss data from these facilities, operating budgets to determine disruption of service, elevation and building/equipment values for use, and road inundation preventing operations personnel access to the facilities. This data, compared to the probability and water surface elevation of various event sizes can produce significant additional avoided damages, From prior experience, and preliminary analysis, it is estimated that these additional benefits, once data is available and calculated, will provide more than double the avoided damages shown for the nearly 18,000 structures for which benefits have been calculated.

8. Alternative Evaluations

Each alternative described above was evaluated using the grading system described in the following paragraphs.

8.1 Grading system

A grading system was developed for this project using a relative ranking system of the six (6) alternatives investigated, as described above. This ranking system was devised in order to facilitate comparison of numerous individual project components and project considerations without a more traditional weighting of any item relative to other items.

This grading system considers two major categories of items: those related to project costs which can be quantified in the course of the design of the project (i.e.: construction costs, right-of-way, property value protected, etc.), those for which actual project costs cannot be directly computed (i.e.: project aesthetics, disruption to transportation systems, etc.) or those for which computation methodologies are less well defined (i.e.: environmental considerations, social considerations, etc). Numerous individual items were evaluated, as shown in Table 7-1. Most of the items identified in the table are self-explanatory, such as the construction cost items and the items identifying areas or values protected. The reasoning for including those items which are not self-explanatory is described in the following paragraphs.

8.1.1 Benefit/Cost Ratio

Since the source of funding for this project is not known at the time of the development of this feasibility study, the Benefit/Cost (B/C) Ratio for this project was computed by Jeffrey S. Ward Associates according to the FEMA mitigation model as described in Section 7. The benefit/cost ratio numbers are incomplete at this time and require further analysis during the next phase of the feasibility study.

8.1.2 Losses Avoided

Losses Avoided are the economic losses and property damages which would have occurred within a protected area had the project not been constructed. Levee heights used in this study were based on the predicted storm surge elevation (see Section 3.2.2) which would be caused by a Hurricane Ike type event, shifted to make landfall at or near Sabine Pass. Because this Level of Protection is in excess of the 100 year event, the potential losses associated with the 100 yr. event were computed and used for this parameter.

8.1.3 Design Complexity

This parameter considers the relative complexity of the general design elements of each alternative, for instance the design of an earthen levee section is much less complex than the design of a gate structure or floodwall section. This parameter was used to compare alignment options in the early steps of this study and is used to compare the overall complexity of the preliminary levee alignments and the associated gate structures at transportation crossings and floodwall alignments, as depicted on the exhibits.

8.1.4 Innovative Design Elements vs. Proven Technology

This parameter is a simple measure of the technology and innovation inherent in the use of earthen levees versus gated structures across the major rivers. The proven technology of earthen levees along the east bank of the Neches River as compared to the innovative technology of the proposed large river gate was included as a separate item. The costs of each of the alternative designs are included in the cost estimates for each alignment alternative investigated. It should be noted that the sector gate, proposed for the Neches River crossing alternative, is a type of gate which has been used in similar sized installations in the Netherlands as previously discussed, with smaller installations at many locations in the United States.

8.1.5 Navigation Considerations

This parameter includes two considerations relating to the potential for interaction between the protection system and the shipping and barge traffic along the Neches and Sabine Rivers: 1) the potential disruption of traffic prior to landfall of an event for which the ports/rivers would be closed and 2) the need for close coordination between the port authorities and the levee management authority in the days preceding and following an event.

8.1.6 Maintenance and Operations Considerations

This parameter is a comparative measure of the potential maintenance and operations considerations of each alternative, including maintenance costs, complexity of maintenance activities, accessibility of the various project elements, and the potential complexity of operational decision points.

8.2 Grade Assessments

Each alternative presented in the previous sections were assessed grades using the above described methodology. The resulting overall scores are shown in **Table 8-1**, below:

TABLE 8-1
ORANGE COUNTY LEVEE PROJECT
PROJECT ALTERNATIVE GRADING SYSTEM

			ALTERNATIVES									
			A		B		C		D		E	
			Industries Alignment (ID)		Orange & Jefferson Counties (SR + NR)		Orange & Jefferson Counties (SR + NR + NRW)		Orange & Jefferson Counties (SR + NX)		Neches & Sabine Crossings (NX + SR + SRX)	
			35		63		74		47		60	
No.	CRITERION	UNITS	QUANTITY	RANK	QUANTITY	RANK	QUANTITY	RANK	QUANTITY	RANK	QUANTITY	RANK
a	Estimated Total Project Cost (including ROW)	$	$212,000,000	1	$1,472,000,000	2	$1,738,000,000	4	$1,540,000,000	3	$1,830,000,000	5
b	Population Protected	EA	236	5	47,646	4	69,288	3	73,736	2	74,652	1
c	Area Protected	AC	5,276	5	76,712	4	87,601	3	148,345	2	177,397	1
d	Property Value Protected	$	$22,741,622	5	$2,143,848,845	4	$3,362,667,804	3	$3,581,863,830	2	$3,589,084,614	1
e	Benefit-Cost Ratio	N/A										
f	Estimate of Damages Prevented (based on Ike Losses)	$										
g	Right of Way Takings											
	Total Acreage	AC	628	1	2237	4	2768	5	1379	2	1509	3
	Number of Tracts	EA	190	1	536	4	788	5	246	2	188	3
	Availability	N/A		1		3		5		2		4
h	Environmental Considerations Impacts/Mitigation/Permitting Requirements											
	Impacted Area	AC	273	1	1913	4	2126	5	1020	2	1144	3
	Mitigation Costs	$	21,848,832	1	153,040,000	4	170,080,000	5	81,600,000	2	91,520,000	3
	Permitting Requirements	N/A		1		3		4		2		5
i	Existing Infrastructure Conflicts/Coordination Efforts/Disruption											
	Number of Roadway Crossings	EA	12	1	44	4	70	5	21	2	18	3
	Agency Coordination	N/A		3		4		5		1		2
	Traffic Disruption	N/A		3		4		5		1		2
j	Pipeline/Utility Crossings and Adjustments											
	Pipeline Crossings/Adjustments	EA	61	1	114	4	174	5	46	3	38	2
	Pipeline Crossings/Adjustments	$	21,451,000	1	58,656,000	4	76,246,000	5	24,372,000	3	11,704,000	2
k	Design Complexity	N/A		1		2		2		4		5
l	Innovative Design Components vs. Proven Technology	N/A		1		1		1		4		5
m	Navigation Considerations											
	Modifications to Major Waterways (Gates/Locks)	EA	0	1	2	2	2	2	3	4	4	5
	Temporary Disruption to Commercial Shipping/Traffic during Events	N/A		1		2		2		4		5

A review of the individual ranks assigned to each alternative, for each grading criteria was performed in order to determine the total number of times a particular rank was assigned to an alternative (i.e.: Alternative 1 was assigned Rank 1: 14 times; Rank 2: 0 times, etc.). This information may aid in the determination of the alternative that most closely achieves the goal of each individual criterion. In other words, an alternative that achieves a majority of Rank 2 assessments may be a better overall choice over an alternative with fewer Ranks 1, 2 and 3, even with a lower overall score.

8.3 Stakeholder Feedback

Stakeholder input regarding the proposed flood protection system was solicited as described in Section 2.5.3. The input sought and used in the preliminary design and project considerations included recommendations on levee/floodwall alignments, areas to be protected, closure structure types and access restrictions/requirements. This information was used by the design team to develop the preliminary earthen levee segment alignments, floodwall alignments, roadway and railway crossing/closure structure types, and the various alignment alternatives described in the preceding sections.

Upon completion of the preliminary design analyses, a draft report was presented to the various stakeholders for their review and comment. Revisions to the report were made which incorporated the relevant comments and suggestions of the stakeholders.

The purpose of seeking stakeholder input in the early phases of this feasibility study and receiving stakeholder feedback after the preparation of the draft report was to illicit the local entities needs and to obtain, as much as possible, consensus on the concepts used to develop each of the alignment alternatives. With this local input and feedback the specific local needs of each major stakeholder group can be accommodated by and incorporated into the alternative selected for further study and preliminary engineering design, as described in the section below.

8.4 Alternative Selection

The grading assessments and ranks, described above, were applied to each of the alignment alternatives investigated. Each of the alternatives was then evaluated based on the overall numeric rank assigned through the assessment process and the number of times each rank was assessed. Review of the results indicates that Alternative A, the Industries Alignment, has the lowest rank, with Alternative D, the Neches River Crossing and Sabine River Alignment, has the second lowest rank.

Since one of the primary goals of this feasibility study is to identify a project which would provide county-wide protection, at least for Orange County, Alternative D provides this protection at the lowest cost and with the best economic benefit of the alternatives investigated. Based on this assessment, this alignment should be further investigated. A Preliminary Engineering Report (PER) should be prepared which investigates the detailed alignment and design components for each segment. This preliminary engineering would better identify the specific design and construction cost considerations for such major items as pipeline crossings, public and municipal utility line crossings, roadway and railway crossings/closure structures, levee/floodwall alignments, pump station sizing and locations, and design of major channel crossing structures/closures. Other engineering investigation, such as environmental and geotechnical studies would also be conducted in the PER phase.

Based on the grading assessments assigned above for each alternative, a second alternative, the Industries Alignment should also be further investigated in the PER phase. The segment of this alignment along the Sabine River is also a segment of the Sabine River Alignment, thus this alternative may serve as a first phase of a larger future project which would protect a larger portion of Orange County or the Upper Texas Gulf Coast.

9. Project Delivery and Financing

In order to facilitate the construction and funding of the selected alternative alignment, several project delivery and financing options should be investigated. The most common are listed below. Each of these options briefly addresses the ownership and maintenance responsibilities by a public entity, and funding mechanisms which may be available to such entities. In order for a levee system certification to be recognized by FEMA as providing reasonable assurance of protection from the BFE, a public entity must own or operate such systems, therefore in all of the delivery scenarios considered, ownership or sponsorship of the project is vested in a public entity.

9.1 Local Ownership, Funding and Long-term Financing

This option assumes that the owner(s) of the protection facilities will be the county or counties which are within the protected area. These entities would be responsible for operating and maintaining the levees, floodwalls, closure structures and pump stations through either a separate department, dedicated to this purpose, or incorporated into an existing county-wide department, such as the Orange County Drainage District. The initial construction costs would be funded through the issuance of locally backed municipal bonds to raise the funds necessary for construction of the project. An ad-valorem tax, assessed by the county, would be necessary to re-pay the bonds and maintain adequate funds for operations and maintenance costs. This option is similar to the Special Use District option described below.

9.2 Special Use District

This option assumes that a new Special Use District would be created which incorporates the protected areas into a separate entity. This type of district, similar to the Jefferson County Drainage District No. 7, which owns and operates the Port Arthur Hurricane Flood Protection System, would be a separate entity with all of the power and authorities necessary to operate and maintain the facilities. The funding for the initial construction of the facilities could be obtained through a number of means, including municipal bonds backed by the State of Texas, direct funding from the federal government, private funding through long-term financing agreements or ad-valorem taxes levied on the properties within the district.

9.3 Public-Private Partnerships

This option assumes that a private organization in conjunction with a local governmental agency would create a partnership to provide the funding for the initial construction and a local governmental agency, such as one described above, would provide the long-term financing mechanism for repayment of the initial investment. This type of partnership could be developed using several models:

9.3.1 Concession

Using this model, the private entity finances, constructs, operates and maintains the facilities under contract with the local entity, with the entity re-paying the financing of the project through ad-valorem taxes. This model may also include a design-build component, whereby the private entity also performs those portions of the project, as described below.

9.3.2 Design-Build

Using this model, the private entity partner designs, constructs and funds the project with private investment funds and is re-paid through a financing agreement with the local entity. The local entity would fund the re-payment through ad-valorem tax revenues, as described in the above sections.

9.3.3 Private Investment

Using this model, a private entity funds the project with re-payment of the debt service guaranteed through a contract with the local entity. The local entity would perform the design, construction, operation and maintenance of the facilities. Repayment of the debt service would be funded from revenues from ad-valorem taxes, as described in the above sections.

9.4 Federal Funding

There are three common potential federal funding methods commonly used for similar projects. It can be assumed that with each of the following federal funding scenarios that a portion of the costs will be borne by the local community as part of a cost sharing of project costs. Typically this cost sharing percentage is 20-25% contributed by the local entity.

9.4.1 WRDA Funding

Funding can be included by the U.S. Congress in a Water Resources Development Act (WRDA) bill, which directs funding to specific projects. Such WRDA bills are presented to Congress periodically to fund various water and flood control/protection projects nation-wide. This process is similar to a separate funding bill, however it is intended by Congress as a means of funding projects of this type.

9.4.2 Specific Congressional Funding Bill

Funding can be provided through a specific funding bill approved by and through Congress for this project. These types of funding bills can be difficult to have approved by Congress due to numerous procedural factors associated with specific Congressional actions.

9.4.3 Corps of Engineers Funding

Funding can be provided through the U.S. Army Corps of Engineers (USACE) by including the project into the USACE budgeting process. This method would require that the normal project feasibility, design and procurement procedures be followed, which historically, have taken a significant amount of time to complete the construction of a project.

9.5 Potential Impact to Property Tax Rates

The majority of the above described funding methods for the proposed project assume that ad-valorem property taxes would be levied on the properties within the protected areas or county-wide. The tax rate would have two components; a debt service rate, and an operations and maintenance (O&M) rate. The total tax rate is a function of the tax revenue generating capacity of the protected properties versus the value of the properties.

10. Conclusions and Recommendations

10.1 Conclusions

The following conclusions are based on the review and assessment of the criteria and grade assessments presented in the preceding sections.

Two alignment alternatives were selected for further investigation in a Preliminary Engineering Report (PER) based on the grade assessments and feasibility criteria. The PER should address the determination of final alignments of the levee/floodwall systems, design parameters and considerations for each system component, sizing and locations of pump stations and outfall/closure structures, roadway and railway crossings/closure structures, and design considerations and parameters for all pipeline, public utility and municipal utility crossings.

Selected Alternative

<u>Neches Crossing and Sabine River Alignment</u>

This alignment was selected based on the fact that it met the requirement of providing county-wide protection for Orange County. Since this alternative also can provide protection to the west bank of the Neches River up to the City of Beaumont, it well exceeds that requirement. In addition to the grading rank, this alternative was chosen based on the Assessed Valuation Protected and Potential Flood Damage Losses Prevented, since these parameters are some of the most important in evaluating a protection system. This alignment protects the industrial areas and the majority of the land area within Orange and Jefferson Counties.

<u>Industries Alignment</u>

This alignment was also selected based on the parameters of the Grading System and the Overall Construction Cost. This alignment protects the major industrial area within Orange County and will be further investigated to serve as the first phase of a larger future project in the region.

Estimated Construction and Project Costs

<u>Neches Crossing and Sabine River Alignment</u>

The preliminary estimates of construction and project costs for this alignment alternative are presented in Appendix E. The total estimated project costs are $1,540,000,000, which includes the acquisition of right-of-way, preliminary construction costs, engineering and construction management fees, and an allowance for unforeseen contingencies.

<u>Industries Alignment</u>

The preliminary estimates of construction and project costs for this alignment alternative are presented in Appendix E. The total estimated project costs are $212,000,000, which includes the acquisition of right-of-way, preliminary construction costs, engineering and construction management fees, and an allowance for unforeseen contingencies.

Project Delivery and Funding

The methods for the execution and delivery of and the funding of this project should be further investigated based on the availability funding from either private or public sources. The detailed discussion and investigation of the various means are beyond the scope of this study and should be further investigated concurrently with the PER development discussed above.

10.2 Recommendations

The following recommendations for providing a hurricane flood protection system for Orange County are offered:

- Develop a Preliminary Engineering Report (PER) which addresses the specific design requirements of the Neches River Crossing and Sabine River Alignment and the Industries Alignment as a possible first phase of construction.
- Investigate potential funding and financing sources and methods in order to provide adequate funds for the design and construction of the project.
- Investigate methods for the maintenance and operations responsibilities of the system, through the creation of a separate public entity or the addition of such responsibilities to a department of an existing public entity.

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