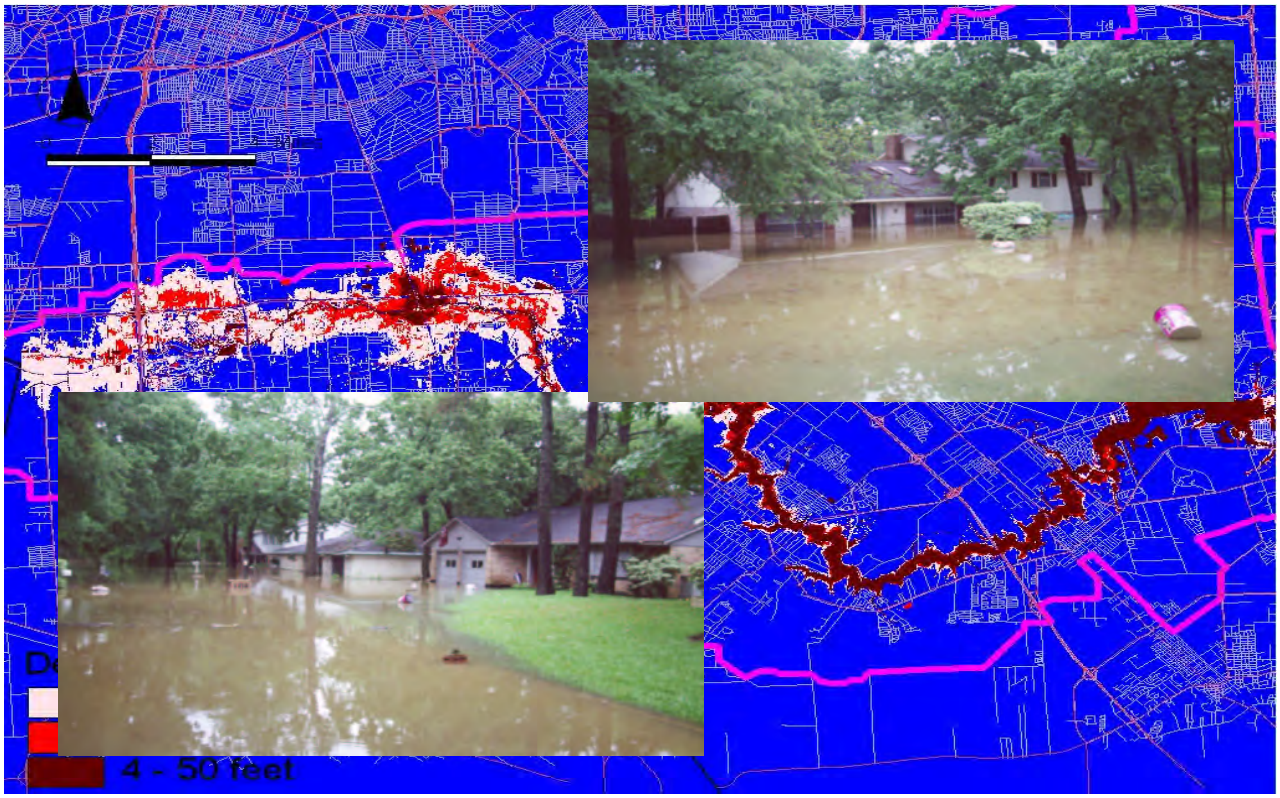
U.S. Army Corps
of Engineers

Galveston District
Southwestern Division

Clear Creek, Texas

Flood Risk Management

Final
General Reevaluation Report



October 2012

CLEAR CREEK, TEXAS
FLOOD RISK MANAGEMENT
EXECUTIVE SUMMARY

INTRODUCTION

Clear Creek, a wooded stream, drains an area south of and partially within the City of Houston. The Clear Creek watershed is located in four counties, includes sixteen cities and covers approximately 260 square miles of land. The watershed is composed of relatively flat coastal plain with elevations varying from near sea level at Clear Lake to about 75 feet mean sea level on the western watershed boundary (Figure 1-ES). Clear Creek receives flow from 17 principal tributaries. Clear Lake is the flooded lower extremity of the Clear Creek entrenched channel, now forming an estuarine lake tributary to Galveston Bay. The Lake area is between 1,500 and 2,000 acres depending on the tide. The average depth of Clear Lake is about 3.4 feet. Clear Lake is used extensively for boating, sailing and skiing. The Clear Lake area contains one of the largest marina development areas in the United States. The 1 percent (100-year) annual exceedance probability (AEP) floodplain contains an area of approximately 19,000 acres. Many communities and subdivisions along the creek are subject to flooding and recent floods (1973, 1976, twice in 1979, 1989, October 1994, June 2001, October 2006 and April 2009) have caused extensive property damage. A flood in July 1979 caused more than $90 million (1979 price level) in damages in the Clear Creek watershed. Additionally, minor flood events in June 2006 and August 2007 also caused damage within the watershed.

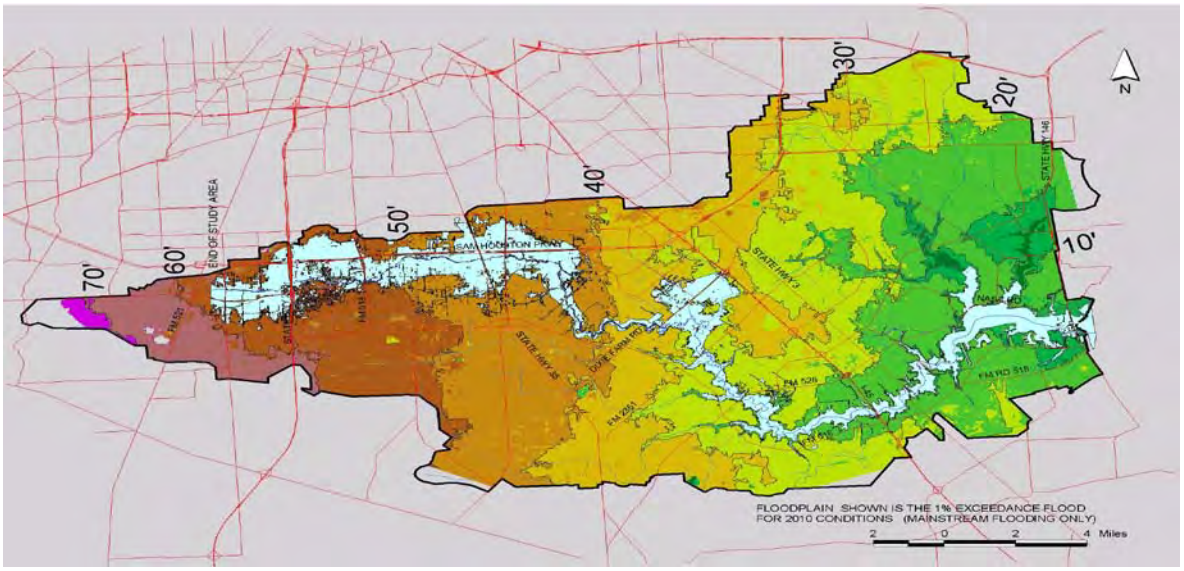


Figure 1-ES
Clear Creek Watershed, 1% Floodplain (light blue) and Associated Land Surface Elevations

As a result of numerous storms and flooding events, the Flood Control Act of 1962 authorized the initial investigation of flood problems on Clear Creek. In 1968, a survey report recommending construction of flood control measures along the main channel of Clear Creek was submitted to Congress. The recommendation was for an improved grass-lined channel 31 miles long, which would replace about 41 miles of existing winding channel. The grass-lined channel was designed to contain flood flows up to and including the 1 percent (100-year) AEP flood event. In submitting the report, the Secretary of the Army directed that the recommended plan be reviewed during the preconstruction planning stage and modified to achieve the most reasonable balance between structural modification of the creek, floodplain regulations, and a broad program of floodplain management. Congress authorized the Clear Creek Flood Control project in the Flood Control Act of 1968, as described in House Document No. 351, 90th Congress, 2nd Session, including the condition of authorization stipulated by the Secretary of the Army. In his transmittal letter the Secretary of the Army stated that "If the project is authorized, the Chief of Engineers, during the pre-construction planning stage, will review the size and scope of the proposed project and modify the plans as needed to achieve the most reasonable balance between structural works, flood plain regulation and a broad program of flood plain management. The objective of this review is to avoid uneconomic, hazardous or unnecessary development of the area subject to flooding." This stipulation, together with subsequent Congressional actions, administrative changes to water resources planning policies, changes in the project area, and changes in the attitude of the affected public, required a comprehensive restudy of the Clear Creek project.

As a result of that restudy, a preconstruction authorization planning report was completed in May 1982. This document recommended a modification for the project from the previous 1 percent (100-year) AEP flood event level of protection to a 10 percent (10-year) AEP flood event level. This plan consisted of channel enlargement and easing of bends within the existing stream from stream mile 3.8 to 26.05 (Mykawa Road), to contain within banks the floodwater flows for a 10 percent (10-year) AEP storm. No buyout of structures in the residual 1 percent (100-year) AEP floodplain was included. Nonstructural measures, such as local regulations restricting future development in the residual 1 percent floodplain, were to be required. Bottom widths of the channel varied from 130 feet near Clear Lake to 50 feet at Mykawa Road.

That plan would have required excavation of approximately 11.9 million cubic yards of material. For disposal of that material, approximately 594 acres of temporary easement and acquisitions would have been required. Approximately 569 acres of rights-of-way would have been required for construction of that plan.

Construction of the authorized plan was initiated in the 1990s with the modification of two railroad bridges and construction of the second outlet and gated structure. The additional outlet

between Clear Lake and Galveston Bay was constructed to ensure that the channelized creek would not induce flood damages on the lake community by keeping water levels in the lake from increasing when the proposed upstream enlargement occurred. The gated structure was constructed to minimize changes to existing environmental and hydraulic conditions, which include salinity and sediment transport and the rate of tidal inflows.

Upon completion of the second outlet but before the initiation of construction on the channelized portion of the creek, issues were raised by concerned citizens about the amount of environmental and hydraulic impacts associated with the project. Based on the concerns raised, the sponsors developed the Sponsor Proposed Alternative for consideration, but the plan was considered substantially different from the authorized project by the U.S. Army Corps of Engineers (USACE) and could not be considered for construction under the existing authorization at that time. Because of the uncertainties associated with the authorized project, at the request of the sponsors, the USACE initiated a general reevaluation study in 1999 with the Harris County Flood Control District and, Galveston County, acting as sponsors.

PURPOSE AND AUTHORITY

The purpose of this study is to develop and evaluate alternatives for flood risk management and ecosystem restoration in the Clear Creek watershed. Authority for the flood risk management portion of the Clear Creek Flood Control Project is contained in Section 203 of the Flood Control Act approved August 13, 1968 (Public Law 90-483). As detailed in this report, it was the team's intent to develop ecosystem restoration opportunities; however, no additional cost share sponsors were identified and no new authority was given so ecosystem restoration was dropped from consideration during the General Reevaluation Report.

The pertinent part of the Act is as follows:

> *The project for flood protection on Clear Creek, Texas, is hereby authorized substantially in accordance with the recommendations of the Chief of Engineers in House Document Number 351, ninetieth Congress, at an estimated cost of $12,600,000.*

Another authority affecting the analysis included in this report is Section 575 of the Water Resources Development Act (WRDA) of 1996. This authority was developed for Harris County to ensure that local actions that were taken during a study process would not negatively affect study outcomes. Section 575 does not specifically mention Clear Creek, but subsequent language was included in WRDA 1999 that included it. The wording of Section 575, as revised in 1999, is as follows:

Section 575. Harris County, Texas

(a) IN GENERAL.—During any evaluation of economic benefits and costs for projects set forth in subsection (b) that occurs after the date of the enactment of this Act, the Secretary shall not consider flood control works constructed or nonstructural actions by non-Federal interests within the drainage area of such projects prior to the date of such evaluation in the determination of conditions existing prior to construction of the project or nonstructural actions.

(b) SPECIFIC PROJECT — The projects to which subsection (a) apply are—

(1) the project for flood control, Buffalo Bayou Basin, Texas, authorized by section 203 of the Flood Control Act of 1954 (68 Stat. 1258);

(2) the project for flood control, Buffalo Bayou and tributaries, Texas, authorized by section 101(a) of the Water Resources Development Act of 1990 (104 Stat. 4610);

(3) the project for flood control, Cypress Creek, Texas, authorized by section 3(a)(13) of the Water Resources Development Act of 1988 (102 Stat. 4014); and

(4) the project for flood control, Clear Creek, Texas, authorized by section 203 of the Flood Control Act of 1968 (82 Stat. 742).

WITHOUT-PROJECT CONDITION/NO ACTION

The USACE planning guidance requires analysis of a without-project plan as one of the alternatives. Also, to comply with the requirements of the National Environmental Policy Act of 1969, a "no action" plan must be included in the alternative array. The "without-project" plan for this project is synonymous with the No Action Plan. The "without-project" plan also forms the basis against which all other alternative plans are measured.

The Without-Project Condition would retain the existing Clear Creek at its current configuration. Many of the municipalities in the area have incorporated no impact policies in addressing new development. These are generally established to protect the flow at a 100-year level of protection. However, these requirements are not in place for the entire watershed. Development upstream of Clear Lake will continue to increase flows into Clear Creek. These increased flows will continue to cause increases in water elevation sufficient to cause flooding in many areas.

The period of analysis begins in the year 2020, the first year in which a project would become operational. Therefore, the base year is defined as 2020. The period of analysis extends 50 years in the future to the year 2070, in accordance with Engineering Regulation (ER) 1105-2-100,

Appendix D-6(a) (2), dated April 22, 2000. The most probable future condition reflects changes in hydrologic conditions from anticipated development within the watershed tempered by runoff restrictions imposed by local authorities over the period of analysis, 2020 to 2070. This assumption is consistent with current guidance.

SCREENING PROCESS - NED

In 2001, the project team began collecting information on potential measures to reduce flood damages on the main stem of Clear Creek. This was done through public scoping meetings and meetings with resource agencies. The previously authorized project included channelization of a large segment of Clear Creek. This was deemed unacceptable by the public and sponsors because large portions of the creek remain in a natural state or were modified so long ago that they have returned to high quality habitat. Because of this, the team developed a different strategy for evaluation of a newly proposed flood risk management project. This is apparent in the team's newly developed objectives. The creek was divided into 19 different economic reaches delineated by easily identifiable landmarks (Figure 2-ES). This was done in order to identify the areas with highest damages in an attempt to provide flood risk management in areas where it is most needed.

Property surveyed within the most likely future median 0.2 percent (500-year) AEP floodplain of the Clear Creek main stem was allocated to the nearest stream cross-section between river cross-section 0+00 and 236609+00. These cross-sections were aggregated into 19 economic reaches in order to facilitate analysis. The following Table 1-ES shows the aggregations of cross-sections into economic reaches with geographic or other physical descriptors. The backwater effects of the main stem on the tributaries in the study area were incorporated into the main stem analysis. Properties that lie on the tributaries but whose hydrology was controlled by that of the main stem were assigned to the main stem.

Without-project documentation shows that areas of highest damages include reaches 15 through 18 (City of Pearland) and reaches 7 through 10 (City of Friendswood). From the public and agency input a list of 72 structural and non-structural flood risk management measures specific to a single reach or limited number of adjacent reaches was developed. The team then performed an analysis of these measures and formulated a list of 24 measures (Table 2-ES) that would meet the four planning criteria of completeness, efficiency, effectiveness, and acceptability. These 24 measures are called "First Added Measures".

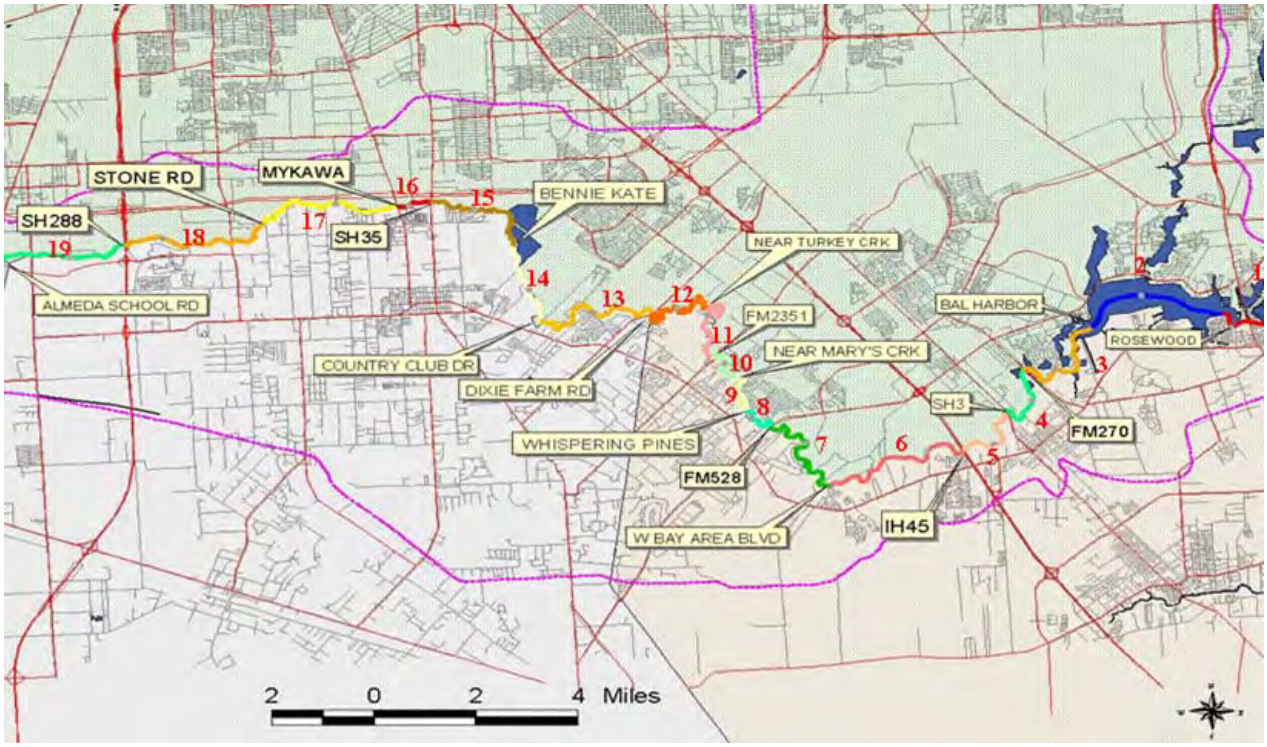


Figure 2-ES
Economic Reaches of Main Stem Clear Creek

Table 1-ES
Economic Reach Delineations for Clear Creek Main Stem

Reach	Lower XSec	Lower Limit Near	Upper XSec	Upper Limit Near
1	0	GALVESTON BAY	7020	ROSEWOOD
2	7020	ROSEWOOD	23263	BAL HARBOR
3	23263	BAL HARBOR	37212	FARM-TO-MARKET ROAD (FM)270
4	37212	FM270	46388	STATE HIGHWAY (SH)3
5	46388	SH3	55615	INTERSTATE HIGHWAY (IH)45
6	55615	IH45	73893	W BAY AREA BLVD
7	73893	W BAY AREA BLVD	90072	FM528
8	90072	FM528	95406	WHISPERING PINES
9	95406	WHISPERING PINES	103330	NEAR MARYS CRK
10	103330	NEAR MARYS CRK	112394	FM2351
11	112394	FM2351	125782	NEAR TURKEY CRK
12	125782	NEAR TURKEY CRK	143346	DIXIE FARM RD
13	143346	DIXIE FARM RD	160053	COUNTRY CLUB DR
14	160053	COUNTRY CLUB DR	170703	BENNIE KATE
15	170703	BENNIE KATE	185548	SH35
16	185548	SH35	189373	MYKAWA
17	189373	MYKAWA	205888	STONE RD
18	205888	STONE RD	223445	SH288
19	223445	SH288	236609	ALMEDA SCHOOL RD

note: All properties north of the main stem lie in Harris County; Properties in Reaches 1-12 south of the main stem lie in Galveston County; properties in Reaches 13-19 south of the main stem lie in Brazoria County

Table 2-ES
Measures Included in First Added Analysis

Proposed Measure	**Acronym**
Interstate 45 Bridge Widening	I-45
Expand Existing Detention at Site A521	A521
Additional Clear Lake Outlet Capacity	ACLO
Offline Detention just West of SH 288	B1
Offline Detention just West of Country Club Road	B2
Conveyance Improvement of Main Stem from Stone Road to Bennie Kate Road	C1
Expand Existing Detention at David L Smith Site	DLS1
High Flow Bypass Downstream of Dixie Farm Road	HFB1
Detention on Marys Creek	MC1
Detention on Mud Gully	MG1
Remove Dredged Material/Deepen for Conveyance	RDM1
Detention on Turkey Creek	TC1
Cowart Creek Detention	CWT1
Conveyance Improvement of Main Stem from SH 288 to Stone Road	C2
Linear Detention on Main Stem from Stone Road to Mykawa Road	LD1
Enlarge High Flow By Passes on Main Stem	EHFB
Large Scale Linear Detention on Marys Creek	LD2
Selective Clearing and Snag Removal	CS
Large Scale Linear Detention on Cowart Creek	LD3
Detention on Chiggers Creek	CHG1
Global Watershed Management Practices	GWMP
Conveyance Improvement on Main Stem from Downstream of Country Club Road to FM 528	C3
Conveyance Improvement on Main Stem from Downstream of FM 2351 to West Bay Area Boulevard	C4
Buyouts along Clear Creek	GBO
Legacy Plan	
Sponsor Proposed Alternative	SPA
Authorized Federal Project	AFP

Three sizes of each of these measures were then carried forward into detailed hydraulic, economic, and environmental analyses. Each measure was evaluated on a standalone basis for its potential impact to the entire watershed and its capability for reduction of flood damages. Detailed descriptions of each measure as well as determinations of costs, net excess benefits, and benefit-to-cost ratios for each of these measures can be found in the First Added Notebook (Appendix F).

As a result of these analyses, potential measures were identified for further consideration on a second added basis. The team concentrated on the most successful First Added Measures (Figure 3-ES) and began a series of modifications and combinations that would lead to the National Economic Development (NED) Plan. The decision was made to begin with upstream measures that would reduce damages in the hardest hit reaches, then begin combining successful downstream measures in a systems approach until a final plan was developed.

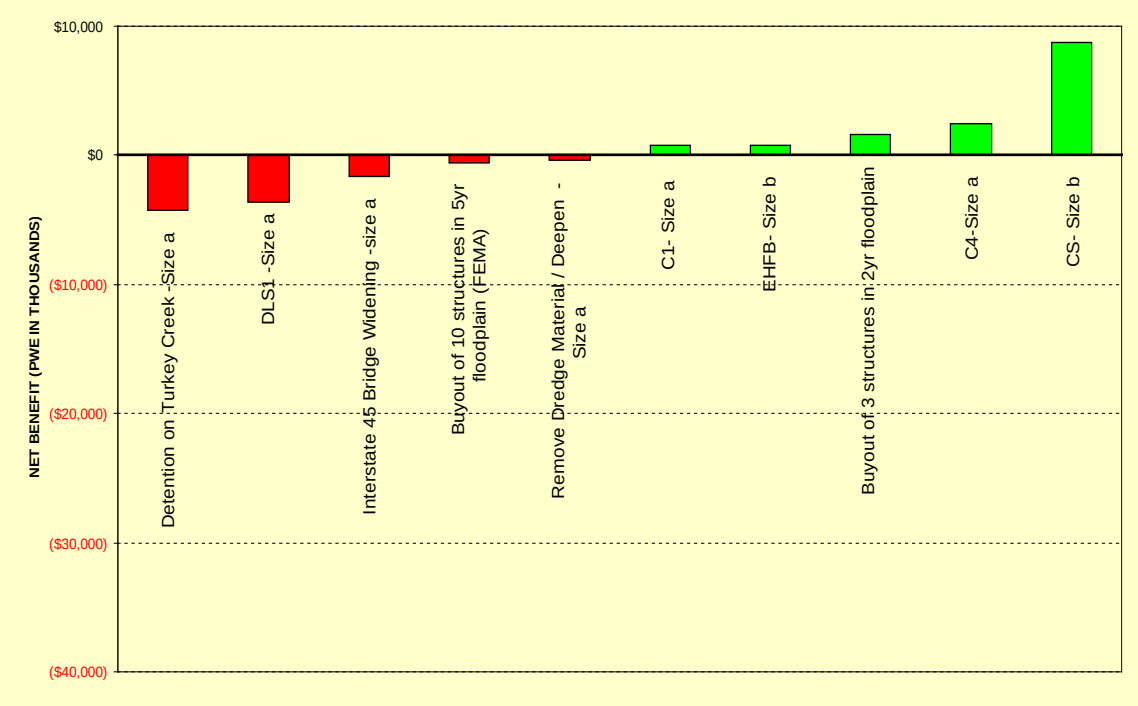


Figure 3-ES
Graphic Representation of Net Excess Benefits
for the 10 Best First Added Measures

Based on these considerations Measure C1, the conveyance improvement of the main stem from Stone Road to Bennie Kate Road was combined with C2, the conveyance improvement from State Highway 288 to Stone Road, and identified as an anchor component. This modified measure was renamed as Super C. Three sizes of Super C were originally modeled; however, none of these measures broke the curve in generating maximum net excess benefits. Two more sizes were modeled and size Super C(d) was identified as a measure that generates positive net excess benefits. This is an approximately 10 mile conveyance measure which includes a 200-foot bottom width bench cut from State Highway (SH) 288 to Bennie Kate Road. The measure is designed to prevent/restore habitat associated with a low flow channel (Figure 4-ES). This measure would successfully reduce flood damages in the Pearland area, most notably in a 50 percent (2-year) and 20 percent (5-year) AEP events.

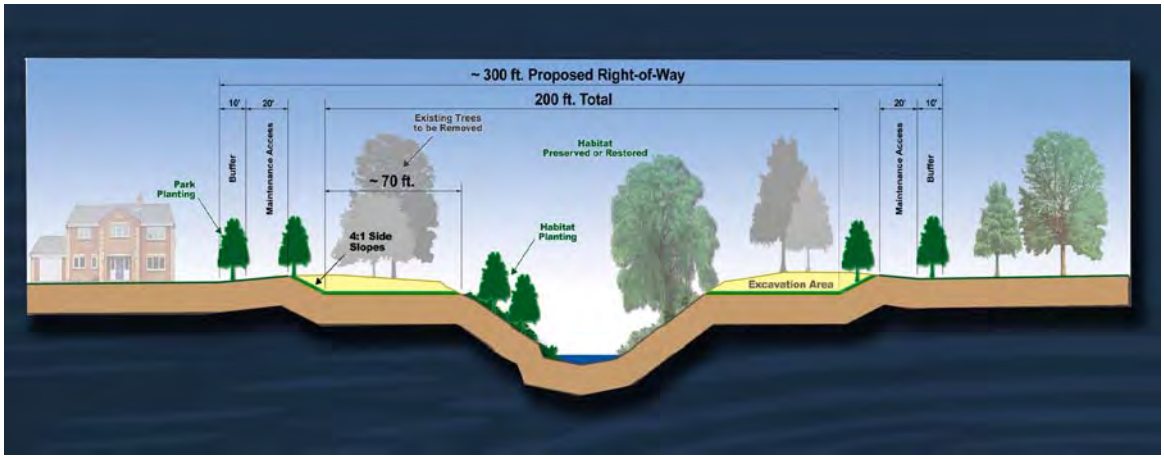


Figure 4-ES
Cross Section of Measure Identified as Super C

Based on its success, Super C(d) was added to the model and subsequent measures downstream were modeled for additional flood risk management. This next round of model runs led to the modification of a previously modeled measure, the removal of dredged material and deepening for conveyance, and the identification of C5, a conveyance measure extending from the downstream end of the Super C measure. These combined measures were successful at one size in increasing net excess benefits. This lead to the inclusion of C5(d) as an NED component. This measure is a 90-foot bottom width bench cut on the main stem of Clear Creek that extends from Bennie Kate Road (the downstream extent of Super C(d)) to Dixie Farm Road (Figure 5-ES).

During the evaluation of alternatives, additional information was collected in the watershed, including flood damage information on the tributaries and the potential to reduce these damages became clear. The team identified additional conveyance measures for the tributaries and modeled these as well. Components that were successful became part of the NED Plan and include conveyance on Mud Gulley, Turkey Creek, and Marys Creek. All three are trapezoidal channels by design. Mud Gulley conveyance (MUC(1)(b)) is the only measure that requires concrete lined conveyance. It is 4,300 feet in length with a bottom width of 45 feet. It extends from downstream of Sagedowne Road to downstream of Astoria Road. Proposed Turkey Creek conveyance (TKC(1)(d)) measures 2,400 feet in length and varies from 20 to 25-foot bottom widths. Proposed Marys Creek conveyance (MAC(2)(a)) measures 11,200 feet in length with bottom widths of 15, 27, and 35 feet.

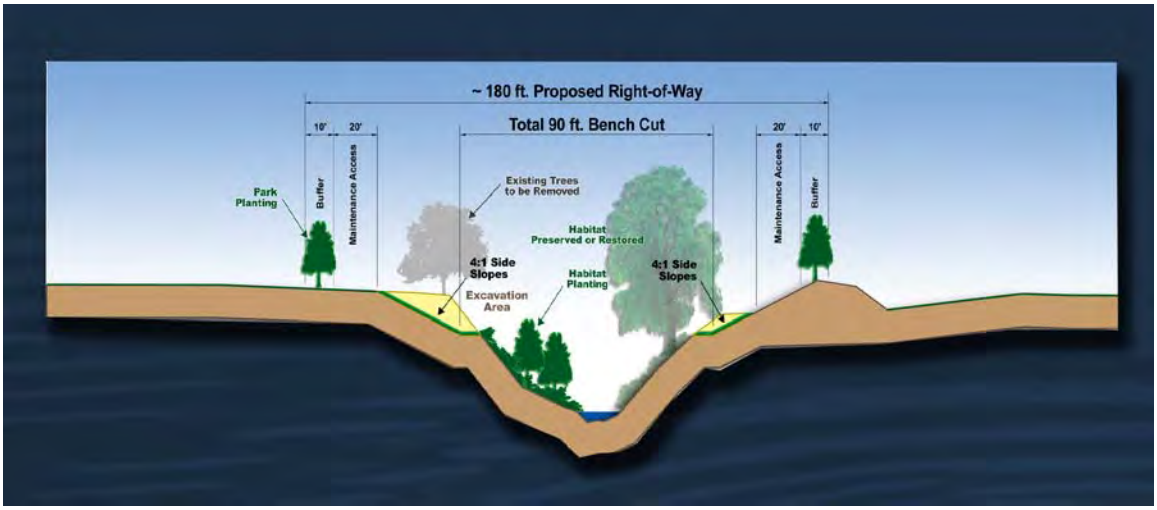


Figure 5-ES
Cross Section of Measure C5(d)

Further evaluation of additional downstream measures was performed, but no other features that were moderately successful in the first added analysis were identified that generated positive net excess benefits. These features combined to form the NED Plan (Table 3-ES). Detention was not considered on a second added basis due to its poor performance in the first added analysis.

Table 3-ES
Initial NED Flood Risk Management Components

Measure	Length Ft	Length Miles	Width Ft	Description
Main Stem				
SuperCd	53,000	10.0	200-ft bench cut	SH288 to 4,000 ft downstream of Bennie Kate Road
C5d	27,100	5.1	90-ft bench cut	Bennie Kate Road to Dixie Farm Road
Tributaries				
MUC1b	4,300	0.8	Bottom Width (BW) =45'	Downstream of Sagedowne to downstream of Astoria
TKC1d	12,400	2.4	BW = 20'&25'	Dixie Farm Road to Mouth
MAC2a	11,200	2.1	BW = 15', 27', & 35'	Harkey Road to SH35

This preliminary NED plan was submitted to the sponsors for consideration. One factor raised concerns with the plan was that, while generating significant benefits in high damage reaches, the combined measures also induced damages in portions of the study area. The sponsors were unwilling to support a project that induced damages and they requested modeling of detention components for inclusion in a locally preferred plan. Several detention features at several sizes were identified both on the mainstem of Clear Creek and on the tributaries. Modeling of these features determined that detention, while not successful on a standalone basis, can be successful

in increasing net excess benefits as part of an overall system. With the new modeling results, the NED Plan was modified to include one detention component.

The detention feature is referred to as inline detention. In certain reaches of the Super C conveyance measure the high flow measure leaves the footprint of the existing low flow channel. This allows for additional excavation in those reaches with minimal environmental impact (Figure 6-ES). This measure will generate 500 acre-feet of capacity.

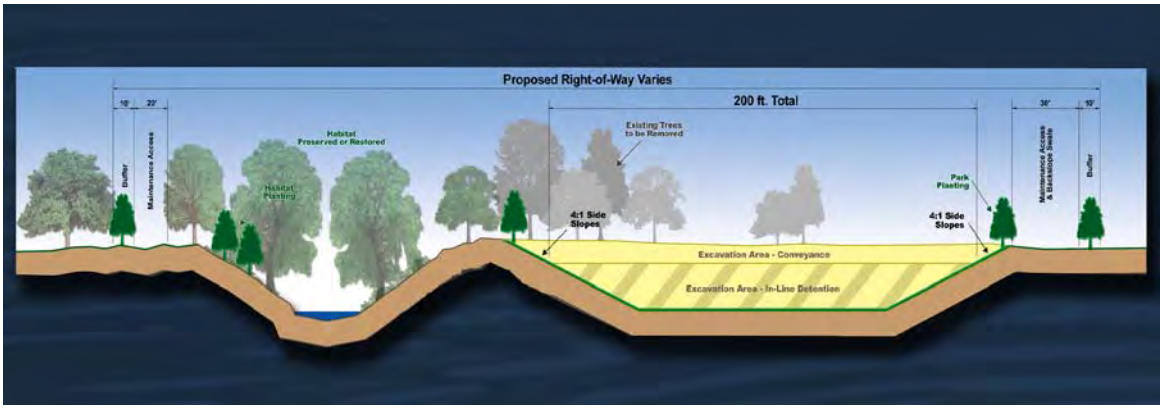


Figure 6-ES
Cross Section of In-Line Detention Measure

RECOMMENDED PLAN/MODIFIED AUTHORIZED PLAN

The Recommended Plan for Clear Creek, Texas is the NED Plan. Table 4-ES summarizes the benefits and costs for the Recommended Plan at the current discount rate of 4.0 percent. Detailed calculations for interest during construction and operations and maintenance costs are shown in the Economic Appendix.

The intent of the GRR was to re-evaluate the unconstructed portion of the authorized Clear Creek Project, and to recommend a plan which, when combined with the constructed components, would result in a Modified Authorized Project. The total cost of the Modified Authorized Project would include the cost of the newly formulated portion added to all previous actual construction costs. This includes the actual costs of the second outlet and gated structure, associated lands, easements, rights of way, relocations, and disposal areas, and finally all costs for conducting the GRR. The Modified Authorized Project will serve as a basis for modifying the existing Local Cooperation Agreement between the Corps and the non-Federal sponsors.

Project cost share requirements using the project total first costs are detailed in Table 5-ES. The sponsor is required to provide all lands, easements, rights-of-way, relocations, and disposal

areas. In addition, the sponsor must provide a cash contribution equaling 5 percent of the total project cost.

The Fully Funded Cost Allocation for the Modified Authorized Project is detailed in Table 6-ES. The non-Federal cash calculations use the total cost for the Modified Authorized Project to account for the additional cash contribution needed to reach the 5 percent required cash from the non-Federal sponsor. Additionally, the non-Federal sponsor's cost share (LERRD and cash) for this total project cost, including the previously constructed portions, is required to be at least 25 percent of the total costs. Table 33 shows that the non-Federal cost (non-Federal LERRD and non-Federal cash) will be $101,377,000 or almost 39 percent of the $262,433,000 total.

Table 4-ES
Equivalent Annual Benefits and Costs
Clear Creek, Texas
For Recommended Plan
(October 2011 Price Levels, 50-year Period of Analysis, 4 Percent Discount Rate, dollar values in thousands)

	Costs
Investment Costs	
Total Project Construction Costs	$189,135,000
Interest During Construction	$5,929,000
Total Investment Costs	$194,064,000
Average Annual Costs	
Interest and Amortization of Initial Investment	$9,080,300
OMRR&R	$1,060,700
Total Average Annual Costs	$10,141,000
Average Annual Benefits	$23,110,000
Net Annual Benefits	$12,969,000
Benefit-Cost Ratio	2.3

Table 5-ES
Total First Costs
Cost Sharing
For Modified Authorized Project
Clear Creek, Texas
(October 2011 Price Levels)

	Item	Federal Cost ($)	Non-Federal Cash ** ($)	Non-Federal LERRD ($)	Total Cost ($)
Flood Risk Management (FRM)*					
01	Lands & Damages - Non-Federal (100%)	0	0	51,147,000	51,147,000
01	Lands & Damages (Federal Review)	306,000	24,000		330,000
02	Relocations - Non-Federal (100%)	0	0	32,404,000	32,404,000
02	Relocations - GH&H Rail Road Bridge	2,010,000	0		2,010,000
02	Relocations -BN&SF Rail Road Bridge	1,958,000	0		1,958,000
02	Relocations (Federal Review)	134,000	11,000		145,000
06	Fish & Wildlife Services	15,540,000	1,305,000		16,845,000
09	Channels & Canals	80,512,000	6,739,000		87,251,000
18	Cultural Resources	1,949,000	163,000		2,112,000
30	Engineering & Design	23,700,000	1,959,000		25,659,000
30	Engineering and Design (GRR)	15,394,000	1,231,000		16,625,000
31	Construction Management	6,586,000	551,000		7,137,000
Total Modified Authorized Project Costs		148,089,000	11,983,000	83,551,000	243,623,000

* FRM Cost Shared 75/25 based on 1986 Authorization

** Non-Federal cash is based on minimum 5% of TPCS (excluding the RR Bridges)

Table 6-ES
Cost Sharing
Fully Funded Project Cost
For Modified Authorized Project
Clear Creek, Texas
(October 2011 Price Levels)

	Item	Federal Cost ($)	Non-Federal Cash ** ($)	Non-Federal LERRD ($)	Total Cost ($)
Flood Risk Management (FRM)*					
01	Lands & Damages - Non-Federal (100%)	0	0	54,290,000	54,290,000
01	Lands & Damages (Federal Review)	305,000	25,000		330,000
02	Relocations - Non-Federal (100%)	0	0	34,176,000	34,176,000
02	Relocations - GH&H Rail Road Bridge	2,010,000	0		2,010,000
02	Relocations -BN&SF Rail Road Bridge	2,205,000	0		2,205,000
02	Relocations (Federal Review)	134,000	11,000		145,000
06	Fish & Wildlife Services	16,847,000	1,397,000		18,244,000
09	Channels & Canals	87,817,000	7,260,000		95,077,000
18	Cultural Resources	2,062,000	170,000		2,232,000
30	Engineering & Design	26,406,000	2,165,000		28,571,000
30	Engineering and Design (GRR)	15,394,000	1,231,000		16,625,000
31	Construction Management	7,876,000	652,000		8,528,000
Total Modified Authorized Project Costs		161,056,000	12,911,000	88,466,000	262,433,000

* FRM Cost Shared 75/25 based on 1986 Authorization

** Non-Federal cash is based on minimum 5% of TPCS (excluding the RR Bridges)

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Table of Contents

VOLUME 1 – MAIN REPORT

List of Tables

List of Figures

List of Appendices

CLEAR CREEK, TEXAS
FLOOD RISK MANAGEMENT
GENERAL REEVALUATION REPORT

I. INTRODUCTION

Clear Creek drains an area south of and partially within the City of Houston. The Clear Creek watershed is located in four counties, includes 16 cities and covers approximately 260 square miles of land (Figure 1). The watershed is composed of relatively flat coastal plain with elevations varying from near sea level at Clear Lake on the eastern edge of the watershed to about 75 feet mean sea level (MSL) on the western watershed boundary (Figure 2). Clear Creek receives flow from 17 principal tributaries. The Clear Creek watershed 1 percent (100-year) annual exceedance probability (AEP) floodplain contains an area of approximately 19,000 acres. Many communities and subdivisions along the creek are subject to flooding and recent floods (1973, 1976, twice in 1979, 1989, October 1994, June 2001, October 2006, and April 2009) have caused extensive property damage. The flood in July 1979 caused more than $90 million (1979 price level) in damages in the Clear Creek watershed. Additionally, minor flood events in June 2006 and August 2007 also caused damage within the watershed.

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The restudy was initiated in the early 1970s, and in 1982, a Preconstruction Authorization Planning Report was completed recommending a modified project. The modification consisted of a change from the previous 1 percent (100-year) AEP flood event level of protection in the

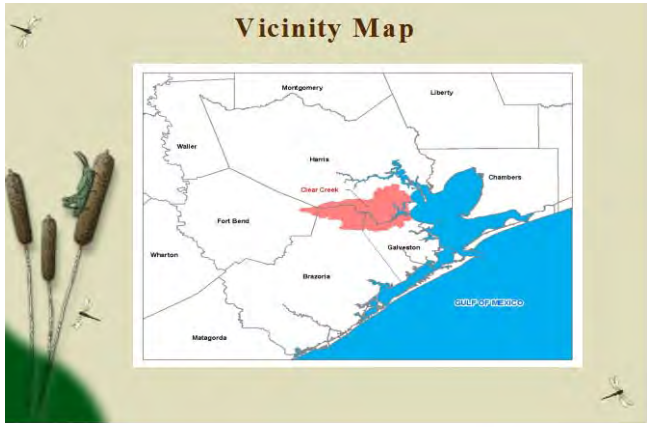

Figure 1
Clear Creek Watershed
With City and County Boundaries

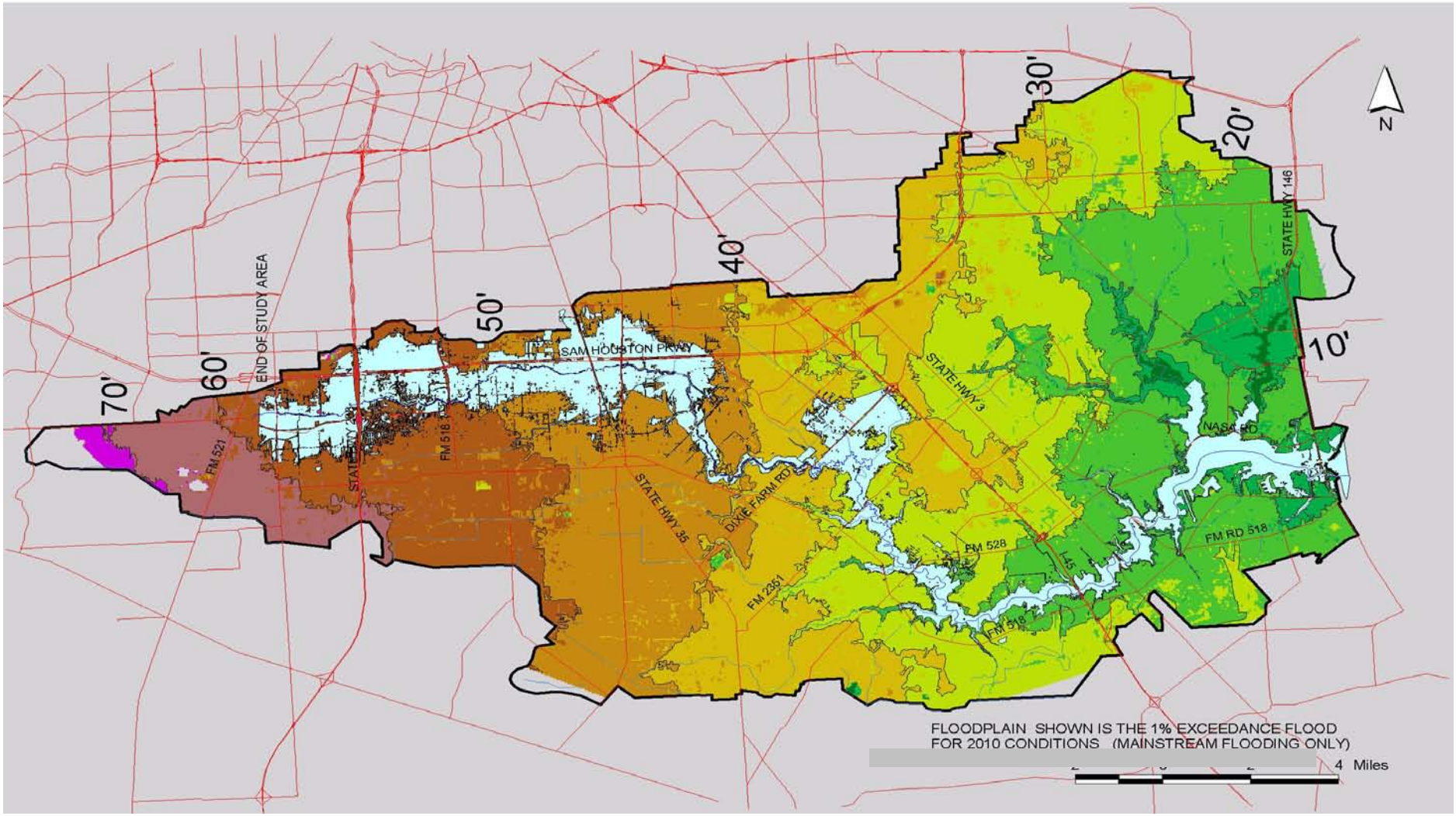

Figure 2. Clear Creek Watershed, 1% Floodplain (light blue) and Associated Land Surface Elevations

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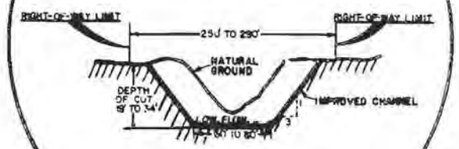
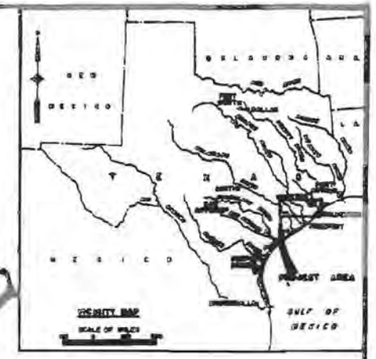
TYPICAL CROSS SECTION
MILE 19.9 TO MILE 29.2



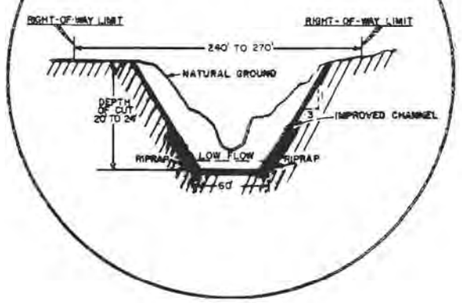
MILE 34.8
UPPER LIMIT
OF AUTHORIZED
PLAN OF
IMPROVEMENT

HARRIS CO.
FORT BEND CO.
CLEAR CREEK
HARRIS CO.
BROOKSIDE VILLAGE
BRAZORIA CO.
HARRIS CO.
PEARLAND
MARYS CREEK
FRIENDSWOOD
COWART CREEK
BRAZORIA CO.
GALVESTON CO.
CHIGGER CREEK
HARRIS CO.
WEBSTER
LEAGUE CITY
GALVESTON CO.
FORT BEND CO.
BRAZORIA CO.
DEER PARK
PASADENA
MORGANS POINT
LA PORTE
GALVESTON BAY
SEABROOK
CLEAR LAKE
KEMAH
ELLINGTON AIR FORCE BASE
HORSEPEN BAYOU
CLEAR LAKE CITY
LYNDON B. JOHNSON SPACE CENTER (NASA)
WILLOW BAYOU
BIG ISLAND SLOUGH
ARMAND BAYOU
BAYPORT CHANNEL
7' x 75' NAVIGATION CHANNEL

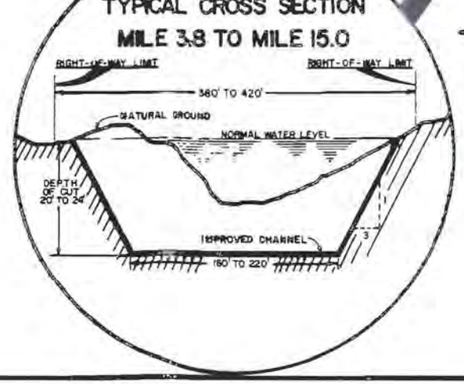


MILE 3.8
LOWER LIMIT
OF AUTHORIZED
PLAN OF
IMPROVEMENT

TYPICAL CROSS SECTION
MILE 15.0 TO MILE 19.9



TYPICAL CROSS SECTION
MILE 3.8 TO MILE 15.0



LEGEND

- WATERSHED DIVIDE
- ROAD OR RAILROAD BRIDGE
- STREAM MILEAGE (IMPROVED CONDITION)
- FLOOD CONTROL CHANNEL ALLIGNMENT
- LIMIT OF FLOODING FROM 100-YEAR FLOOD (IMPROVED CONDITIONS)

CLEAR CREEK, TEXAS
FLOOD CONTROL
AUTHORIZED PLAN
SCALE OF MILES
U.S. ARMY ENGINEER DISTRICT, GALVESTON, TEXAS

FIGURE 3

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1968 authorization to a 10 percent (10-year) AEP flood event level. The new plan consisted of channel enlargement and easing of bends within the existing stream from stream mile 3.8 to 26.05 (Mykawa Road), to contain within banks the floodwater flows for a 10 percent (10-year) AEP storm. No buyout of structures in the residual 1 percent (100-year) AEP floodplain was included. Nonstructural measures, such as local regulations restricting future development in the residual 1 percent floodplain, were required. Bottom widths of the channel varied from 130 feet near Clear Lake to 50 feet at Mykawa Road. It was determined that this plan is within the scope of the 1968 authorization, with no further Congressional authorization required to implement the project. This plan is shown on Figures 4, 5, and 6.

The modified plan would have required excavation of approximately 11.9 million cubic yards of material. Disposal of material would require approximately 594 acres of temporary easement and acquisitions. Approximately 569 acres of rights-of-way would have been required for construction.

A Local Cooperation Agreement (LCA) was signed in 1986 by Harris County Flood Control District (HCFCD), Galveston County and the U.S. Army Corps of Engineers (USACE). The Non-Federal Sponsors had begun acquisition of lands, easements, rights-of-way, relocations, and disposal areas (LERRD) up to the State Highway (SH) 3 bridge as well as bridge replacements, pipeline adjustments, and rights-of-way acquisition. Construction of the authorized plan was initiated in the 1990s with the modification of two railroad bridges and construction of the Second Outlet and Gate Structure (Figure 6 and 7). This channel outlet and gate structure is 6,000 feet long, 70 feet wide, and 16 feet deep. The additional outlet between Clear Lake and Galveston Bay was constructed to ensure that the channelized creek would not induce flood damages on the lake community by keeping water levels in the lake from increasing when the proposed upstream enlargement occurred. The gated structure was constructed to minimize changes to existing environmental and hydraulic conditions, which include salinity and sediment transport and the rate of tidal inflows. In 1998, operations of the Second Outlet and Gate Structure were transferred to HCFCD, which operates the gates in an effort to reduce flood levels produced from rainfall runoff. The Flood Control District staff monitors the conditions in the watershed using rainfall and stage gages, along with information from other sources. Using set operation criteria, the gates will be opened to prevent certain lake level increases. The lake level estimates are based on actual and predicted rainfall, actual water levels in the lake and upstream, as well as tide forecasts.

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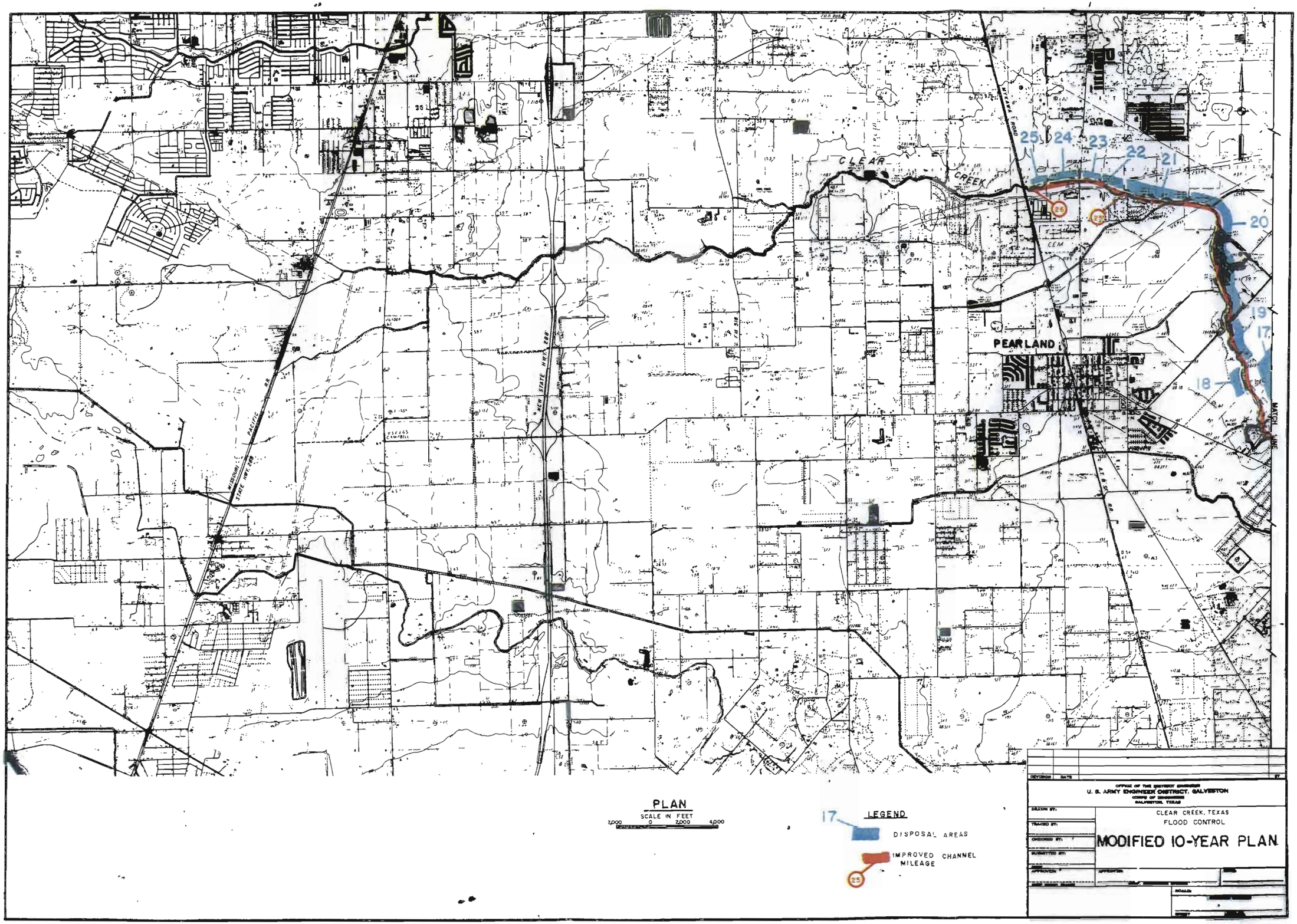
CLEAR CREEK
PEARLAND
MACEK LANE
NEW STATE HWY. 288
WILSON-CAMPBELL
STATE HWY. 288
25
24
23
22
21
20
19
17
18
PLAN
SCALE IN FEET
2,000 0 2,000 4,000
LEGEND
DISPOSAL AREAS
IMPROVED CHANNEL MILEAGE
U. S. ARMY ENGINEER DISTRICT, GALVESTON
CLEAR CREEK, TEXAS
FLOOD CONTROL
MODIFIED 10-YEAR PLAN

Figure 4

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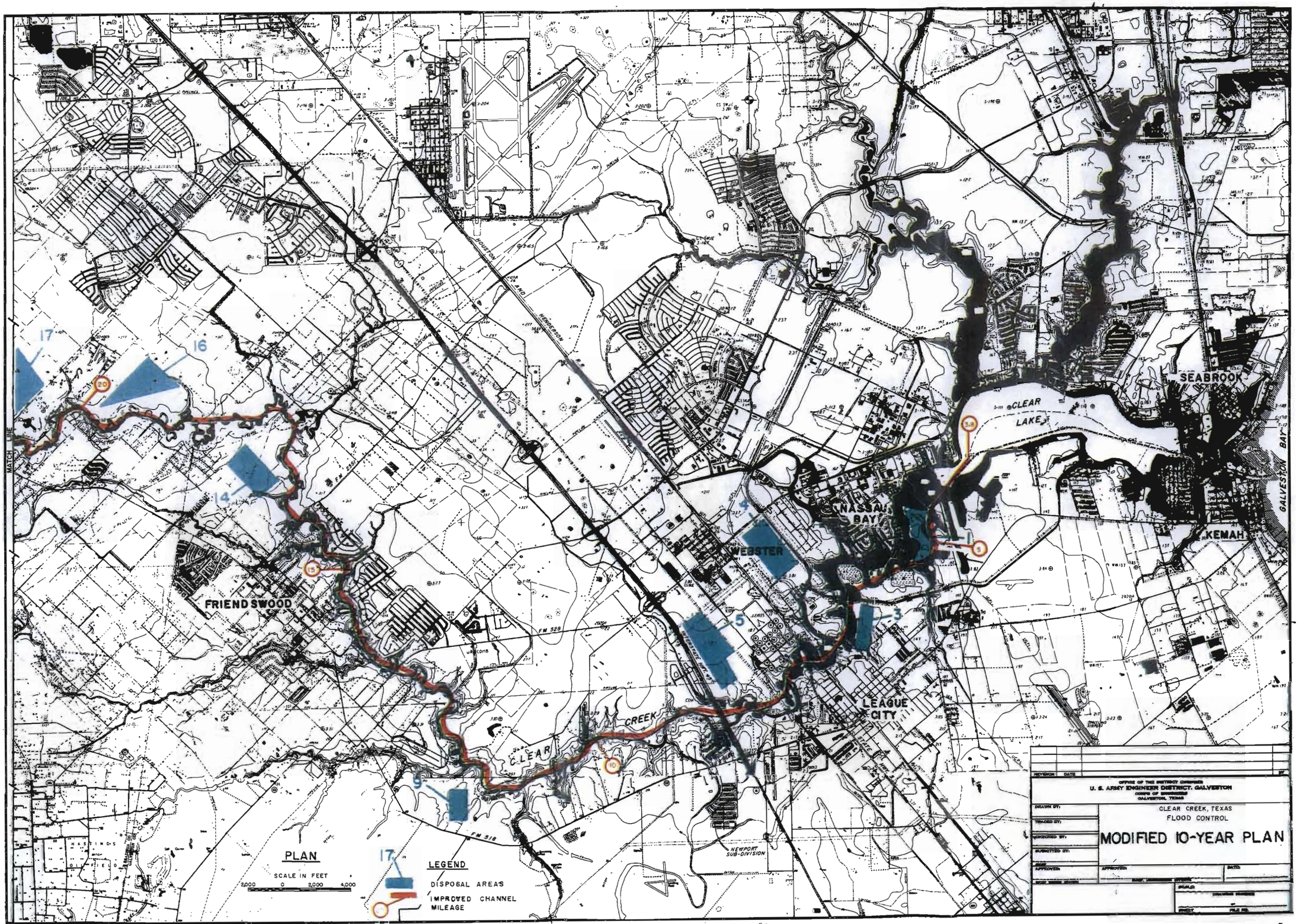
SEABROOK
CLEAR LAKE
NASSAU BAY
KEMAH
WEBSTER
LEAGUE CITY
FRIEND SWOOD
CLEAR CREEK
NEWPORT SUB-DIVISION
GALVESTON BAY
MATCH LINE
HOUSTON AND HENDERSON
FM 2351
FM 528
FM 518
PLAN
SCALE IN FEET
2,000 0 2,000 4,000
LEGEND
DISPOSAL AREAS
IMPROVED CHANNEL MILEAGE
OFFICE OF THE DISTRICT ENGINEER
U. S. ARMY ENGINEER DISTRICT, GALVESTON
CORPS OF ENGINEERS
GALVESTON, TEXAS
CLEAR CREEK, TEXAS
FLOOD CONTROL
MODIFIED 10-YEAR PLAN

Figure 5

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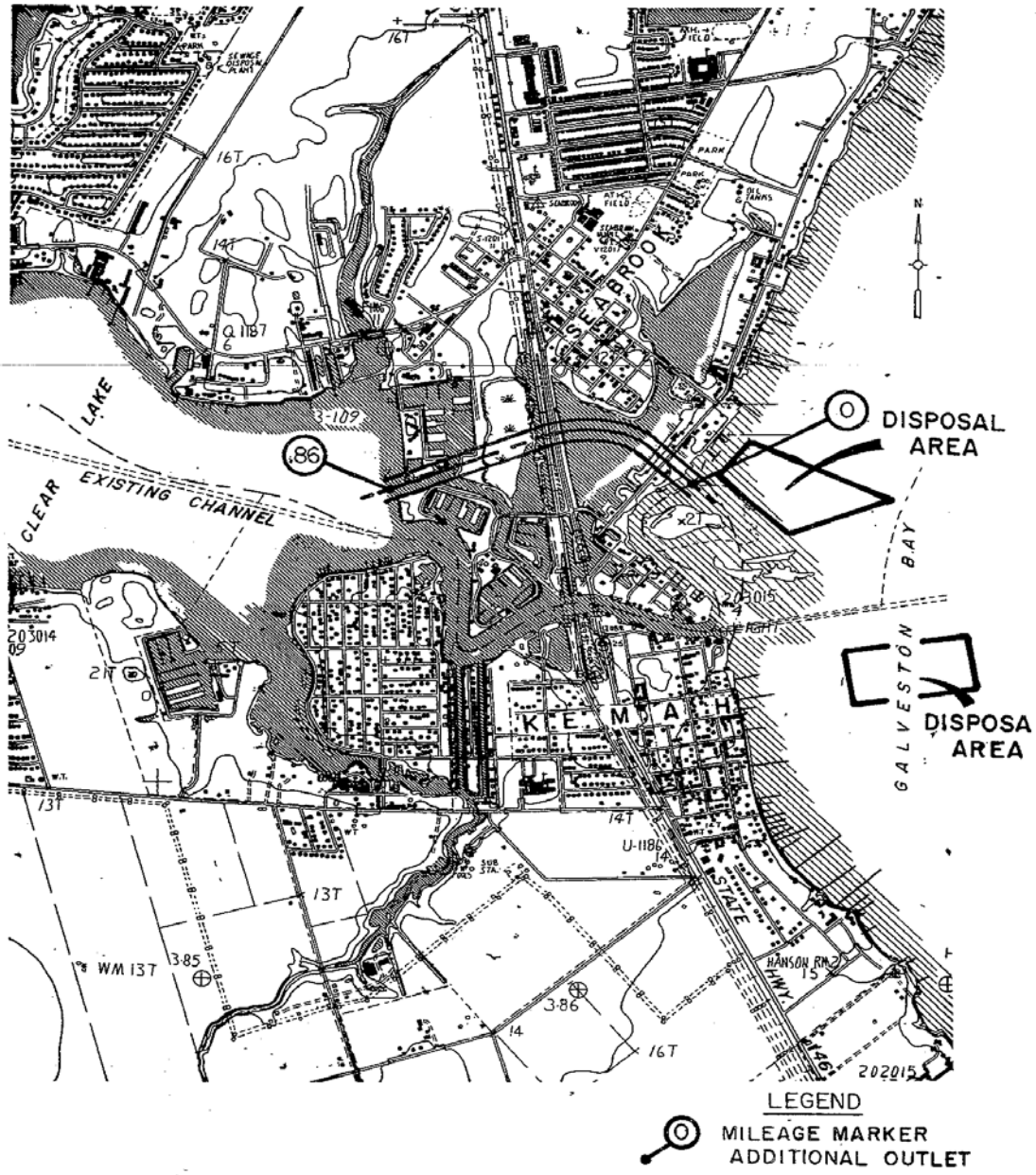


Figure 6
Second Outlet Channel Between
Clear Lake and Galveston Bay

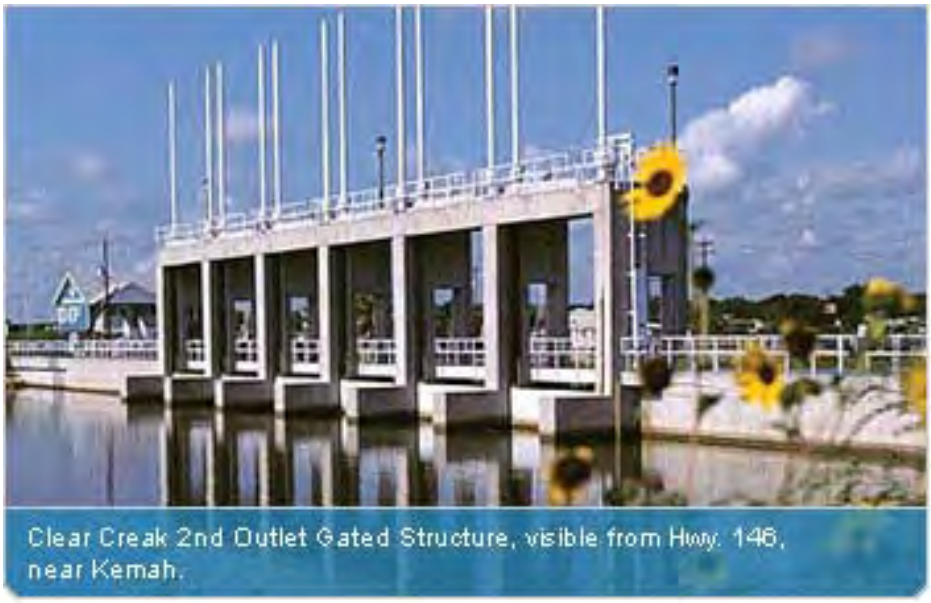


Figure 7 – Photo of Second Outlet and Gate Structure

Upon completion of the second outlet but before the initiation of construction on the channelized portion of the creek, issues were raised by concerned citizens about the amount of environmental and hydraulic impacts associated with the project. Based on the concerns raised, the sponsors asked that construction on the authorized channel be suspended for 6 months. HCFCD developed the Sponsor Proposed Alternative (SPA) for consideration, but the plan was considered substantially different from the authorized project by the USACE and could not be considered for construction under the existing authorization at that time. Because of the uncertainties associated with the authorized project, at the request of the sponsors, the USACE initiated a general reevaluation study in 1999 with the HCFCD, and Galveston County, acting as sponsors.

PURPOSE AND AUTHORITY

The purpose of this Clear Creek General Reevaluation Report (GRR) study is to develop and evaluate alternatives for flood risk management and ecosystem restoration in the Clear Creek watershed. Authority for the flood risk management portion of the Clear Creek Flood Control Project is contained in Section 203 of the Flood Control Act approved August 13, 1968 (Public Law 90-483). As detailed in this report, it was the team's intent to develop ecosystem restoration opportunities; however, no additional cost share sponsors were identified and no new authority was given so ecosystem restoration was dropped from consideration during the GRR.

The pertinent part of the Act is as follows:

> *The project for flood protection on Clear Creek, Texas, is hereby authorized substantially in accordance with the recommendations of the Chief of Engineers in House Document Number 351, ninetieth Congress, at an estimated cost of $12,600,000.*

Another authority affecting the analysis included in this report is Section 575 of the Water Resources Development Act (WRDA) of 1996. This authority was developed for Harris County to ensure that local actions that were taken during a study process would not negatively affect study outcomes. Section 575 does not specifically mention Clear Creek, but subsequent language was included in WRDA 1999 that included it. The wording of Section 575, as revised in 1999, is as follows:

> *Section 575. Harris County, Texas*
>
> *(a) IN GENERAL.—During any evaluation of economic benefits and costs for projects set forth in subsection (b) that occurs after the date of the enactment of this Act, the Secretary shall not consider flood control works constructed or nonstructural actions by non-Federal interests within the drainage area of such projects prior to the date of such evaluation in the determination of conditions existing prior to construction of the project or nonstructural actions.*
>
> *(b) SPECIFIC PROJECT — The projects to which subsection (a) apply are—*
>
> *(1) the project for flood control, Buffalo Bayou Basin, Texas, authorized by section 203 of the Flood Control Act of 1954 (68 Stat. 1258);*
>
> *(2) the project for flood control, Buffalo Bayou and tributaries, Texas, authorized by section 101(a) of the Water Resources Development Act of 1990 (104 Stat. 4610);*
>
> *(3) the project for flood control, Cypress Creek, Texas, authorized by section 3(a)(13) of the Water Resources Development Act of 1988 (102 Stat. 4014); and*
>
> *(4) the project for flood control, Clear Creek, Texas, authorized by section 203 of the Flood Control Act of 1968 (82 Stat. 742).*

PROJECT AREA DESCRIPTION

The Clear Creek watershed is located south of the City of Houston and includes parts of Harris, Galveston, Brazoria, and Fort Bend Counties (Figure 8). The Clear Creek watershed covers approximately 260 square miles and is partly inclusive of the City of Houston. There are an additional 16 cities that are at least partially within the watershed including Pasadena, Pearland, Friendswood, Webster, and League City. Clear Creek flows from west to east and drains into Clear Lake and then into western Galveston Bay through a natural channel as well as a man-made constricted channel (second outlet). Armand and Taylor Bayous are also two large tributaries that flow into Clear Lake from the north. Within this discussion, Clear Lake, Armand, and Taylor Bayous will be considered part of the Clear Creek watershed. For purposes of the study, no measures were identified for consideration on Armand or Taylor Bayous due to the small amount of flood damages on those two water bodies. A large portion of the Armand Bayou watershed is a protected nature area, which will undergo limited development in the future.

Figure 8. Clear Creek Watershed and Tributaries Subdivided by County

.

Clear Lake is the flooded lower extremity of the Clear Creek entrenched channel, now forming an estuarine lake tributary to Galveston Bay. The Lake area is between 1,500 and 2,000 acres depending on the tide. The average depth of Clear Lake is about 3.4 feet. Clear Lake is used extensively for boating, sailing, and skiing. The Clear Lake area contains one of the largest marina development areas in the United States.

The watershed is approximately 45 miles long and is relatively flat, typical of the Gulf Coast Plains. Elevations vary from less than 5 feet above MSL near Clear Lake to approximately 75 feet above MSL at the western end. The floodplain is much broader and fairly shallow in the upstream extents. It becomes narrow and deeper downstream towards Clear Lake (Figure 2). The only significant irregularities in the slope are the valleys cut by the creek and its tributaries. Because of the relatively flat terrain, the watershed divides are not well defined.

Flooding of residential and commercial developments situated near Clear Creek and its tributaries is the principal problem within the watershed. Prior to the mid-1980s, none of the municipalities in the Clear Creek watershed took part in the Federal Emergency Management Agency (FEMA) National Flood Insurance Program (NFIP) and structures were constructed in areas prone to flooding. In 1984, HCFCD implemented a new detention policy for proposed construction in an attempt to prevent continued increases in flooding as a result of rapid expansion and urbanization. These requirements are helping prevent increased flooding in certain situations; however, flood events that exceed capacities of existing facilities continue to cause increased flood damages in the study area.

Extensive pumping and withdrawals of ground water in the Houston metropolitan area have caused approximately three to four feet of subsidence in some areas of the watershed since 1943.

The subsidence is caused by the dehydration and compaction of the water-saturated clay beds separating the sand beds of the aquifers, resulting in a volume reduction, and consequent irreversible surface elevation declination. As subsidence continues, the areal extent of flooding from high tides and rainfall runoff will increase in the lower reaches of Clear Creek. However, upstream of Interstate Highway (IH)-45, the areal extent of flooding caused by rainfall is not expected to change appreciably as a result of subsidence. In May 1975, the Texas Legislature created the Harris-Galveston Coastal Subsidence District (H-GCSD) whose responsibility is to permit all water wells in the Harris-Galveston region in order to ascertain the demand upon the aquifer systems of the area. Since the implementation of the H-GCSD, the rate of subsidence in the area has substantially decreased.

NON-FEDERAL SPONSOR AND COORDINATION

The District Engineer, Galveston District, USACE, is responsible for the overall management of the study and report preparation. The HCFCD, Galveston County, and BDD #4 are the non-Federal Sponsors for the study. The study is being coordinated with interested Federal, State, and local agencies, and the public. The following are some of the agencies and groups that provided input during preparation of the report:

Federal Agencies

- U.S. Fish and Wildlife Service (USFWS)
- U.S. National Marine Fisheries Service (NMFS)
- U.S. Environmental Protection Agency (EPA)
- Natural Resources Conservation Service (NRCS)

State Agencies

- Texas Commission on Environmental Quality (TCEQ)
- Texas General Land Office (GLO)
- Texas Parks and Wildlife Department (TPWD)
- State Historic Preservation Officer (SHPO)
- Texas Department of Transportation (TxDOT)
- Texas Railroad Commission (TRC)

Regional, County, and Local Agencies

- Harris County Flood Control District (HCFCD)
- Galveston County
- Brazoria County Drainage District #4 (BDD #4)

Other Interests

- Clear Creek Steering Committee (CCSC)
- Clear Creek Citizens Advisory Committee (CAC)
- City of Friendswood
- City of Pearland
- Clear Lake Communities
- Numerous other cities in the watershed

An Interagency Coordination Team (ICT) made up of representatives from the non-Federal Sponsors, resource agencies, and the USACE was established to provide guidance on matters relating to the evaluation of environmental impacts of this project. Several technical workgroups composed of members of the ICT were established to focus on specific, environmentally related issues of the project.

STUDY AND REPORT PROCESS

The study process provided for a systematic preparation and evaluation of alternate plans, which address study area problems and opportunities. The process involved all of the six functional planning steps:

1) Specify Problems and Opportunities
2) Inventory and Forecast Conditions
3) Formulate Alternative Plans
4) Evaluate Effects of Alternative Plans
5) Compare Alternative Plans
6) Select Recommended Plan

The earlier authorizations emphasized problem identification and formulation of alternatives. This GRR is a full and new evaluation of existing and additional alternatives, assessment of impacts, and selection of a recommended plan for Clear Creek and its tributaries.

II. PROBLEMS AND OPPORTUNITIES

FLOOD RISK MANAGEMENT

Flooding along Clear Creek and its tributaries has historically been, and currently remains, a problem associated with severe rainfall events falling on a flat, slow-draining terrain. The watershed also exhibits numerous characteristics, both natural and man-made, that increase the risk of flooding during storm events. The watershed exhibits a broad, fairly shallow floodplain on the upstream end, which causes flood events to cover large topographic areas while being fairly shallow. As flood waters flow towards Clear Lake, the floodplain changes, becoming narrower due to greater slopes causing flood waters to be confined closer to the creek but deeper as compared to that seen in upstream flooding. Both of these factors facilitate slow drainage of storm waters during intense events. The watershed is also located south of Houston and encompasses several small cities that have exhibited steady growth. During the early study years for this project in the 1960s, these factors caused a steady increase of impermeable surface within the watershed and increased flows into the creek and its tributaries. Floodplain managers have instituted policies since then to prevent large increases in damages due to continuing construction; however, events that exceed the capacity of these measures continue causing damages to those structures built at lower elevations.

The problems in the watershed can be better described through the presentation of statistics associated with some of the storms, named and un-named, that have impacted the watershed. The first, Tropical Storm Claudette, formed on July 15, 1979, and, fluctuating between tropical depression and tropical storm status, the disorganized storm drifted slowly westward before making landfall along the Texas/Louisiana border on July 24th. Claudette produced torrential rains in both Texas and Louisiana when it made landfall (Figure 9). The highest one-day total was reported near Alvin, Texas, where approximately 45 inches of rain fell. This remains the twenty-four hour rainfall record for any location in the United States. Two other towns also reported rainfall totals exceeding 30 inches. There was one death from drowning. Many residents had to be rescued from low-lying areas that were flooded.

In October 1994, the Clear Creek watershed received 15 to 25 inches of rain over a four-day period primarily upstream of IH-45. From Dixie Farm Road upstream to SH 288, near record water levels were in the FEMA regulatory to 500-year flood level range and exceeded the 1979 flood levels. Downstream of Dixie Farm Road, water levels were in the FEMA 10-year to 50-year level range and were less than the 1979 flood levels. An estimated 3,400 houses and businesses in 90 subdivisions flooded in Harris County.

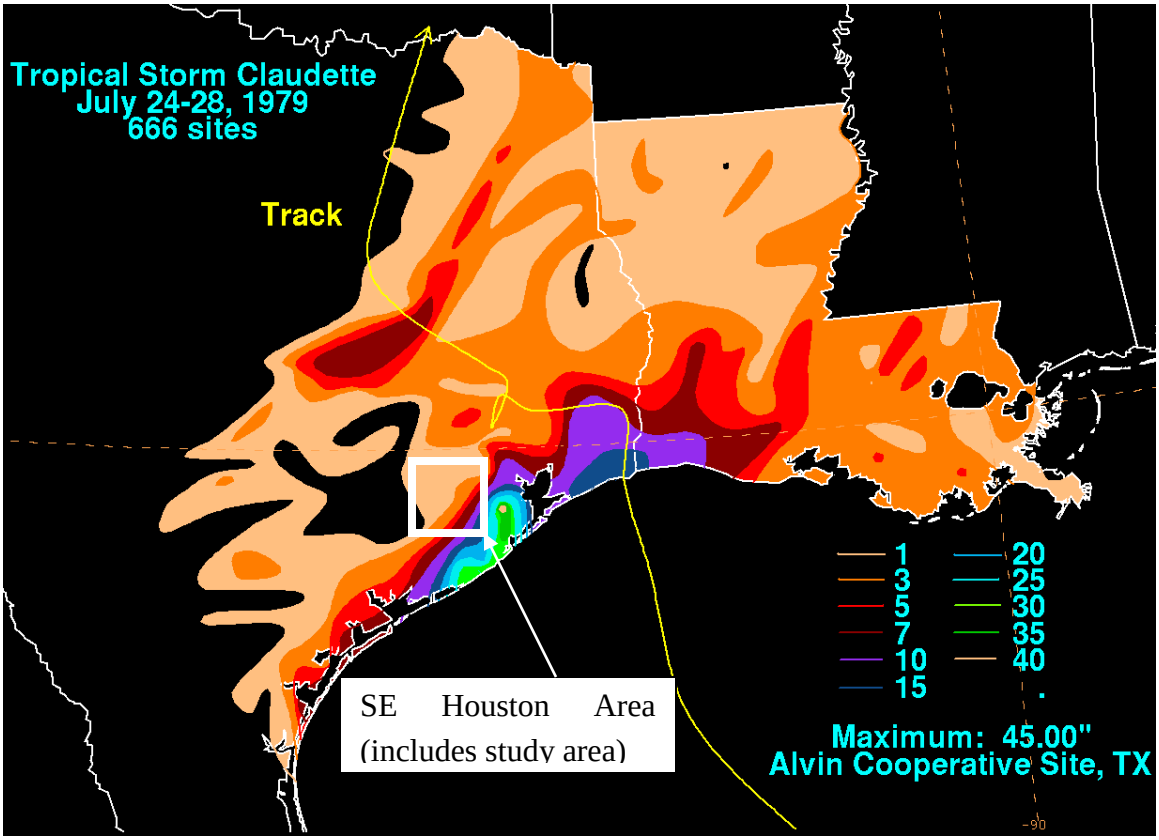


Figure 9. Rain Totals for Hurricane Claudette in 1979 (National Climatic Data Center, Asheville, North Carolina)

On the afternoon of June 5, 2001, Tropical Storm Allison formed just south of Galveston and slowly moved inland over Galveston and into Harris County. Intense rainfall began in the Clear Creek watershed as the tropical storm moved slowly northward and through the area. Intense rainfall rates averaging 2 to 3 inches per hour caused extensive street flooding and some local house flooding (Figure 10). The highest intensity recorded was 5.8 inches per hour.

In the afternoon of June 8, 2001, the remnant low from Tropical Storm Allison began drifting back southward. Significant rainfall began in northern Harris County and Montgomery County. Through midnight, very intense rainfall occurred and accumulations were significant enough to cause severe flooding in several watersheds. The remnant low continued to slowly drift south. All of Harris County except the far western and eastern ends received extreme amounts of rainfall. Because the watersheds were saturated, most rainfall ran off into the drainage systems. The large extent of rainfall amounts, exceeding 10 inches in 10 or less hours was extraordinary. The highest intensity rainfall recorded was 4.9 inches per hour. Severe and record breaking flooding was inevitable for over 15 major bayous in the center two-thirds of Harris County. The 25 inches of rain in 10 hours that occurred on the lower reaches of Greens Bayou may be a

record rainfall for that duration. Many roads and freeways were flooded early in the day, making travel very difficult. Many rescues were needed. Several downtown Houston and Texas Medical Center buildings sustained flooded basements that resulted in power outages.

Figure 10
Examples of Flooding Associated
With Tropical Storm Allison

Subsequent to the initiation of this study, flood events have continued in the watershed. In October of 2006, rainfall totaling 3 to 10 inches over a three-day period caused flooding of 115 to 125 homes in Harris County, as well as flooding of 110 to 120 homes in Brazoria County. Again in April 2009 the Clear Creek watershed received anywhere between 2 and 12 inches of rain in one afternoon caused by rainfall rates of 5 to 7 inches per hour in some areas, causing the flooding of 54 homes.

The problem along Clear Creek is flood damages to residential, commercial, and public investment caused by frequent low-level flood events associated with localized rainfall events and larger less frequent events with significant levels of flooding usually associated with tropical events. These frequent events with up to a four percent probability of occurrence impact about 1,500 structures. Of the frequently flooded structures, the majority are located on Clear Creek, particularly in the upper and middle reaches in the cities of Brookside, Pearland, Friendswood, and Houston. The frequently flooded structures on the main stem of Clear Creek (representing almost 56 percent of the total frequently flooded structures) consist primarily of slab-on-grade, single-family residential homes. In addition, frequent events also impact structures along Marys Creek, primarily in the city of Pearland; however, they represent only 36 percent of the most frequently flooded structures. The frequently impacted structures on Marys Creek are similar in character to those on the main stem, and consist primarily of single-family residential, slab-on-

grade construction. Mud Gully and Turkey Creek also experience frequent flooding to structures, but with fewer structures being impacted. Mud Gully's frequently impacted structures represent approximately six percent and Turkey Creek represent less than one percent of the most frequently impacted structures. Both Chigger Creek and Cowart Creek experience a relatively insignificant number of frequently flooded structures when compared with the entire study area. The frequently flooded structures typically would have less than one foot of flooding on their first floors. The larger events, represented by events with a 2 percent or less probability of occurrence, impact upwards of 7,500 structures across a wide area of the basin with slightly more significant flood levels. On average, homes will experience water levels on their first floors of over one foot to several feet with the more infrequent events.

The previously-authorized Federal flood control project consisted of an earthen channel that would widen and straighten Clear Creek. Included in the project was the construction of a second outlet from Clear Lake to Galveston Bay, previously described in Section I of this report that would allow for the additional flows from Clear Creek once the channel modifications were made. Construction of the Second Outlet and Gate Structure was completed in 1997. Operation and maintenance of the structure was handed over to the HCFCD in 1999. Interest groups and concerned citizens presented credible and qualified objections regarding the project to the non-Federal Sponsors. The non-Federal Sponsors expressed concerns about the project that included:

1) Use of outdated flood-control technology. Specifically, opponents were concerned that the design was old (1960s study) and relied only on conveyance measures such as trapezoidal channels without looking for other answers to the problem.

2) Enlargement of Clear Creek would overpower the second outlet at Clear Lake, especially under high tides.

3) Recreational concerns were raised about the use of environmentally sensitive areas as placement sites for dredged materials.

4) Excessive environmental impacts. The Clear Creek watershed contains some of the last remaining, natural, unchannelized stream beds in the area. The area also contains some high quality riparian habitat that would have been impacted.

5) Lack of less intrusive measures such as buyouts, regional detention, and natural corridor bypasses.

The non-Federal Sponsors analyzed and identified enhancements and updates that would address the concerns. The non-Federal Sponsors attempted to develop "minor" changes to the authorized project so that construction could restart quickly. However, the USACE determined that the

recommendations exceeded prior authority. In February 1999, the USACE decided that a general reevaluation study would be needed, and in April 1999, the non-Federal Sponsors agreed to accept the USACE recommendation to conduct the general reevaluation study. To facilitate this process the non-Federal Sponsors maintained a group of interested citizens and stake holders formed during the sponsor's reevaluation effort, known as the Clear Creek CAC, to provide feedback on flood risk management options.

Because of continued flooding impacts in the watershed as well as continued concerns about environmental impacts of previously authorized projects, for this study the team attempted to identify measures that reduce flooding in specific high damage reaches and incorporate features that preserve or create habitat in important corridors. Much of the flood damages are concentrated in high damage reaches. This and consideration of the Environmental Operating Principals allowed the team to evaluate both regional alternatives, as well as alternatives that can reduce flooding in specific reaches while reducing impacts throughout the entire reach of the waterbody. Private individuals and public entities have also remained very interested and involved in solving the problems identified in the watershed. Because of this continued involvement, the team has been able to utilize a large wealth of existing knowledge in collecting information on existing conditions as well as development of alternatives for consideration.

ENVIRONMENTAL

Clear Creek is located in an area of rapid urban growth that has realized extensive impacts to natural and cultural resources. Historically and ecologically important habitats within the Clear Creek watershed have been degraded and lost to agricultural range improvement and urbanization in the Houston area and surrounding municipalities. Still existing habitat ranges from heavily degraded to natural, high value riparian habitat. However, the remaining habitat is highly fragmented and continues to be severely threatened by exotic invasive species and development.

Numerous opportunities exist to preserve remaining habitat as well as create additional habitat to supplement or connect existing high importance areas. The Clear Creek floodplain provides an opportunity to restore an important corridor of riparian habitat consisting of bottomland forests, wetlands, and estuarine marshes. The upper reach of the watershed contains undeveloped prime farmlands and coastal prairie interspersed with prairie potholes. Clear Lake is considered one of the most important fish and shellfish nurseries within the Galveston Bay system (Lhose and Tyson, 1973), and, because the Clear Creek channel is relatively undisturbed in some reaches, it also supports a diversity of freshwater fauna. Archeological investigations have revealed

numerous prehistoric sites within the watershed that reflect prehistoric human use of the area, especially along the banks of Clear Creek and Clear Lake. It is this diversity that has prompted the public's concern regarding the impact of flood risk management options within the watershed.

The Clear Creek watershed occurs within a biological transition zone between the southern mixed hardwood forest, the coastal prairie, and the coastal salt marshes. The region contains remnants of one of the few remaining native tall-grass prairies in the region, small areas of shallow, tidal marshlands, and bottomland hardwood or riparian woodland areas.

Riparian wetlands occur along Clear Creek and its tributaries and freshwater and brackish wetlands are interspersed within the prairies, forests, and tidal marsh habitats within the floodplain. Many of these areas may remain wet several months to year round. These unique areas provide important functions including wildlife habitat, ground and surface water quality protection and improvement, and flood protection. However, due to their location water quality is sometimes affected during storm events by runoff from adjacent developed areas. Restoring and enhancing vegetation that would facilitate removal of pollutants, as well as lowering temperature in the waters to increase dissolved oxygen would allow for opportunities to increase water quality throughout the watershed.

The Clear Creek watershed is a highly urbanized area with limited passive recreational opportunities. Flood risk management projects generally tend to utilize long, linear tracts of land ideal for recreational activities such as biking, hiking, and running. Combined with the opportunity to create habitat along these same corridors, opportunities exist to increase the utilization and access for additional recreational opportunities throughout the watershed.

Because of all of these factors, opportunities exist to preserve/enhance/create many habitat types including riparian, prairie, salt marsh, and others. Presentations were made to six different organizations which had some interest in acting as a non-Federal sponsor for restoration activities. Due to the uncertainty of the extent or cost of the numerous proposed alternatives none of them was willing to share the cost of the study.

III. FORMULATION OBJECTIVES, CONSTRAINTS, AND CRITERIA

FEDERAL OBJECTIVES

The fundamental objective of Federal participation in water resources development projects is to assure that an optimum contribution is made to the welfare of all people. The Water Resources Council's Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies dated March 1983 and the National Environmental Policy Act of 1969 (NEPA) provide the basis for Federal policy for planning Federal water resources projects. These authorities have established the procedures for formulation and evaluation of water resources projects. Additional policies and regulations, derived from executive and legislative authority, further define the criteria for assessment of plan impacts, risk analysis, review and coordination procedures, and project implementation.

Principles and Guidelines (P&G) state that the Federal objective of water and related land resources planning is to contribute to national economic development (NED) consistent with protecting the Nation's environment, in accordance with Federal environmental statutes, applicable executive orders, and other Federal planning requirements. The P&G use of the term objective should be distinguished from study planning objectives, which are more specific in terms of expected or desired outputs. The P&G's objective (Federal objective) may be considered more of a national goal. Water and related land resources project plans shall be formulated to alleviate problems and take advantage of opportunities in ways that contribute to study planning objectives and, consequently, to the Federal objective.

Federal objectives are designed to assure systematic interdisciplinary planning, assessment, and evaluation of plans addressing natural, cultural, and environmental concerns, which will be responsive to Federal laws and regulations. The team met the objectives with the consideration and development of alternatives that addressed six Federal objectives. These objectives include:

1) *NED*. For all project purposes except ecosystem restoration, the alternative plan that reasonably maximizes net economic benefits consistent with protecting the Nation's environment, the NED plan, shall be selected. The Assistant Secretary of the Army for Civil Works (ASA (CW)) may grant an exception when there are overriding reasons for selecting another plan based upon other Federal, State, local, and international concerns.

2) *National Ecosystem Restoration (NER)*. For ecosystem restoration projects, a plan that reasonably maximizes ecosystem restoration benefits compared to costs, consistent with

the Federal objective, shall be selected. The selected plan must be shown to be cost effective and justified to achieve the desired level of output. This plan shall be identified as the NER Plan.

3) *Combined NED/NER.* Projects, which produce both NED and NER benefits, will result in a "best" recommended plan so that no alternative plan or scale has a higher excess of NED benefits plus NER benefits over total project first costs. This plan shall attempt to maximize the sum of net NED and NER benefits and to offer the best balance between two Federal objectives. Recommendations for multipurpose projects will be based on a combination of NED benefit-cost analysis and NER benefits analysis, including cost effectiveness and incremental cost analysis.

4) *Effects on Environmental Quality (EQ).* The EQ account identifies the nonmonetary effects on significant natural and cultural resources (ER 1105-2-100). The primary impact of any recommended plan is the expected direct impact to floodplain forest that is often located adjacent to streams and creeks in the Clear Creek watershed. Early in the study process, opportunities to avoid or offset impacts were evaluated. This can be seen in the environmentally sensitive design of both the conveyance and detention features considered. Also, to ensure sufficient consideration of environmental impacts, an ICT was formed to recommend and evaluate potential mitigation measures. This multidisciplinary ICT oversaw the development and application of the Habitat Evaluation Procedure (HEP) model used to evaluated ecological effects of the Clear Creek project.

5) *Regional Economic Development (RED).* The RED account identifies changes in the distribution of regional economic activity. Evaluations of regional effects are to be carried out using nationally consistent projection of income, employment, output, and population (ER 1105-2-100). Federal objectives would allow for a small increase in damages in some areas so long as reduction in damages in other areas is significantly decreased. This study was successful in identifying those potential regional effects and identifying measures that work within a system to prevent those negative regional effects. The sponsors are also aggressively implementing the requirement for development of a floodplain management plan. They are in talks with floodplain administrators throughout the watershed to insure continued benefit from the selected plan throughout the period of economic analysis with minimal actions by locals that will have negative regional impacts.

6) *Other Social Effects (OSE).* The OSE account identifies the plan effects from perspectives that are relevant to the planning process, but are not reflected in the NED/NER, EQ, and RED accounts (ER 1105-2-100). Structural and nonstructural alternatives must reflect close coordination with interested Federal and State agencies and the affected public. The effects of these measures on the environment must be carefully identified and compared with technical, economic, and social considerations and evaluated in light of public input. Any plan considered by this study would likely not have an effect on population growth trends within the study area. As a result of the recommended plan, demand for community facilities, services, and housing would not increase in the study area. The proposed project would not be located within a minority area. The minority and low-income populations living within the study area would likely experience no adverse changes to the demographic, economic, or community cohesion characteristics within their respective neighborhoods as a result of the recommended plan.

The construction of the recommended plan would create opportunities for increased recreation within the study area and proposed environmentally sensitive design measures of the recommended plan are expected to have beneficial impacts to recreational activities by providing additional habitats important to current wildlife watching.

PLANNING OBJECTIVES

During early coordination efforts, the sponsors and USACE identified concerns of numerous stakeholders. The stakeholders consolidated these concerns and asked that the USACE consider as many as possible during the reevaluation process. The concerns include:

1) Reducing riverine flood damages along Clear Creek and its tributaries;

2) Maximizing the net economic benefits of any identified Federal flood risk management project;

3) Avoiding adverse environmental impacts when possible. Minimizing and mitigating unavoidable adverse environmental impacts;

4) Recognizing and considering the existing aesthetic qualities of Clear Creek;

5) Identifying recreational opportunities;

6) Preserving cultural resources. Minimizing and mitigating unavoidable impacts to these resources;

7) Identifying possible eco-friendly flood risk management solutions; and

8) Identifying any possible ecosystem restoration opportunities.

Taking these concerns into consideration as well as the newest guidance, a comprehensive set of detailed planning objectives was developed for this project. Planning Objectives identified for this study include:

1) Reducing flood risk for economic, social, and environmental purposes, along Clear Creek and tributaries through 2070;

2) Restoring fish and wildlife resources of Clear Creek and tributaries, for the purpose of attracting more and varied species of fish and wildlife, through 2070;

3) Preserving and protecting natural and cultural resources for public education and historical appreciation purposes through 2070;

4) Developing opportunities for recreation in the Clear Creek and tributaries through 2070;

5) Facilitating stabilization of the stream banks of Clear Creek and tributaries through 2070; and

6) Restoring the quantity and quality of habitat on Clear Creek and its tributaries through ecosystem restoration activities through 2070.

PLANNING CONSTRAINTS

Plans must be formulated with regard to addressing the problems and needs of the area, taking into consideration future without-project (FWOP) conditions. The plans should identify tangible and intangible benefits and costs from economic, environmental, social, and regional perspectives. Institutional implementation constraints should also be identified. The formulation framework requires the systematic preparation and evaluation of alternative solutions to the recognized water resource-related problems within the study area. The process also requires that

impacts of the proposed action be measured and results displayed or accounted for in terms of contributions to NED, EQ, RED, and OSE.

Interaction with other interests must be maintained throughout the planning process to avoid duplication of effort, minimize conflicts, obtain consistency, and assure completeness. The following constraints apply to this feasibility study:

1) The study should limit proposed measures to the study area within the Clear Creek watershed within Harris, Galveston, and Brazoria Counties in creeks/streams that exceed the 800 cubic feet per second (cfs) standard required for USACE involvement (ER 1105-2-100, Chapter 3-3(b)(6)). In urban and urbanizing areas, provision of a basic drainage system to collect and convey local runoff is a non-Federal responsibility. Water damage problems may be addressed under flood risk management authorities, downstream from the point where the flood discharge is greater than 800 cfs for the 10 percent probability exceedance event (one chance in ten of being equaled or exceeded in any given year) under conditions expected to prevail during the period of analysis;

2) Recommended plans must be consistent with specific environmental conditions of the area including soil conditions, topography, and terrestrial and aquatic ecosystems;

3) The study must be conducted in compliance with Federal, state, and local laws and regulations and guided by applicable administrative position and USACE guidance;

4) Recommended plans formulated to improve flood risk management should avoid damaging the environment to the extent practicable and contain measures to minimize or mitigate unavoidable environmental damages;

5) Recommended plans should be compatible with risk management needs and consistent with the requirements of the day-to-day managers of the watershed and water bodies. Recommended plans must be formulated to comply with local stormwater management of floodplain regulations;

6) Recommended plans should cause no increase in flood surface elevations in downstream reaches;

7) Selected plans, whether structural, nonstructural, or a combination of both, should maximize net benefits; however, unquantifiable features must be addressed subjectively; and

8) Plans proposed for implementation should have an overall favorable impact on the social well-being of affected interests and have overall public acceptance.

Current guidance (ER 1105-2-100) specifies that the Federal objective of planning is to contribute to NED consistent with protecting the Nation's environment. The following general criteria are applicable to all water resource studies. They have generally guided the formulation of this study. Technical, economic, environmental, and social criteria have been established to guide the project development process. These criteria are discussed below.

TECHNICAL CRITERIA

Technical criteria require the utilization of properly evaluated models so that the team can adequately evaluate measures that assist with the management of flood risk in the watershed. Formulation of alternative alignments and dredged material placement alternatives and their evaluation was accomplished by analysis of historical and projected flooding rates, economic information, and general structural and nonstructural alternatives applicable for conditions, which are specific to this area. Technical information, both historical data and specific information prepared for this project, used during this study included, but was not limited to, hydrologic and hydraulic (H&H) modeling, economic models, habitat mapping and modeling, aerial photography, historical flooding records, and previously published scientific reports related to this area.

ECONOMIC CRITERIA

The economic criteria require that tangible benefits attributable to projects exceed economic costs. Project benefits and economic costs are reduced to average annual equivalent (AAE) values and related in a benefit-to-cost ratio (BCR). This ratio must exceed unity to meet the NED objective. These criteria are used to develop plans that achieve the objective of NED and provide a base condition for consideration of economically unquantifiable factors, which may impact on project proposals.

All structural and nonstructural measures for flood risk management projects should be evaluated using the appropriate period of analysis and the currently applicable interest rate. Total annual

costs should include amounts for operation, maintenance, major replacements, and mitigation, as well as amortization and interest on the investment.

ENVIRONMENTAL CRITERIA

The general environmental criteria for flood risk management projects are identified in Federal environmental statutes, executive orders, and planning guidelines as well as the Environmental Operating Principles of the USACE. It is the Federal policy that fish and wildlife resource conservation be given equal consideration with other study purposes in the formulation and evaluation of alternative plans. The basic guidance during planning studies is to assure that care is taken to preserve and protect significant ecological, aesthetic, and cultural values and to conserve natural resources. These efforts also should provide the means to maintain and restore, as applicable, the desirable qualities of the human and natural environment. Particular emphasis was placed on the following:

1) Protection, preservation, and improvement of the existing fish and wildlife resources along with the protection and preservation of riparian forest, estuaries and wetland habitats, and water quality;

2) Consideration in the project design of the least disruptive construction techniques and methods;

3) Mitigation for project-related unavoidable impacts. Mitigation, as detailed in 40 Code of Federal Regulations (CFR) 1508.20, includes:

   (a) Avoiding the impact altogether by not taking a certain action or parts of an action.

   (b) Minimizing impacts by limiting the degree or magnitude of the action and its implementation.

   (c) Rectifying the impact by repairing, rehabilitating, or restoring the affected environment.

   (d) Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action.

   (e) Compensating for the impact by replacing or providing substitute resources or environments;

4) Preservation of significant historical and archeological resources through avoidance of effects. This is the preferable action to any other form of mitigation since these are finite, nonrenewable resources.

Also developed were preliminary alternatives for the evaluation of ecosystem restoration opportunities; however, during the study no cost-share sponsors were identified that would undertake the development of these measures. Based on this consideration, the objective to identify opportunities for ecosystem restoration was removed from consideration.

PLAN FORMULATION RATIONALE

The backbone of the rationale for formulating and developing alternative solutions is the Planning Guidance Notebook (ER 1105-2-100) and the requirements detailed therein. In August 2006, as a result of lessons learned from Hurricanes Katrina and Rita, the USACE Chief of Engineers initiated the "Actions for Change" in an effort to transform the USACE planning, design, construction, and operation and maintenance principles and decision-making processes. This program has been further developed into the Campaign Plan. The USACE is moving forward with this Campaign Plan to transform the way business is done. The USACE Campaign Plan is available on the internet at:
http://www.usace.army.mil/about/campaignplan/Pages/Home.aspx (USACE, February 2011)

The successful achievement of the goals and objectives contained in this Campaign Plan are dependent on actions implemented by the entire USACE team. The Campaign Plan included four goals for the USACE. These goals are:

> **Goal 1: Ready for all Contingencies** – Deliver USACE support to combat, stability, and disaster operations through forward deployed and reachback capabilities.
> **Goal 2: Engineering Sustainable Water Resources** - Deliver enduring and essential water resource solutions through collaboration with partners and stakeholders.
> **Goal 3: Delivering Effective, Resilient, Sustainable Solutions -** Deliver innovative, resilient, sustainable solutions to the Armed Forces and the Nation.
> **Goal 4: Recruit and Retain Strong Teams** – Build and cultivate a competent, disciplined, and resilient team equipped to deliver high quality solutions.

Goals 1 and 4 do not apply directly to the USACE planning process and will not be discussed in detail. Goals 2 and 3 pertain to water resources planning and directly to the Clear Creek GRR study. These goals are described in more detail below.

Goal 2: Engineering Sustainable Water Resources

With Goal 2 USACE focuses on comprehensive, sustainable, and integrated solutions to the Nation's water resources challenges through collaboration with stakeholders. This goal refers to not only developing and delivering comprehensive and lasting solutions but also ensuring that these solutions are long lasting, integrated, and holistic to respond to today's and future challenges. This study included the following processes to assure that Goal 2 was attained.

1) Employ Integrated, Comprehensive Systems-Based Approach - This study utilized detailed hydrologic modeling in conjunction with comprehensive flood damage information, as well as a targeted damage evaluation method to ensure that measures developed were the best for the watershed without impacting areas that do not experience high risk. The consideration of these targeted measures throughout the entire watershed allowed measures to be developed that together act better than the results of each individual measure on a stand-alone basis.

2) Employ Adaptive Planning and Engineering Systems - Measures identified utilize adaptive management techniques in consideration of long term maintenance requirements. Alternatives identified took into consideration both hydraulic capabilities as well as environmental opportunities.

3) Focus on Sustainability - Strategies employed include those that require minimal maintenance of natural channels and detention basins, with maintenance targeted for easily accessible areas.

Goal 3: Delivering Effective, Resilient, Sustainable Solutions

Goal 3 emphasizes that the USACE will provide innovative, resilient, and sustainable infrastructure solutions for the Nation today and in the future. The USACE is the Nation's premier public service engineering and construction organization and can provide infrastructure support to serve both the military and national civilian arenas. This effort will improve resilience and lifecycle investment in critical infrastructure, deliver reliable infrastructure using a risk-informed asset management strategy, and develop and apply innovative approaches to delivering quality infrastructure. This study attained this goal with the following steps.

1) Employ Risk-Based Concepts in Planning, Design, Construction, Operations and Major Maintenance – The study utilized risk-based analysis for the H&H, economic modeling, and cost estimating efforts.

2) Review and Inspect Completed Works - Different strategies employed in and around the watershed are the reason that authorization of this project has been unsuccessful in the past. New ideas were needed that would address the need for new flood risk management ideas. This study also takes into consideration completed works already in the ground.

3) Effectively Communicate Risk - The study utilized continuous communication with all parties interested in the outcome of the project. This included parties interested in realizing a reduction in flood damages as well as parties interested in insuring that any measure proposed for construction did not have detrimental environmental impacts.

4) Establish Public Involvement Risk Reduction Strategies - Innovative and award winning techniques were utilized to ensure that the public has a clear picture of the risks associated with the project.

5) Continuously Reassess and Update Policy for Program Development, Planning Guidance, Design and Construction Standards - Existing and new guidance, as well as legislation related specifically to the non-Federal Sponsors (Section 575, WRDA 96), was considered during the study.

6) Employ Dynamic Independent Review - The study utilized Agency Technical Review (ATR) from other USACE districts, review by the vertical team, as well as continuous review and involvement from the non-Federal Sponsors and local engineering expertise to ensure that ideas are continuously updated and that technical information is accurate. Review by the ATR team and independent external peer review were utilized to ensure a complete and technically sound document.

7) Assess and Modify Organizational Behavior - This project utilized an ICT process developed by the Galveston District to bring resource agencies closer to the process of study development. This, as well as continuous communication with the sponsors and public, ensured a transparent process.

8) Manage and Enhance Technical Expertise and Professionalism - The study has utilized a vast network of technical experts from the public and private sector, including the

9) Galveston District, Institute for Water Resources, Engineering Research and Development Center (ERDC), private consultants, as well as local and city experts to assist in the evaluation of the identified measures and recommended plan.

10) Invest in Research - The study has attempted to ensure that the models utilized are the most current and accurate. ERDC was utilized to develop a new environmental model for the evaluation of environmental impacts on a community basis and assist in determination of adequate mitigation. This is newly developed technology that will allow a much more comprehensive determination of mitigation necessary to offset impacts.

The planning framework requires the systematic preparation and evaluation of alternative ways of addressing problems, needs, concerns, and opportunities while considering environmental factors. The criteria and broad planning objectives previously identified form the basis for subsequent plan formulation, screening, and ultimately plan selection.

The planning process for this study has been driven by the overall objective of developing environmentally sensitive flood risk management. The first phase of this process was to establish the magnitude and extent of the problems and then to develop and evaluate an array of alternative solutions to meet the existing and long-range future needs of the area. The Environmental Operating Principles created the framework utilized in developing the measures. These principles foster unity of purpose on environmental issues, reflect a new tone and direction for dialogue on environmental matters, and ensure that employees consider conservation, environmental preservation and restoration in all USACE activities.

During the reevaluation phase, lines of communications were opened with Federal, State, and local agencies, private groups, and the affected public. Through scoping and other coordination meetings, public involvement activities were continued throughout the planning process.

The expected FWOP scenario was first developed for comparison with other alternatives. Nonstructural and structural plans were developed to address the planning objectives. For the structural plans an array of conveyance modifications and detention alternatives were developed, evaluated, and screened. The modifications were investigated as to possible means to satisfy the objectives of reducing flood damages in the watershed.

Through a two-phased screening process, a plan was ultimately selected. Further preliminary design refinements were accomplished for the selected plan prior to developing a baseline cost estimate for this plan.

IV. PLAN FORMULATION

WITHOUT-PROJECT CONDITION/NO ACTION

The USACE is required to consider the option of "No Action" as one of the alternatives in order to comply with Engineering Regulation (ER) 1105-2-100 and the requirements of NEPA. With the No-Action Alternative, which in this case is synonymous with the FWOP condition, it is assumed that no project would be implemented by the Federal Government. The No-Action Alternative forms the basis against which all other alternative plans are measured.

The Clear Creek study area is characterized as a relatively flat floodplain with shallow flooding associated with all events. Velocities do not pose a significant threat to life in any studied reach, with velocities typically ranging from one to five cfs for all flood events.

Main Stem

Development on the main stem consists of approximately 92 percent residential structures followed by 6 percent commercial structures. Public and industrial occupancy types make up an insignificant portion of the floodplain properties. Of the residential structures identified within the main stem floodplain, 70 percent are one-story single family residential, primarily of slab-on-grade construction. Another 22 percent of the residential structures are two-story single family residential, again constructed slab-on-grade. There are no basements within residential structures in the study area. The average structure value for residential structures surveyed on the main stem is just over $117,000. The average structure value for commercial structures on the main stem is approximately $147,000.

The problem along the Clear Creek main stem is flood damages to residential, commercial, and public investment caused by frequent low-level flood events associated with localized rainfall events and larger less frequent events with significant levels of flooding usually associated with tropical events. These frequent events (up to a four percent probability of occurrence) impact over 850 structures on the main stem with an average depth of flooding of 0.7 feet. The majority of the frequently flooded structures located on the main stem are located in the upper and middle reaches in the cities of Brookside, Pearland, Friendswood, and Houston. The more infrequent flood events (associated with a 2 percent to 0.2 percent probability of occurrence) impact over 3,100 structures on the main stem with an average depth of flooding of 1.2 feet.

Marys Creek

Development on Marys Creek consists of approximately 82 percent residential structures followed by 15 percent commercial structures. Public and industrial occupancy types make up an insignificant portion of the floodplain properties. Of the residential structures identified in the Marys Creek floodplain, 72 percent are one-story single-family residential, primarily of slab-on-grade construction. Another 19 percent of the residential structures are two-story single family residential, again constructed slab-on-grade. The Marys Creek residential structures also include 7 percent mobile homes. There are no basements within residential structures in the study area. The average structure value for residential structures surveyed on Marys Creek is just over $115,000. The average structure value for commercial structures on Marys Creek is approximately $46,000.

The problem along Marys Creek is again flood damages to residential, commercial and public investment caused by frequent low-level flood events associated with localized rainfall events and larger less frequent events with significant levels of flooding usually associated with tropical events. These frequent events (up to a four percent probability of occurrence) impact approximately 580 structures on Marys Creek with an average depth of flooding of 0.6 feet. The more infrequent flood events (associated with a 2 percent to 0.2 percent probability of occurrence) impact over 1,900 structures on Marys Creek with an average depth of flooding of 0.9 feet.

Turkey Creek

Development on Turkey Creek consists of approximately 99 percent residential structures followed by 1 percent commercial structures. Public and industrial occupancy types make up an insignificant portion of the floodplain properties. Of the residential structures identified in the Turkey Creek floodplain, 83 percent are one-story single-family residential, primarily of slab-on-grade construction. Another 7 percent of the residential structures are two-story single-family residential, again constructed slab-on-grade. The Turkey Creek residential structures also include 11 percent apartments. There are no basements within residential structures in the study area. The average structure value for residential structures surveyed on Turkey Creek is over $92,000. The average structure value for commercial structures on Turkey Creek is approximately $198,000.

The problem along Turkey Creek is again flood damages to residential and commercial investment caused by frequent low-level flood events associated with localized rainfall events

and larger less frequent events with significant levels of flooding usually associated with tropical events. These frequent events (up to a four percent probability of occurrence) impact a minimal number of structures, only 7 structures on Turkey Creek, with an average depth of flooding of 0.2 feet. The more infrequent flood events (associated with a 2 percent to 0.2 percent probability of occurrence), impact over 750 structures on Turkey Creek, with an average depth of flooding of 0.5 feet.

Mud Gully

Development on Mud Gully consists of approximately 96 percent residential structures followed by 4 percent commercial structures. Public and industrial occupancy types make up an insignificant portion of the floodplain properties. Of the residential structures identified in the Mud Gully floodplain, 76 percent are one-story single-family residential, primarily of slab-on-grade construction. Another 20 percent of the residential structures are two-story single-family residential, again constructed slab-on-grade. The Mud Gully residential structures also include 4 percent apartments. There are no basements within residential structures in the study area. The average structure value for residential structures surveyed on Mud Gully is over $46,000. The average structure value for commercial structures on Mud Gully is almost $34,000.

The problem along Mud Gully is again flood damages to residential and commercial investment caused by frequent low-level flood events associated with localized rainfall events and larger less frequent events with significant levels of flooding usually associated with tropical events. These frequent events (up to a four percent probability of occurrence) impact approximately 90 structures on Mud Gully, with an average depth of flooding of 0.2 feet. The more infrequent flood events (associated with a 2 percent to 0.2 percent probability of occurrence) impact over 1,200 structures on Mud Gully with an average depth of flooding of 0.8 feet.

Cowart Creek

Development on Cowart Creek consists of approximately 44 percent residential structures followed by 43 percent commercial structures. Approximately 14 percent of the structures on Cowart Creek are industrial. Public and industrial occupancy types make up an insignificant portion of the floodplain properties. Of the residential structures identified in the Cowart Creek floodplain, 45 percent are one-story single-family residential, primarily of slab-on-grade construction. Another 40 percent of the residential structures are two-story single-family residential, again constructed slab-on-grade. The Cowart Creek residential structures also include 14 percent mobile homes. There are no basements within residential structures in the

study area. The average structure value for residential structures surveyed on Cowart Creek is over $143,000. The average structure value for commercial structures on Cowart Creek is approximately $13,000.

The problem along Cowart Creek is again flood damages to residential and commercial investment caused by frequent low-level flood events associated with localized rainfall events and larger less frequent events with significant levels of flooding usually associated with tropical events. These frequent events (up to a four percent probability of occurrence) impact approximately 34 structures on Cowart Creek with an average depth of flooding of 1.4 feet. The more infrequent flood events (associated with a 2 percent to 0.2 percent probability of occurrence) impact almost 100 structures on Cowart Creek with an average depth of flooding of 1.5 feet.

Chigger Creek

Development on Chigger Creek consists of approximately 88 percent residential structures followed by 12 percent commercial structures. Public and industrial occupancy types make up an insignificant portion of the floodplain properties. Of the residential structures identified in the Chigger Creek floodplain, 43 percent are one-story single-family residential, primarily of slab-on-grade construction. Another 43 percent of the residential structures are two-story single-family residential, again constructed slab-on-grade. The Chigger Creek residential structures also include 14 percent mobile homes. There are no basements within residential structures in the study area. The average structure value for residential structures surveyed on Chigger Creek is approximately $232,000. The average structure value for commercial structures on Chigger Creek is approximately $26,000.

The problem along Chigger Creek is again flood damages to residential and commercial investment caused by frequent low-level flood events associated with localized rainfall events and larger less frequent events with significant levels of flooding usually associated with tropical events. These frequent events (up to a four percent probability of occurrence) impact approximately 6 structures on Chigger Creek with an average depth of flooding of 1.2 feet. The more infrequent flood events (associated with a 2 percent to 0.2 percent probability of occurrence) impact approximately 25 structures on Chigger Creek with an average depth of flooding of 1.4 feet.

The FWOP Condition would retain the existing Clear Creek and tributaries at their current configuration. The local sponsors, as well as local municipalities, have adopted watershed

management policies and practices for minimizing increases in future development-induced runoff. To evaluate the effect of these policies analytically, a hydrologic model, which estimates the impact on discharges were these local ordinances not in place, was also developed. The without-project condition assumes that these local measures are functioning. The without-project "near term" and "most likely future" conditions applied to this analysis incorporate local sponsors' initiatives for minimizing development-induced runoff. While the future without-project H&H condition includes an increase in run-off, the changes in water surface elevations are minimal when compared to the near term. However, the capacity of the detention areas can be exceeded by certain flood events causing eventual increases in future damages.

One project feature from the previous authorization already in place is the Second Outlet and Gate Structure between Clear Lake and Galveston Bay. Modifications to the gate structure were evaluated as alternatives to further reduce flood risk but the gate in its current configuration was incorporated into the FWOP condition. Performing the analysis in this manner would allow documentation of what impacts modifications to the previously constructed feature would have on any additional recommended flood risk management features while taking into account benefits already generated by the second outlet.

The period of analysis begins in the year 2020, the first year in which the project would become operational after construction is completed. Therefore, the base year is defined as 2020. Figure 11 details the without-project 1 percent AEP for the 2020 without-project condition. The period of analysis for this project extends 50 years in the future to the year 2070. This period of analysis was developed in accordance with ER 1105-2-100, Appendix D-6(a) (2), dated April 22, 2000. At the outset of the study, the period of analysis was to begin in 2010 but due to modifications in the study area causing delays in the study process, the period was modified to 2020 and all analyses were subsequently modified accordingly. The most probable future condition reflects changes in hydrologic conditions from anticipated development within the watershed, tempered by runoff restrictions imposed by local authorities over the period of analysis, 2020 to 2070. This assumption is consistent with current guidance.

Data collection for development of the Clear Creek main stem structure inventory began in the year 2000. Data for over 12,000 structures on the main stem were collected during 2000-2001, and data for another 12,000 structures for the tributaries were collected during the period 2002-2003. Values presented in this analysis reflect certified year 2001 tax appraisal district valuations updated and adjusted to October 2011 depreciated replacement values. For purposes of plan formulation and initial screening of flood risk management measures, the year 2001 tax

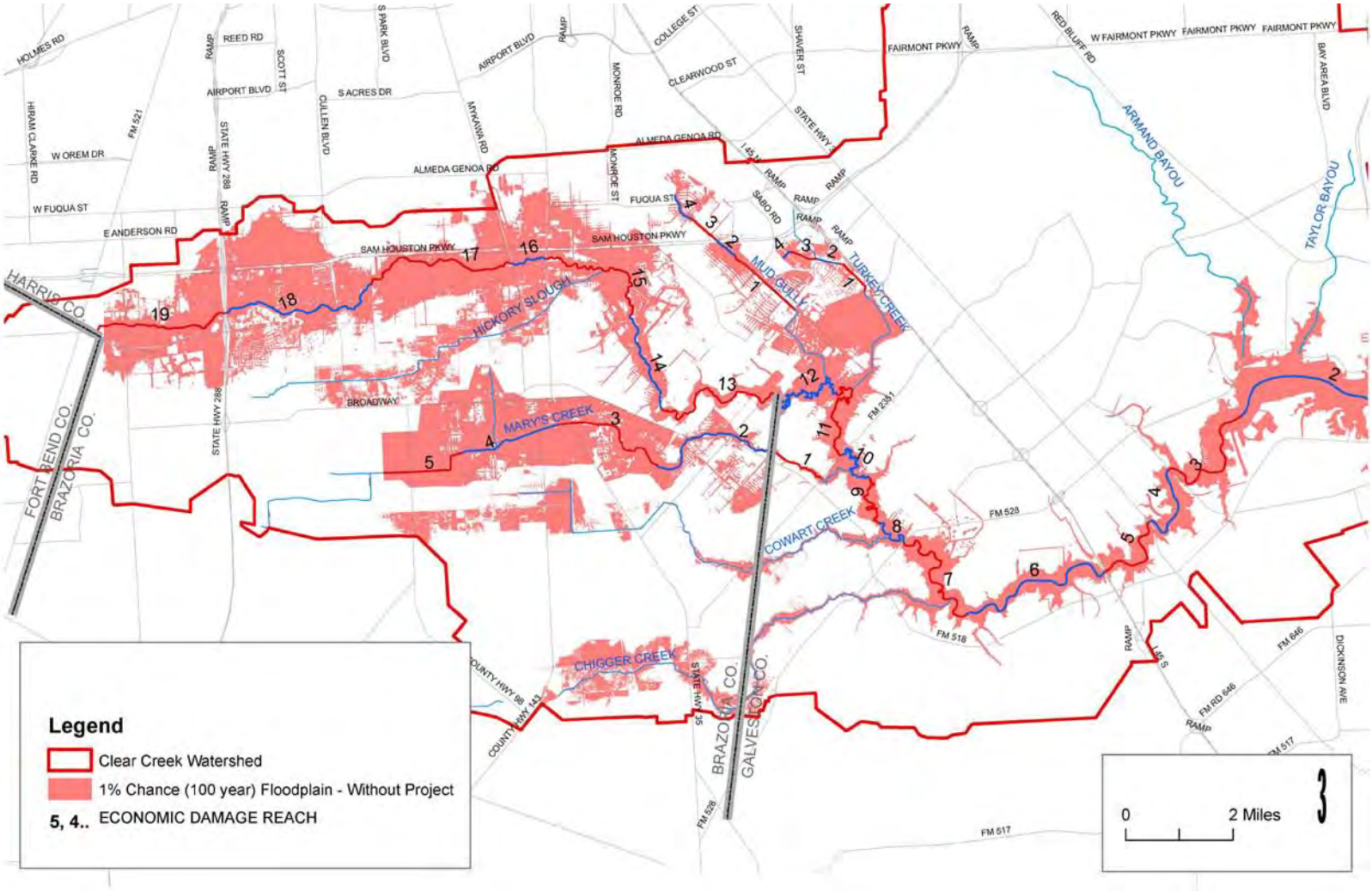


Figure 11
1 Percent AEP Floodplain – Without-Project Condition (2020)

valuations were used as proxy values for depreciated replacement values. For the final refinement of alternatives, prices were adjusted to reflect depreciated replacement values for the current year, as required by guidance.

Table 1 displays a summary of the number of structures and the distribution of capital investment within eight existing median discharge AEP floodplains of the Clear Creek main stem and tributaries based on first floor elevations for the 2020 condition. As can be noted from Table 1, approximately 90 percent of the structures inventoried within the estimated existing median 0.2 percent AEP (500-year) floodplain are residential. In total the 0.2 percent AEP floodplain on the main stem and tributaries contains over 7,300 structures valued at over $741 million dollars at Fiscal Year 12 (October 2011) price levels. Of those inventoried, approximately 163 residential structures have been purchased and removed from the floodplain under the FEMA's Hazard Mitigation Grant Program (HMGP) on the main stem of Clear Creek. Under authority of Section 575, WRDA 96, as amended, those properties will remain in the structure inventory for Federal project justification. Presentation of the Section 575 analysis will be detailed later in this document.

As previously noted, over 24,000 structures were inventoried on the main stem and tributaries. The 7,300 structures identified in Table 1 represent the structures inundated by the 0.2 percent AEP flood event (or the 500-year event) on the main stem and tributaries in the 2020 without-project condition. In other words, only 7,300 structures (of the original 24,000 study area structures inventoried) are actually within the 500-year floodplain; the rest fall outside the 500-year floodplain.

In development of the structure inventory (of 12,000 structures for the main stem and 12,000 structures for the tributaries), the area was over-inventoried because the flood surface elevations had not yet been established and, given the method used, aerial photography with a Digital Terrain Model, no major increase in expense was incurred. The survey boundary was set at the FEMA 500-year plus 1,000 feet outward. Every attempt was made to be absolutely inclusive. Since there is always an issue of induced damages, over-inventorying can capture the effects of a plan that produces stages higher than the FWOP condition.

Table 2 displays the structure inventory and distribution of capital investment within the eight existing median discharge AEP floodplains for the main stem and tributaries for the without-project 2070 condition. As with the 2020 condition, the 2070 condition also reveals the majority of structures in the 0.2 percent AEP floodplain to be residential, representing approximately 91

Table 1
Cumulative Distribution of Structures by Type by Flood Event
Clear Creek – Sum of Maim Stem and All Tributaries
Cumulative Totals Based on First-Floor Elevations and Without-Project 2020 Condition
(Dollar Values in $1,000s, Oct 2011 Price Levels)

Structure Type/Flood Event	50% AEP Floodplain (2-Year)	20% AEP Floodplain (5-Year)"	10% AEP Floodplain or (10-Year)	4% AEP Floodplain (25-Year)	2% AEP Floodplain (50-Year)	1% AEP Floodplain (100-Year)	0.4% AEP Floodplain (250-Year)	0.2% AEP Floodplain (500-Year)
Residential								
Number of Structures	1	133	528	1,298	2,261	3,279	4,944	6,599
Value of Structures	$95	$14,455	$50,301	$118,357	$208,050	$305,633	$479,032	$665,811
Value of Contents	$48	$7,227	$25,178	$59,179	$104,784	$154,642	$243,763	$340,912
Percent of Structures Inundated/Zone	25%	68%	77%	83%	86%	89%	91%	90%
Commercial								
Number of Structures	3	56	131	214	296	352	427	598
Value of Structures	$34	$4,572	$12,523	$15,596	$21,574	$25,983	$35,477	$47,318
Value of Contents	$1	$1,388	$7,442	$9,586	$16,856	$19,777	$28,861	$39,062
Percent of Structures Inundated/Zone	75%	29%	19%	14%	11%	10%	8%	8%
Industrial								
Number of Structures	0	1	14	28	36	38	47	50
Value of Structures	$0	$218	$4,387	$8,374	$9,959	$9,959	$10,000	$10,422
Value of Contents	$0	$1,156	$5,604	$9,481	$14,626	$14,626	$16,026	$16,313
Percent of Structures Inundated/Zone	0%	1%	2%	2%	1%	1%	1%	1%
Public								
Number of Structures	0	6	15	26	34	36	39	59
Value of Structures	$0	$1,291	$2,380	$7,270	$8,300	$8,469	$10,040	$17,326
Value of Contents	$0	$430	$639	$1,655	$2,178	$2,267	$2,946	$5,699
Percent of Structures Inundated/Zone	0%	3%	2%	2%	1%	1%	1%	1%
Total								
Number of Structures	4	196	688	1,566	2,627	3,705	5,457	7,306
Value of Structures	$129	$20,535	$69,591	$149,596	$247,883	$350,044	$534,549	$740,877
Value of Contents	$48	$10,200	$38,863	$79,901	$138,444	$191,312	$291,596	$401,986
Percent of Structures Inundated/Zone	100%	100%	100%	100%	100%	100%	100%	100%

Note: Individual numbers may not sum to totals due to rounding.

Table 2
Cumulative Distribution of Structures by Type by Flood Event
Clear Creek – Sum of Maim Stem and All Tributaries
Cumulative Totals Based on First-Floor Elevations and Without-Project 2070 Condition
(Dollar Values in $1,000s, Oct 2011 Price Levels)

Structure Type/Flood Event	50% AEP Floodplain (2-Year)	20% AEP Floodplain (5-Year)"	10% AEP Floodplain or (10-Year)	4% AEP Floodplain (25-Year)	2% AEP Floodplain (50-Year)	1% AEP Floodplain (100-Year)	0.4% AEP Floodplain (250-Year)	0.2% AEP Floodplain (500-Year)
Residential								
Number of Structures	12	302	713	1,698	2,751	4,348	6,168	7,706
Value of Structures	$1,160	$29,923	$68,593	$157,536	$256,266	$447,374	$638,767	$785,900
Value of Contents	$580	$14,962	$34,324	$78,621	$128,918	$225,706	$322,982	$400,814
Percent of Structures Inundated/Zone	50%	76%	79%	85%	88%	89%	90%	91%
Commercial								
Number of Structures	11	77	152	242	316	457	561	624
Value of Structures	$130	$7,163	$13,129	$17,985	$24,309	$30,727	$43,303	$57,500
Value of Contents	$66	$3,730	$7,844	$12,018	$18,668	$24,765	$35,435	$89,049
Percent of Structures Inundated/Zone	46%	19%	17%	12%	10%	9%	8%	7%
Industrial								
Number of Structures	0	8	21	33	39	41	46	47
Value of Structures	$0	$661	$5,175	$8,965	$9,959	$10,363	$10,807	$10,826
Value of Contents	$0	$2,819	$6,047	$9,884	$14,626	$14,900	$16,575	$16,588
Percent of Structures Inundated/Zone	0%	2%	2%	2%	1%	1%	1%	1%
Public								
Number of Structures	1	9	19	29	33	51	53	64
Value of Structures	$16	$1,443	$2,754	$7,428	$8,300	$16,199	$16,204	$16,719
Value of Contents	$6	$528	$826	$1,722	$2,178	$5,267	$5,270	$5,442
Percent of Structures Inundated/Zone	4%	2%	2%	1%	1%	1%	1%	1%
Total								
Number of Structures	24	396	905	2,002	3,139	4,897	6,828	8,441
Value of Structures	$1,306	$39,191	$89,651	$191,913	$298,834	$504,663	$709,082	$870,945
Value of Contents	$652	$22,039	$49,042	$102,245	$164,390	$270,637	$380,263	$511,893
Percent of Structures Inundated/Zone	100%	100%	100%	100%	100%	100%	100%	100%

Note: Individual numbers may not sum to totals due to rounding.

percent. For the 2070 condition, the 0.2 percent AEP floodplain contains over 8,400 structures valued at over $870 million dollars. For a break-down of the distribution of capital investment within the individual tributaries and main stem floodplains, see the Economic Appendix.

Determination of Flood Damages to Existing Development

Flood damages were estimated for all property within the most likely future median 0.2 percent AEP floodplain of Clear Creek. Damages from inundation are based on data obtained from the survey of existing development. Damage estimates were computed for structures and contents of various types of physical properties classified as residential, commercial, public, or industrial. Damages were also estimated for vehicles, utilities, and roads, as well as other costs associated with post disaster recovery. Intangible damages were not evaluated. Benefits not evaluated include erosion, reduced fill, fill, aesthetics, affluence, or intensification.

Single Occurrence Damages

A summary of damages expected to accrue from various flood events along the main stem and tributaries of Clear Creek is displayed in Table 3. These values represent damages expected for individual events under the without-project, near-term hydrologic condition and include structure and content damages, as well as other benefit categories. Similarly, Table 4 displays the summary of single occurrence damages by event for the tributaries in the future hydrologic condition. The detailed single occurrence damages for the main stem and tributaries individually are shown in Enclosure 1 to the Economic Appendix. That enclosure details the single occurrence damages in both the near-term and FWOP conditions as well.

In comparing Table 1 and Table 3, the 50 percent AEP flood, or 2-year event, produces an estimated $532,000 in residential damages (Table 3); however, Table 1 shows that only one residential structure in the 50 percent AEP flood zone. This structure has a total value of structures and contents of $143,000, making the damages seem illogical. The reason for the high level of damages at the 50 percent AEP flood event is that some structure depth-percent damage curves have start-of-damages below the structure's first floor. In fact, some depth-percent damage curves have start-of-damages at -2.0 feet below the first floor (i.e. mobile homes). Structures are assigned to the flood zone coinciding with their finished floor elevation. Single event damages are being incurred with a 50 percent AEP event by structures that actually sit in a higher flood zone. This same effect is carried throughout all the flood zones but is not as readily apparent in the tables as with the 50 percent AEP event.

Table 3
Single Occurrence Damages by Event
Without-Project 2020 Condition
Clear Creek – Sum of Mainstem and All Tributaries
(Dollar Values in $1,000s, Oct 2011 Price Level)

	Annual Exceedance Probability Events							
Damage Category	50% or "2-Year"	20% or "5-Year"	10% or "10-Year"	4% or "25-Year"	2% or "50-Year"	1% or "100-Year"	0.4% or "250-Year"	0.2% or "500-Year"
Residential	$532.0	$11,027.1	$36,320.7	$76,160.8	$117,701.6	$167,019.8	$242,603.8	$328,203.9
Public	$0.1	$1.7	$20.2	$64.2	$97.6	$111.3	$1,754.4	$2,799.9
Commercial	$8.2	$480.1	$1,793.0	$3,644.1	$5,434.6	$6,580.9	$10,260.9	$15,066.6
Industrial	$0.0	$0.9	$588.5	$4,404.9	$6,634.9	$6,673.8	$7,447.8	$14,042.2
Damages to Structures, Contents	$540.3	$11,509.8	$38,722.5	$84,274.1	$129,868.6	$180,385.7	$262,066.9	$360,112.5
Postdisaster Recovery Costs	$413.4	$4,533.6	$11,995.0	$23,093.7	$35,054.8	$47,976.6	$65,899.4	$81,260.0
Utilities	$15.6	$170.6	$451.6	$869.4	$1,319.7	$1,806.2	$2,480.9	$3,059.2
Vehicles	$0.8	$565.6	$1,982.5	$4,906.0	$8,756.2	$13,506.2	$23,070.8	$39,107.9
Roads	$327.5	$801.3	$1,448.5	$2,087.4	$2,580.1	$3,108.6	$4,111.9	$7,273.4
Total Damages by Event	$1,297.6	$17,580.9	$54,600.0	$115,230.5	$177,579.5	$246,783.4	$357,630.0	$490,813.1
Percent Distribution by Event								
Residential	41.0%	62.7%	66.5%	66.1%	66.3%	67.7%	67.8%	66.9%
Public	0.0%	0.0%	0.0%	0.1%	0.1%	0.0%	0.5%	0.6%
Commercial	0.6%	2.7%	3.3%	3.2%	3.1%	2.7%	2.9%	3.1%
Industrial	0.0%	0.0%	1.1%	3.8%	3.7%	2.7%	2.1%	2.9%
Postdisaster Recovery Costs	31.9%	25.8%	22.0%	20.0%	19.7%	19.4%	18.4%	16.6%
Utilities	1.2%	1.0%	0.8%	0.8%	0.7%	0.7%	0.7%	0.6%
Vehicles	0.1%	3.2%	3.6%	4.3%	4.9%	5.5%	6.5%	8.0%
Roads	25.2%	4.6%	2.7%	1.8%	1.5%	1.3%	1.1%	1.5%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Note: Individual numbers may not sum to totals due to rounding.

Table 4
Single Occurrence Damages by Event
Without-Project 2070 Condition
Clear Creek – Sum of Mainstem and All Tributaries
(Dollar Values in $1,000s, Oct 2011 Price Level)

	Annual Exceedance Probability Events							
Damage Category	50% or "2-Year"	20% or "5-Year"	10% or "10-Year"	4% or "25-Year"	2% or "50-Year"	1% or "100-Year"	0.4% or "250-Year"	0.2% or "500-Year"
Residential	$1,882.8	$20,553.2	$47,508.4	$94,858.8	$142,524.2	$218,641.2	$300,207.1	$371,428.6
Public	$0.4	$9.4	$26.7	$92.9	$108.6	$617.6	$2,440.5	$2,785.6
Commercial	$45.1	$746.4	$2,195.6	$4,101.1	$5,988.3	$8,177.4	$12,883.1	$16,723.5
Industrial	$0.0	$33.7	$945.8	$6,061.8	$6,115.0	$10,716.1	$17,958.6	$23,440.3
Damages to Structures, Contents	$1,928.4	$21,342.7	$50,676.5	$105,114.6	$154,736.1	$238,152.2	$333,489.4	$414,378.0
Postdisaster Recovery Costs	$1,034.9	$7,814.0	$14,946.7	$28,926.3	$42,382.9	$58,015.7	$76,343.5	$91,418.7
Utilities	$38.8	$294.2	$562.7	$1,089.0	$1,595.6	$2,184.1	$2,874.1	$3,441.6
Vehicles	$9.3	$976.2	$2,816.6	$6,394.6	$10,698.8	$21,832.1	$33,803.2	$44,506.3
Roads	$511.5	$1,155.7	$1,687.3	$2,285.1	$2,787.3	$3,284.0	$5,532.8	$7,245.9
Total Damages by Event	$3,522.8	$31,582.8	$70,689.7	$143,809.6	$212,200.7	$323,468.2	$452,043.0	$560,990.5
Percent Distribution by Event								
Residential	53.4%	65.1%	67.2%	66.0%	67.2%	67.6%	66.4%	66.2%
Public	0.0%	0.0%	0.0%	0.1%	0.1%	0.2%	0.5%	0.5%
Commercial	1.3%	2.4%	3.1%	2.9%	2.8%	2.5%	2.8%	3.0%
Industrial	0.0%	0.1%	1.3%	4.2%	2.9%	3.3%	4.0%	4.2%
Postdisaster Recovery Costs	29.4%	24.7%	21.1%	20.1%	20.0%	17.9%	16.9%	16.3%
Utilities	1.1%	0.9%	0.8%	0.8%	0.8%	0.7%	0.6%	0.6%
Vehicles	0.3%	3.1%	4.0%	4.4%	5.0%	6.7%	7.5%	7.9%
Roads	14.5%	3.7%	2.4%	1.6%	1.3%	1.0%	1.2%	1.3%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Note: Individual numbers may not sum to totals due to rounding.

The Hydrologic Engineering Center's Flood Damage Analysis Version 1.2.5 release (HEC-FDA) was modified to assure that no damages are being accrued to the 1-year event (100 percent AEP event). This was done by adding a line under the exceedance probability-discharge portion of HEC-FDA corresponding to a 0.999 probability and a corresponding nondamaging flow. This method is recommended by the Hydrologic Engineering Center as the best method to assure no 1-year damages accrue. This modification was prepared by H&H personnel during input of H&H data into HEC-FDA to ensure correctness.

Additional measures were taken to ensure that damages are not being overstated in the 2-year event (50 percent AEP event). For structures that are low-lying, the associated depth-damage curve was altered by zeroing-out the percent damage below the first floor. In addition, the ground elevations of all structures located in the frequent events were re-checked and corrected (if necessary) for the final analysis.

In the without-project 2020 condition, a 1 percent AEP event is expected to cause approximately $180 million in structural damages. The value of properties located in the 1 percent AEP floodplain is on the order of $350 million. Damages to structures and contents as a percent of total value of the structures and contents are approximately 51 percent. The average value of the floodplain properties in the 1 percent AEP floodplain is $95,000.

In the without-project 2070 condition, a 1 percent AEP event is expected to cause approximately $238 million in structural damages. The value of properties located in the 1 percent AEP floodplain is on the order of $504 million. Damages to structures and contents as a percent of total value of the structures and contents are approximately 47 percent. The average value of the floodplain properties in the 1 percent AEP floodplain is $103,000.

Expected Annual and Average Annual Equivalent (AAE) Damages

Expected annual and AAE damages over the 50-year period of analysis are presented for the without-project or base condition in Table 5 for the main stem and Table 6 for the tributaries inventoried. These damages reflect damages accruing to structures and their contents, utilities, vehicles, roads, and costs associated with post-disaster recovery. As can be seen in Table 5 over two-thirds of the damages along the main stem are concentrated within the three reaches numbered 15, 17, and 18.

As shown in Table 6, over 95 percent of the damages along Mud Gully are concentrated in reaches numbered 1 and 2. Over 50 percent of the damages for Turkey Creek are concentrated

Table 5
Expected Annual and Average Annual Equivalent Damages
All Damage Categories
Without-Project Condition
Clear Creek Main Stem
(Values in 1000s, Oct 2011 Price Levels)

TRIBUTARY & REACH	LOWER LIMIT NEAR	UPPER LIMIT NEAR	EXPECTED ANNUAL DAMAGES		EQUIVALENT ANNUAL DAMAGES, 4.0%	PERCENT DISTRIBUTION
			2020	2070		
MAIN STEM						
1	GALVESTON BAY	ROSEWOOD	$105	$138	$116	1.0%
2	ROSEWOOD	BAL HARBOR	$84	$111	$93	0.8%
3	BAL HARBOR	FM 270	$88	$106	$94	0.8%
4	FM 270	SH 3	$118	$125	$121	1.0%
5	SH 3	IH 45	$0	$0	$0	0.0%
6	IH 45	W BAY AREA BLVD	$179	$185	$181	1.6%
7	W BAY AREA BLVD	FM 528	$589	$658	$612	5.3%
8	FM 528	WHISPERING PINES	$331	$370	$344	3.0%
9	WHISPERING PINES	NEAR MARY'S CRK	$210	$241	$220	1.9%
10	NEAR MARY'S CRK	FM 2351	$330	$398	$353	3.1%
11	FM 2351	NEAR TURKEY CRK	$49	$59	$52	0.5%
12	NEAR TURKEY CRK	DIXIE FARM RD	$107	$125	$113	1.0%
13	DIXIE FARM RD	COUNTRY CLUB DR	$766	$835	$789	6.8%
14	COUNTRY CLUB DR	BENNIE KATE	$159	$175	$164	1.4%
15	BENNIE KATE	SH 35	$3,428	$3,655	$3,505	30.4%
16	SH 35	MYKAWA	$294	$294	$294	2.5%
17	MYKAWA	STONE RD	$1,078	$1,118	$1,091	9.5%
18	STONE RD	SH 288	$2,965	$3,526	$3,154	27.3%
19	SH 288	ALMEDA SCHOOL RD	$235	$251	$240	2.1%
		SUBTOTAL - Mainstem	$11,115	$12,370	$11,537	100%

Note: Includes damages to structures, contents, vehicles, utilities, roads and post disaster recovery costs. Does not include NFIP benefits.
Individual numbers may not sum to totals due to rounding.

Table 6
Expected Annual and Average Annual Equivalent Damages
All Damage Categories
Without-Project Condition
Clear Creek Tributaries
(Values in 1000s, Oct 2011 Price Levels)

TRIBUTARY & REACH	LOWER LIMIT NEAR	UPPER LIMIT NEAR	EXPECTED ANNUAL DAMAGES		EQUIVALENT ANNUAL DAMAGES, 4.0%	PERCENT DISTRIBUTION
			2020	2070		
MUD GULLY						
1	90 DEGREE TURN SW	HALL RD	$1,209	$1,504	$1,076	61.4%
2	HALL RD	BELTWAY 8	$839	$999	$606	34.6%
3	BELTWAY 8	KINGSPOINT	$90	$115	$51	2.9%
4	KINGSPOINT	UPPER LIMIT	$443	$625	$20	1.1%
		SUBTOTAL - Mud Gully	$2,581	$3,242	$1,753	100.0%
TURKEY CREEK						
1	START	NYACK	$68	$115	$84	13.5%
2	NYACK	SCARSDALE	$76	$124	$92	14.8%
3	SCARSDALE	BELTWAY 8	$96	$148	$114	18.3%
4	BELTWAY 8	SAGEDOWNE	$284	$427	$332	53.4%
		SUBTOTAL - Turkey Creek	$525	$813	$622	100.0%
MARY'S CREEK						
1	EDDEWOOD DR.	COUNTY LINE	$78	$87	$81	1.6%
2	COUNTY LINE	LONGHERRIDGE DR	$925	$1,396	$1,084	20.7%
3	LONGHERRIDGE DR.	AT&SF RR	$1,273	$2,151	$1,568	30.0%
4	AT&SF RR	HARKEY RD	$853	$1,373	$1,028	19.6%
5	HARKEY RD	CHARLES AVE	$1,342	$1,736	$1,474	28.2%
		SUBTOTAL - Mary's Creek	$4,471	$6,743	$5,235	100.0%

Note: Includes damages to structures, contents, vehicles, utilities, roads and post disaster recovery costs. Does not include NFIP benefits.
Individual numbers may not sum to totals due to rounding.

Table 6 (continued)
Expected Annual and Average Annual Equivalent Damages
All Damage Categories
Without-Project Condition
Cleear Creek Tributaries
(Values in 1000s, Oct 2011 Price Levels)

TRIBUTARY & REACH	LOWER LIMIT NEAR	UPPER LIMIT NEAR	EXPECTED ANNUAL DAMAGES 2020	EXPECTED ANNUAL DAMAGES 2070	EQUIVALENT ANNUAL DAMAGES, 4.0%	PERCENT DISTRIBUTION
COWART CREEK						
1	CASTLEWOOD	SUNSET DR	$28	$31	$29	9.6%
2	SUNSET DR	COUNTY LINE	$100	$110	$102	34.5%
3	COUNTY LINE	800 CFS LIMIT	$163	$174	$166	55.9%
		SUBTOTAL - Cowart Creek	$290	$316	$297	100.0%
CHIGGER CREEK						
1	FM 518	GREENBRIAR	$81	$101	$88	28.9%
2	GREENBRIAR	NARINA	$35	$41	$37	12.0%
3	NARINA	CONFLUENCE W/ BYPASS (800 CFS LIMIT)	$176	$186	$179	59.0%
4	CONFLUENCE WITH BYPASS	BRAZORIA COUNTY LINE	$0	$0	$0	0.0%
5	BRAZORIA COUNTY LINE	HEADWATERS OF STREAM	$0	$0	$0	0.0%
		SUBTOTAL - Chigger Creek	$292	$328	$304	100.0%
TOTAL - MAIN STEM AND ALL TRIBUTARIES			**$19,274**	**$23,812**	**$19,748**	

Note: Includes damages to structures, contents, vehicles, utilities, roads and post disaster recovery costs. Does not include NFIP benefits.
Individual numbers may not sum to totals due to rounding.

within Reach 4. Additionally, Table 6 shows the damages on Marys Creek relatively evenly distributed throughout the tributary's Reaches 2 through 4 with little damage in Reach 1. Approximately 55 to 60 percent of the damages incurred along Cowart Creek and Chigger Creek are coincidentally centered in Reach 3 of both of the tributaries.

It should be noted, once again, that the increase in damages occurring over the period of analysis is attributed solely to increases in runoff. No projections were made on the economic side of the analysis (i.e. the floodplain investment remains as it currently stands). Overall, there is an increase in damages of 38 percent from 2020 to 2070. This is equivalent to an average annual growth in damages of approximately 0.65 percent.

As seen from Table 6, Marys Creek has the most significant increase in damages between the 2020 and 2070 condition with a 63 percent increase in damages. Investigation of the water surface elevations reveals that the average increase in water surface elevation between 2020 and 2070 is less than 0.5 feet for the 100-year event (1 percent AEP event) on Marys Creek. The increase in the number of structures inundated by that slight increase in water surface is almost 900 structures. The increase in damages is simply due to the distribution of structures and the flat nature of the floodplain. With the Clear Creek floodplain, a small increase in flood depth (i.e. less than 0.5 feet) can cause hundreds of additional structures to be inundated.

ENVIRONMENTAL IMPACT STATEMENT

An environmental impact statement (EIS) will document environmental resources and potential impacts from any recommended plan as a result of the general reevaluation. The Clear Creek Project study area is located in Harris, Galveston, Brazoria, and Fort Bend counties in southeast Texas. While previous authorizations have focused on the immediate Clear Creek channel, the general reevaluation study may involve not only Clear Creek but various locations within the watershed. Therefore, the project study area encompasses the Clear Creek watershed, including Clear Creek, its tributaries, Clear Lake, and the surrounding riparian and upland environments. Clear Creek generally flows from west to east and drains into Clear Lake, which eventually drains into Galveston Bay at Seabrook, Texas. The Clear Creek watershed covers approximately 260 square miles, which is partly inclusive of the City of Houston and surrounding smaller cities such as Pasadena, Pearland, Friendswood, Webster, and League City. The major tributaries to Clear Creek are Mud Gully, Turkey Creek, Marys Creek, Cedar Gully, Cowart Creek, Chigger Creek, and Magnolia Bayou.

BASELINE (AFFECTED ENVIRONMENT) AND WITHOUT-PROJECT (NO ACTION) CONDITIONS

Likely controversial issues linked to the project are potential impacts to fish and wildlife habitat and resources, water and sediment quality, flooding, air quality, recreation, and aesthetics.

Without project implementation, air quality within the area will continue at current trends. The Clear Creek watershed is within a nonattainment area for ozone. Although mobile emission sources are expected to increase in the area, EPA standards for cleaner burning engines and fuel sources are expected to reduce emissions. Over the past 15 years, ozone-monitored values have decreased, despite a 36 percent increase in area population from 1991 to 2005. This trend is expected to continue through year 2019 due to reductions imposed by the state in its implementation plan control requirements for the area.

Under the FWOP condition, reduced water quality, habitat loss, and flooding would continue. There would be no opportunity to maintain or construct grassy, vegetated channel flood benches and side slopes or shady riparian low-flow channels to help reduce turbidity by decreasing erosion during flood events. Future flood damages would continue for those homes constructed prior to joining the NFIP. Other homes would also be impacted during flood events that exceed the capacity of the existing conveyance and detention measures in the watershed. As a result of these large flood events, frequency and velocities of episodic flooding in the area will increase.

A more complete description of the affected environment and FWOP condition for the study may be found in the attached Supplemental Draft EIS Clear Creek Flood Control Project Brazoria, Fort Bend, Galveston, and Harris Counties, Texas.

USE OF ECOLOGICAL MODELS – COMMUNITY-BASED HABITAT EVALUATION PROCEDURE

As part of the reevaluation study and environmental impact assessment of the proposed project, ecological modeling was conducted to evaluate impacts and benefits of flood risk management features and mitigation measures. An ICT was established to: (1) identify environmental issues and concerns; (2) evaluate the significance of fish and wildlife resources and select resources; (3) recommend and review environmental studies; (4) evaluate potential impacts; and (5) recommend and evaluate potential mitigation measures. Members of the ICT include the USFWS, NMFS, NRCS, EPA, TPWD, GLO, TCEQ and non-Federal Sponsors.

The ICT identified floodplain forest as the priority ecosystem habitat for assessment within the Clear Creek watershed. The floodplain forest includes riparian areas along Clear Creek and its tributaries and the adjacent forest woodlands and wetlands. Much of this forest community immediately within and adjacent to Clear Creek remains intact, despite development within the region. This ecosystem is of particular interest for assessment as public concerns regarding potential impacts to these resources, caused by the previously authorized project, led to the initiation of the current study. The ICT defined the study area for assessment of impact and mitigation alternatives generally as the 0.2 percent AEP (500-year) floodplain to include all areas of floodplain forest likely to be affected by the proposed project (Figure 12).

With assistance and guidance from the ERDC Environmental Laboratory, the ICT conducted a series of workshops over the course of two years to develop a community-specific model to characterize baseline conditions of the floodplain forest and coastal prairie ecosystems within the study area during plan formulation and alternative assessment. The community-based model developed for these ecosystems utilized the HEP. HEP was chosen as the most appropriate ecological modeling procedure based on a number of factors. HEP provides a framework for the use of community-specific models; each with a unique set of variables. Variables included in the community model were selected based on their potential to capture changes to ecosystem integrity within a water, soils, habitat structure, and/or landscape context in response to land and water management activities within the study area.

The floodplain forest community HEP model includes variables that measure or categorize the following: alterations to hydrology, degree of stream erosion, landscape imperviousness, landscape/vegetation roughness, stream sinuosity, stream substrate, stream water depth, tree canopy cover, overhead cover along the stream edge, instream cover, nativeness of vegetation, degree of vegetation layering, adjacent land use (i.e. disturbance), percent wetlands, average area of individual patches of prairie, as well as average core and edge of forest patches, and distance to neighboring forests (fragmentation).

The HEP community-based model approach produces quantitative data and can be run for varying conditions or scenarios. Existing (baseline), FWOP, future with-project and mitigated future with-project conditions may be assessed separately for comparison. The data are formatted in a Geographic Information Systems software (GIS), so map displays and acreage calculations for all scenarios are produced. A more complete description of the community-based HEP model for the project and its development process is presented in a technical report by ERDC in Appendix D. The models utilized in these analyses were provided to the Ecosystem Restoration Planning Center of Expertise (PCX) and approval for one time use was granted.

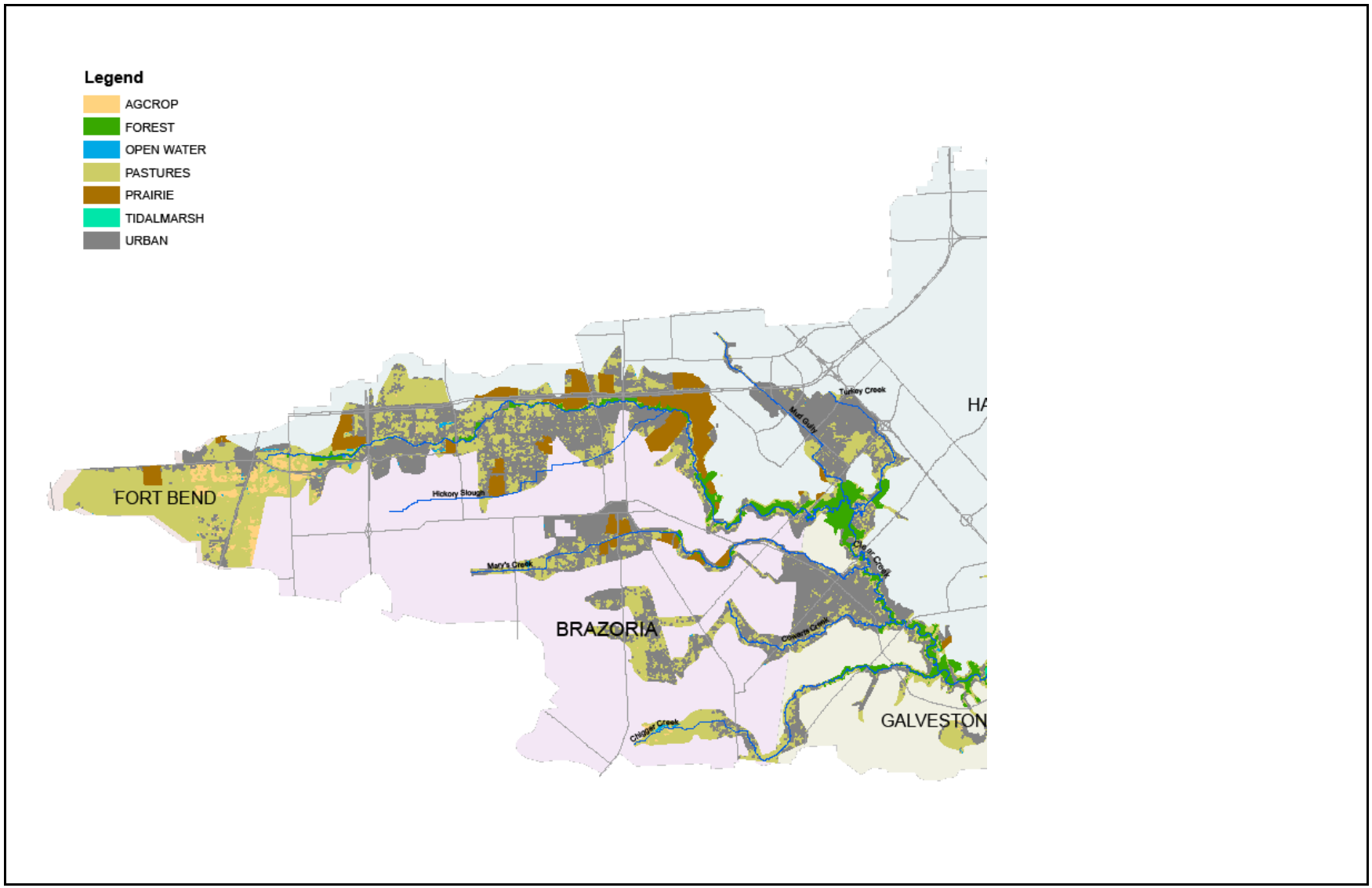


Figure 12. Habitat Study Area Utilized in HEP Modeling

The environmental baseline (year 2000) and without-project acres for the floodplain forest ecosystem located within the habitat assessment area are provided in Table 7.

Table 7. Future Without-Project Acres for Floodplain Forest within the Clear Creek Project Habitat Assessment Area

Habitat Type	**Year**					**Net Change**
	2000	2020	2030	2055	2070	
	Total Acres in Habitat Study Area					
Floodplain Forest	3,802	3,326	3,096	2,508	2,155	-1,647

V. PLAN ASSESSMENT AND SCREENING OF ALTERNATIVES

USACE guidance requires that, "(t)he planning process shall address the Nation's water resources needs in a systems context and explore a full range of alternatives in developing solutions". This involves a comparison between each alternative and the FWOP condition consequences, considering economic, environmental, and social impacts. Based on this requirement alternatives were identified that include both structural and nonstructural opportunities.

The following describes the alternative plans that were considered for the Clear Creek Project. This includes the Authorized Federal Project (AFP) alternative and the SPA plan, which were considered in the 1980s and 1990s and which led to the decision to implement the General Reevaluation Study. Additionally, nonstructural alternatives were considered both alone and in combination with a new structural alternative, the General Reevaluation Plan (GRP). As a result, nine alternatives were considered and are discussed below:

- No Action Alternative
- AFP Alternative
- SPA
- three nonstructural buyout options
- a structural alternative (the GRP)
- the GRP combined with two nonstructural buyout options

The nine alternatives are described in the following subsections. The screening process used to identify the flood risk control measures that have been combined to form the GRP is also described.

NO ACTION ALTERNATIVE

The No Action Alternative would allow Clear Creek and its tributaries to remain in their current configuration. Development upstream of Clear Lake will continue to increase the amount of impervious cover in the study area, increasing flows into Clear Creek. These increased flows will continue to cause increases in water elevation sufficient to cause flooding in many areas. Many of the upstream municipalities in the watershed have incorporated policies to ensure no future impacts due to development at certain flood levels. These policies require certain levels of detention that prevent flow from newly created, impervious areas entering Clear Creek or its tributaries quickly. Some of the downstream communities have not incorporated these policies. These policies will likely ensure that there are no significant increases at certain levels. However,

the capacity of the detention areas can be exceeded by certain flood events, causing eventual increases in future damages.

Under the No Action Alternative, reduced water quality, habitat loss, and flooding would continue to worsen. There would be no opportunity for flood risk management measures to help reduce turbidity by decreasing erosion during flood events. Future flood damages would not be reduced in the area and flooding may continue to increase due to continued urban development (despite local regulations on new developments in some areas) and increased impervious cover, which would reduce the watershed's natural detention capacity. As a result, frequency and velocities of episodic flooding in the area would increase. Flood flows may peak at higher velocities, which would increase erosive forces on stream banks and bottoms and significant bank erosion may occur, resulting in additional sedimentation.

One important aspect of the No Action Alternative is the existence of the Second Outlet Channel and Gate Structure between Clear Lake and Galveston Bay. The Second Outlet Channel and Gate Structure are located on the bayward side of SH 146 and provides additional drainage capacity so the upstream improvements on Clear Creek do not increase flooding in the Clear Lake area. This channel and gate structure is 6,000 feet long, 70 feet wide, and 16 feet deep.

The Second Outlet Channel and Gate Structure are components of the AFP that were actually constructed and became operational prior to the initiation of this reevaluation study. The gates are kept closed under "normal" conditions (i.e., no significant rainfall) to prevent environmental impacts from a second tidal outlet to Galveston Bay. The HCFCD staff monitors the conditions in the watershed using rainfall and stage gages, along with information from other sources. Using set operation criteria, the gates will be opened to prevent certain lake level increases. The lake level estimates are based on actual and predicted rainfall, actual water levels in the lake and upstream, as well as tide forecasts.

Modifications to the gate structure were evaluated as alternatives to further reduce flood risk. As this is an existing structure, the gate in its current configuration was incorporated into the No Action Alternative. Performing the analysis in this manner allows the analysis to document what impacts modifications to the previously constructed feature would have on any additional recommended flood risk management features, while taking into account benefits already generated by the second outlet.

AUTHORIZED FEDERAL PROJECT ALTERNATIVE

The AFP Alternative is described in detail in the Preconstruction Authorization Planning Report dated May 1982. The AFP includes 22 miles of modifications to the Clear Creek channel to improve conveyance including nonstructural measures and a requirement for the non-Federal Sponsors to manage the residual 100-year floodplain. An additional channel opening between Clear Lake and Galveston Bay was incorporated into the AFP to ensure that upstream channel improvements did not contribute to flooding around Clear Lake. This channel opening is referred to as the Second Outlet and Gate Structure or second outlet. The project was designed to contain a 10 percent annual exceedance flood for future watershed development conditions. Conveyance from Mykawa Road to Clear Lake consisted of a trapezoidal earth channel with bottom widths ranging from 70 to 130 feet (Table 8). The Second Outlet was designed to ensure that flows would continue into Galveston Bay without impacting houses around Clear Lake. The channel was gated to ensure that Clear Lake did not experience an increase in salinity due to water flowing in from the bay during high tide circumstances. In 1986 a LCA was signed by the non-Federal Sponsors (HCFCD and Galveston County) and the USACE to construct the 14-mile reach of the project downstream of Dixie Farm Road. Because of concerns raised by the public, non-Federal Sponsors, and agencies regarding potential environmental effects of the AFP, construction of the AFP was halted; the Second Outlet Channel and Gate Structure were the only features constructed. The non-Federal Sponsors also modified bridges and adjusted pipelines to facilitate construction of the remainder of the project.

Table 8
Bottom Widths of
AFP Alternative Reaches

Upper end of Clear Lake (start of project) to Hwy 3	115 feet
Hwy 3 to Whispering Pines	130 feet
Whispering Pines to Farm-to-Market (FM) 2351	120 feet
FM 2351 to confluence of Turkey Creek	100 feet
Turkey Creek to confluence of Mud Gully	75 feet
Mud Gully to Dixie Farm Rd	70 feet

SPONSOR PROPOSED ALTERNATIVE

In response to concerns raised about impacts associated with the AFP, the non-Federal Sponsors requested that construction of the AFP halt so a revised plan with reduced environmental impacts could be developed. Thus, the SPA was developed and introduced in 1997 as an alternative to the AFP. The SPA proposed a trapezoidal channel that generally followed the same alignment as the

AFP with reduced bottom widths (30 to 80 feet) (Table 9) and an added bypass channel to avoid impacts to a natural reach of Clear Creek near the Friendswood area. The bypass channel provided the additional flood capacity without channelizing this portion of the creek.

Table 9
Bottom Widths of SPA Reaches

Upper end of Clear Lake (start of project) to FM 270	80 feet
FM 270 to IH-45	60 feet
IH-45 to FM 2351	80 feet
FM 2351 to confluence of Mud Gully	60 feet
Mud Gully to 0.3 miles upstream of Mud Gully	40 feet
0.3 miles upstream of Mud Gully to Dixie Farm Rd	30 feet

NONSTRUCTURAL ALTERNATIVES

Nonstructural measures were investigated throughout the plan formulation process. Considering the age of the structures inventoried within the study area and the number of commercial structures involved, raising-in-place and relocation were not considered viable options. Thus, structure removal from floodplain areas was further evaluated. Structures prone to flooding from the 50 percent, 20 percent, and 10 percent (2-, 5-, and 10-year, respectively) AEP floodplains would be removed. Removal of these structures would include buy-outs at fair market value.

Based on the experience of the Galveston District with structure removal or buyouts, the analysis of this alternative assumed various levels of participation. With several factors taken into consideration such as time elapsed since the last flood event and level of previous damages, a level of participation was assigned to help determine the number of structures required for the economic analysis. For the nonstructural alternatives described in the following subsections, the levels of participation were assumed to be 75 percent (low), 85 percent (most likely), and 95 percent (high). Ancillary structures, such as barns and sheds, were removed from consideration. Thus, economic analysis was conducted for each buyout scenario described below.

Fifty Percent AEP Nonstructural Alternative

Under this alternative, structures prone to flooding from the 50 percent (2-year) AEP would be removed. Per the analysis, as described above, the most likely (assumes 85 percent participation) number of structures to be removed under this alternative is five.

Twenty Percent AEP Nonstructural Alternative

Under this alternative, structures prone to flooding from the 20 percent (5-year) AEP would be removed. Per the analysis, as described above, the most likely (assumes 85 percent participation) number of structures to be removed under this alternative is 150.

Ten Percent AEP Nonstructural Alternative

Under this alternative, structures prone to flooding from the 10 percent (10-year) AEP would be removed. Per the analysis, as described above, the most likely (assumes 85 percent participation) number of structures to be removed under this alternative is 467.

Details of the buyout alternatives are included in the Economic Appendix.

GENERAL REEVALUATION PLAN (GRP) ALTERNATIVE

Political and environmental concerns identified for past alternatives that had been considered for the Clear Creek Project led to development of a new structural alternative, referred to as the GRP. The GRP Alternative includes a series of flood risk management measures and mitigation areas. Flood risk management measures include conveyance measures and detention areas on or adjacent to Clear Creek from SH 288 to Dixie Farm Road and on three tributaries: Mud Gully, Turkey Creek, and Marys Creek. Mitigation for the GRP Alternative includes the rehabilitation and reestablishment of floodplain forest. Placement areas would be required for placement of excavated material and would occur outside of the 500-year floodplain in areas that are suitable for placement of excavated material associated with the project.

Development of General Reevaluation Alternative

A three-phased formulation and screening process was used to identify the GRP Alternative:

(1) Phase I: Preliminary Screening – preliminary evaluation and screening of numerous structural and nonstructural components to reduce flood damages,
(2) Phase II: First-added Analysis – refinement, hydraulic and economic evaluation and screening of stand-alone alternatives (i.e., first-added measures) to reduce flood damages, and
(3) Phase III: Second-added Analysis – further refinement and detailed evaluation, and screening of alternatives using high-performing, previously screened, first-added measures in combination with additional measures (i.e., second-added measures).

Phase I: Preliminary Screening - In 2001, the Clear Creek project team began collecting information on potential measures, structural and nonstructural, that could reduce flood damages on the main stem of Clear Creek. The collection of this information was performed through public scoping meetings and meetings with resource agencies.

Clear Creek was divided into 19 economic reaches (Figure 13), delineated by easily identifiable landmarks, in an attempt to identify areas most in need of flood risk management. According to the results of the evaluation, the areas with the highest flood damages under the No Action Alternative are reaches 15 through 18 (City of Pearland) and reaches 7 through 10 (City of Friendswood) (Figure 14).

Based on information obtained through previous public and agency coordination and scoping, the project team developed a list of structural and nonstructural measures that could potentially reduce flood risk in the Clear Creek watershed and allow for environmentally sensitive construction opportunities. Structural measures considered included:

- Detention
- Levee and floodwall construction
- Conveyance improvements
- Bridge modification
- Removal of sidecast excavated material
- Reestablishment of cutoff oxbows
- Construction of bypasses
- Selective clearing of heavily vegetated reaches
- Use of habitat creation for opportunities to reduce flood risk

Nonstructural measures considered included buyouts, raising of structures, floodplain preservation, and the adoption of new watershed management requirements.

The 72 structural and nonstructural flood risk management measures identified were specific to single reach or limited number of adjacent reaches. Criteria for screening these initial components were developed to reduce the number of measures for further evaluation and ensure they meet the four USACE planning criteria of completeness, efficiency, effectiveness, and acceptability. These criteria were Flood Risk Management Effect, Environmentally Sensitive, Acceptability/Aesthetics/Recreational Opportunities, Chance of Success/Cost Effectiveness, and Engineering Implementable. Using these criteria, the measures were rated by project team members with emphasis given to each team member's area of expertise and then weighted as appropriate. The evaluation resulted in a list of 24 stand-alone, flood risk management measures that would encompass all activities ranked as high priority in the initial screening. These

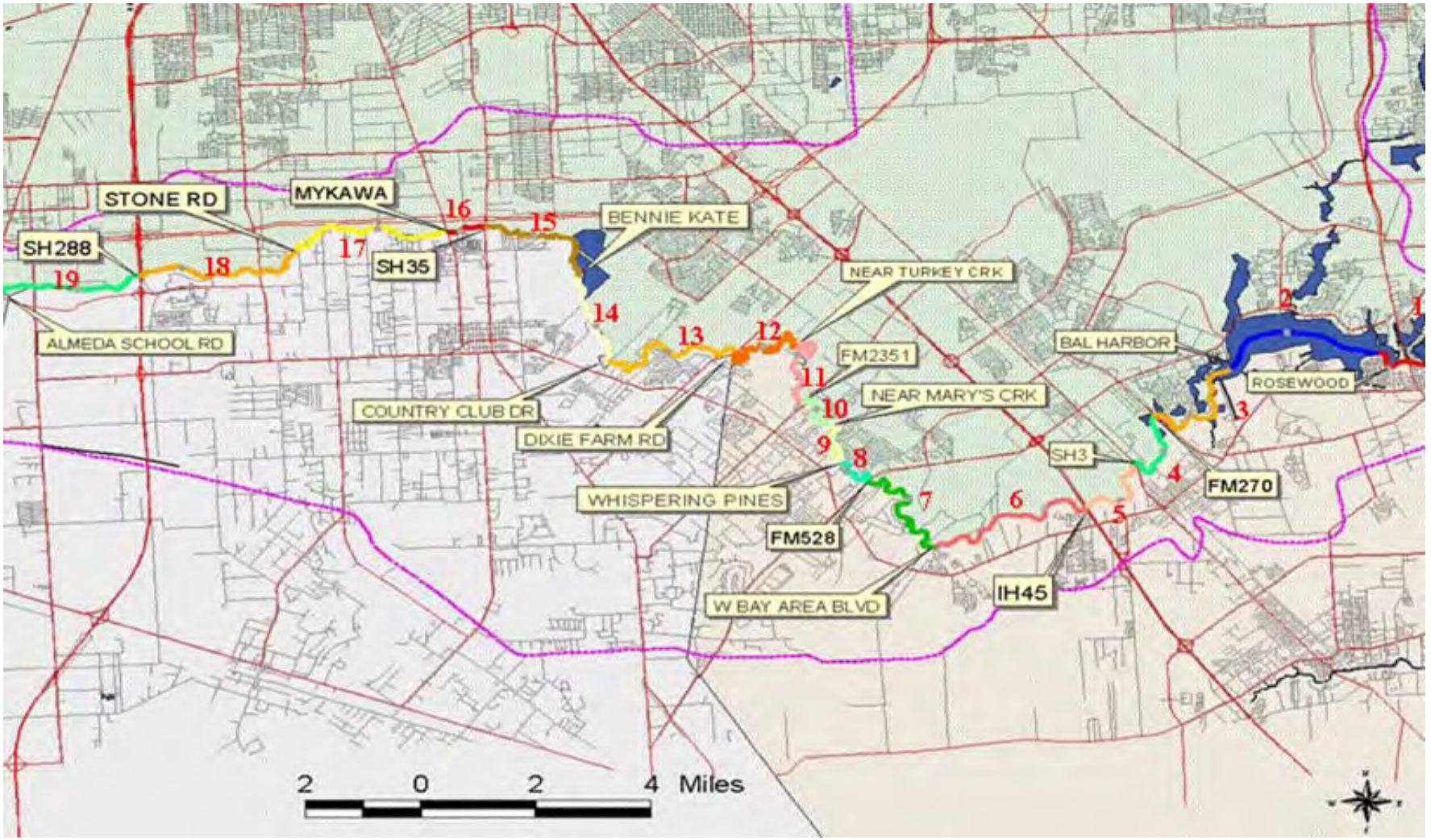
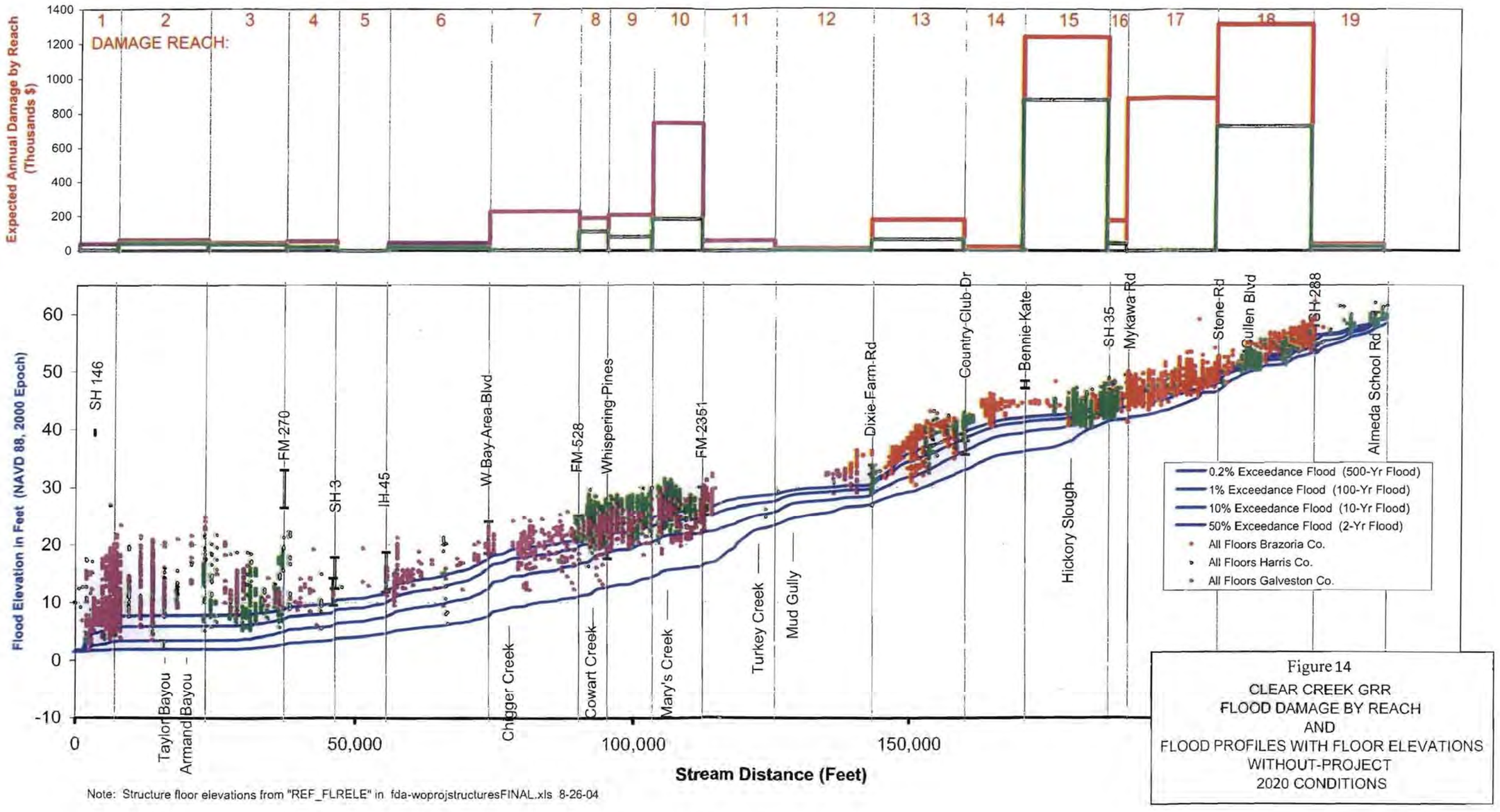


Figure 13
Economic Reaches of Main Stem Clear Creek



Note: Structure floor elevations from "REF_FLRELE" in fda-woprojstructuresFINAL.xls 8-26-04

Figure 14
CLEAR CREEK GRR
FLOOD DAMAGE BY REACH
AND
FLOOD PROFILES WITH FLOOR ELEVATIONS
WITHOUT-PROJECT
2020 CONDITIONS

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measures were carried forward for further evaluation. From these criteria, a list of measures was formulated that would encompass all activities identified as high priority in the initial screening (Appendix E).

Phase II: First-added Analysis - This analysis evaluated the measures on a "first-added" basis, meaning each measure was tested as a stand-alone element. Table 10 lists the 24 structural and nonstructural measures that met the USACE criteria of completeness, efficiency, effectiveness, and acceptability. Figure 15 shows these 24 measures carried forward for further analysis.

Throughout the process, measures were refined to further identify opportunities to reduce flood risk, while preventing environmental damages. Each measure was evaluated on a stand-alone basis for its potential impact to the entire watershed and its capability for reduction of flood damages. The 10 best-ranking first-added measures (i.e., most cost-effective measures that were most successful in reducing flooding) were identified (Figure 16). Only 5 of the 10 highest-ranking, first-added measures had positive net economic benefits:

1) Conveyance Improvement from Stone Road to Bennie Kate Road (C1);
2) Enlargement of High-Flow Bypasses in Reach 9 (EHFB);
3) Buyouts along Clear Creek (Global – Nonstructural) (GBO);
4) Selective Clearing and Snag Removal (CS); and
5) Conveyance Improvement from Downstream of Farm to Market Road (FM) 2351 to West Bay Boulevard (C4)

Detailed descriptions of each measure as well as determination of costs, net excess benefits, and BCRs for each of these measures can be found in the First-added Notebook (Appendix F).

During the analysis of the first-added measures, more detailed information on environmental impacts was becoming available through the use of the environmental model and it became clear that the clearing and snagging alternative created greater riparian impacts than previously estimated, significantly increasing the amount of required mitigation. Due to this, costs were modified and clearing and snagging fell out of further consideration.

Table 10
Measures Included in First Added Analysis

Proposed Measure	**Acronym**
Interstate 45 Bridge Widening	I-45
Expand Existing Detention at Site A521	A521
Additional Clear Lake Outlet Capacity	ACLO
Offline Detention just West of SH 288	B1
Offline Detention just West of Country Club Road	B2
Conveyance Improvement of Main Stem from Stone Road to Bennie Kate Road	C1
Expand Existing Detention at David L Smith Site	DLS1
High Flow Bypass Downstream of Dixie Farm Road	HFB1
Detention on Marys Creek	MC1
Detention on Mud Gully	MG1
Remove Dredged Material/Deepen for Conveyance	RDM1
Detention on Turkey Creek	TC1
Cowart Creek Detention	CWT1
Conveyance Improvement of Main Stem from SH 288 to Stone Road	C2
Linear Detention on Main Stem from Stone Road to Mykawa Road	LD1
Enlarge High Flow By Passes on Main Stem	EHFB
Large Scale Linear Detention on Marys Creek	LD2
Selective Clearing and Snag Removal	CS
Large Scale Linear Detention on Cowart Creek	LD3
Detention on Chiggers Creek	CHG1
Global Watershed Management Practices	GWMP
Conveyance Improvement on Main Stem from Downstream of Country Club Road to FM 528	C3
Conveyance Improvement on Main Stem from Downstream of FM 2351 to West Bay Area Boulevard	C4
Buyouts along Clear Creek	GBO
Legacy Plans	
Sponsor Proposed Alternative	SPA
Authorized Federal Project	AFP

First Added Measures	Description	Type
I45	I-45 on Clear Creek	Bridge Widening
ACLO	Outlet of Clear Creek	Conveyance
C1	From Stone Road to Bennie Kate	Conveyance
C2	Along Clear Creek from SH 288 to Stone Rd.	Conveyance
C3	Downstream of County Club Dr. to F.M. 528	Conveyance
C4	F.M. 2351 to W. Bay Area Blvd.	Conveyance
CS	F.M. 2351 to Downstream of Chigger Creek Confluence	Conveyance
EHFB	F.M. 2351 to F.M. 528	Conveyance
HFB1	Along Clear Creek from Dixie Farm Rd. E. of Beamer Rd.	Conveyance
RDM1	Country Club Dr. to Dixie Farm Rd.	Conveyance
LD1	From Stone Rd. to Mykawa	Linear Detention
LD2	Along Mary's Creek from Centennial Blvd. to Clear Creek	Linear Detention
LD3	Along Cowart Creek from Mansfield Rd. to Clear Creek	Linear Detention
A521	W. of Dixie Farm Rd., N. Side of Clear Creek	Offline Detention
B1	N. Side of Clear Creek, W. of SH 288	Offline Detention
B2	N. Side of Clear Creek, W. of Country Club Dr.	Offline Detention
CHG1	W. of Clear Creek on S. Bank of Chigger Creek	Offline Detention
CWT1	W. of Clear Creek on S. Bank of Cowart Creek	Offline Detention
DLS1	E. of SH 35, S. of Clear Creek	Offline Detention
MC1	W. of Clear Creek on S. Bank of Mary's Creek	Offline Detention
MG1	W. of Dixie Farm Rd.	Offline Detention
TC1	E. of Dixie Farm Rd.	Offline Detention

(Location Not Shown on Map)

GBO	Buyouts along Clear Creek (Global)	Non-structural
GWMP	Watershed Management Practices (Global)	Non-structural

N

LD1
C1
C2
DLS1
MC1
MG1
TC1
B1
B2
RDM1
A521
HFB1
C3
LD2
CS & EHFB
C4
LD3
CWT1
CHG1
I45
ACLO

Legend

Bridge Widening
- I45

Conveyance Alternatives
- ACLO
- C1
- C2
- C3
- C4
- CS
- EHFB1
- HFB1
- RDM1

Linear Detention
- Multiple Alternatives

Offline Detention
- Multiple Alternatives

Note: Locations for all measures are hypothetical and do not indicate an actual proposal.

CLEAR CREEK
GENERAL REEVALUATION REPORT
1ST ADDED MEASURES

Figure 15

Scale: 1:10,000 | July 2004

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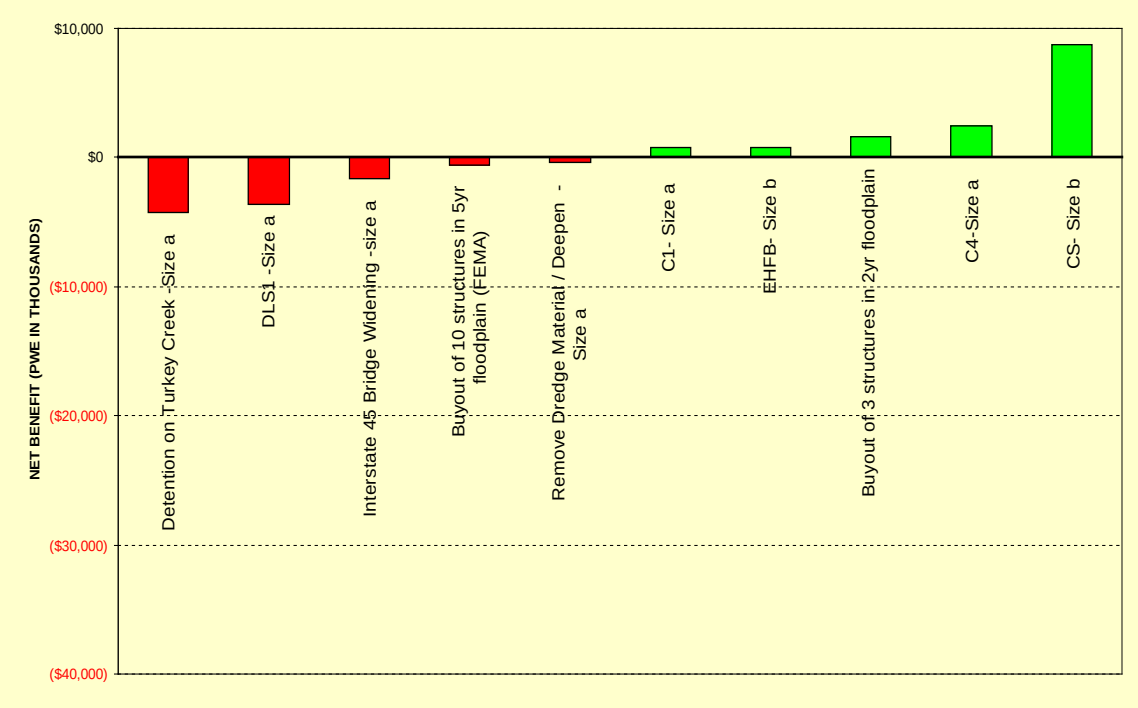


Figure 16
Graphic Representation of Net Excess Benefits
for the 10 Best First-Added Measures

Phase III: Second-added Analysis - The project team concentrated on the most successful, first-added measures and began a series of modifications and combinations called second-added measures to identify the GRP Alternative. The results of the first-added analysis (Phase II) were utilized to identify those measures that were successful on a stand-alone basis and that could then be modified and combined with other measures to reduce flood risk in the high risk reaches of the watershed, while remaining sensitive to environmental impacts. This process identified measures that would come together to work as an overall system. Cost effectiveness was also taken into consideration, which identified those measures that increased conveyance in the most cost-effective manner.

During the evaluation of alternatives, additional information was collected in the watershed including flood damage information on the tributaries and the potential to reduce these damages became clear. Six tributaries were examined for measures that would generate benefits above those seen in the backwater effects of the Clear Creek modification. Each tributary was also divided into economic reaches for evaluation. Figures 17 through 22 identify the economic reaches and structures in the study areas for each of these tributaries. The tributaries added to the

study included Marys Creek (Figure 17), Turkey Creek (Figure 18), Mud Gully (Figure 19), Cowart Creek (Figure 20), Chigger Creek (Figure 21) and Hickory Slough (Figure 22).

Upon further investigation, it was determined that Hickory Slough did not have sufficient flow to be eligible for consideration and Cowart Creek and Chigger Creek did not have sufficient damages to justify Federal involvement. Therefore, these three tributaries were dropped from further consideration as conveyance features. Marys Creek, Turkey Creek, and Mud Gully were identified for additional analysis and inclusion in the second-added phase of the study (Phase III). This second evaluation led to the identification of the most efficient alternative for flood risk management.

The second-added analysis was performed using a series of nine formulation sequences. For each sequence, a series or combination of measures was tested for effectiveness, benefits, and costs. Table 11 is a roadmap detailing the process utilized for identification of the GRP Alternative. Analysis began at the upstream, high-damage reaches of Clear Creek and numerous alternatives were modeled. The highest performing measures that successfully increased benefits (decreased flood damages) greater than estimated costs were added to the system of measures, creating an overall plan that would reduce damages throughout the watershed. Specific results of all analysis are displayed in the Economic Appendix (Appendix B).

The first formulation sequence in the analysis process was the selection and optimization of a Clear Creek upstream anchor component. Based on considerations from the first-added analysis (Phase II), Conveyance Improvement of Main Stem (of Clear Creek) from Stone Road to Bennie Kate Road (Measure C1) was combined with Conveyance Improvement of Main Stem from SH 288 to Stone Road (Measure C2) and identified as an anchor component called Super C. Additional modeling of various sizes of Super C led to the identification of the Super C(d) measure, which generated positive net benefits. Super C(d) is designed to preserve/rehabilitate habitat associated with a low-flow channel.

The second formulation sequence was to test for upper-reach measures to add to Super C(d) for additional flood risk management. This model considered two measures: Measure C5, a benchcut conveyance on Clear Creek from Bennie Kate to Dixie Farm Road (immediately downstream of Super C); and Measure LD4, a linear detention on Clear Creek from Bennie Kate to Dixie Farm Road. Neither of these measures was found to further reduce damages. Therefore, they were not added to the model.

The third and fourth formulation sequences evaluated conveyance measures on Mud Gully, Turkey Creek, and Marys Creek. The measures for each of these tributaries are trapezoidal

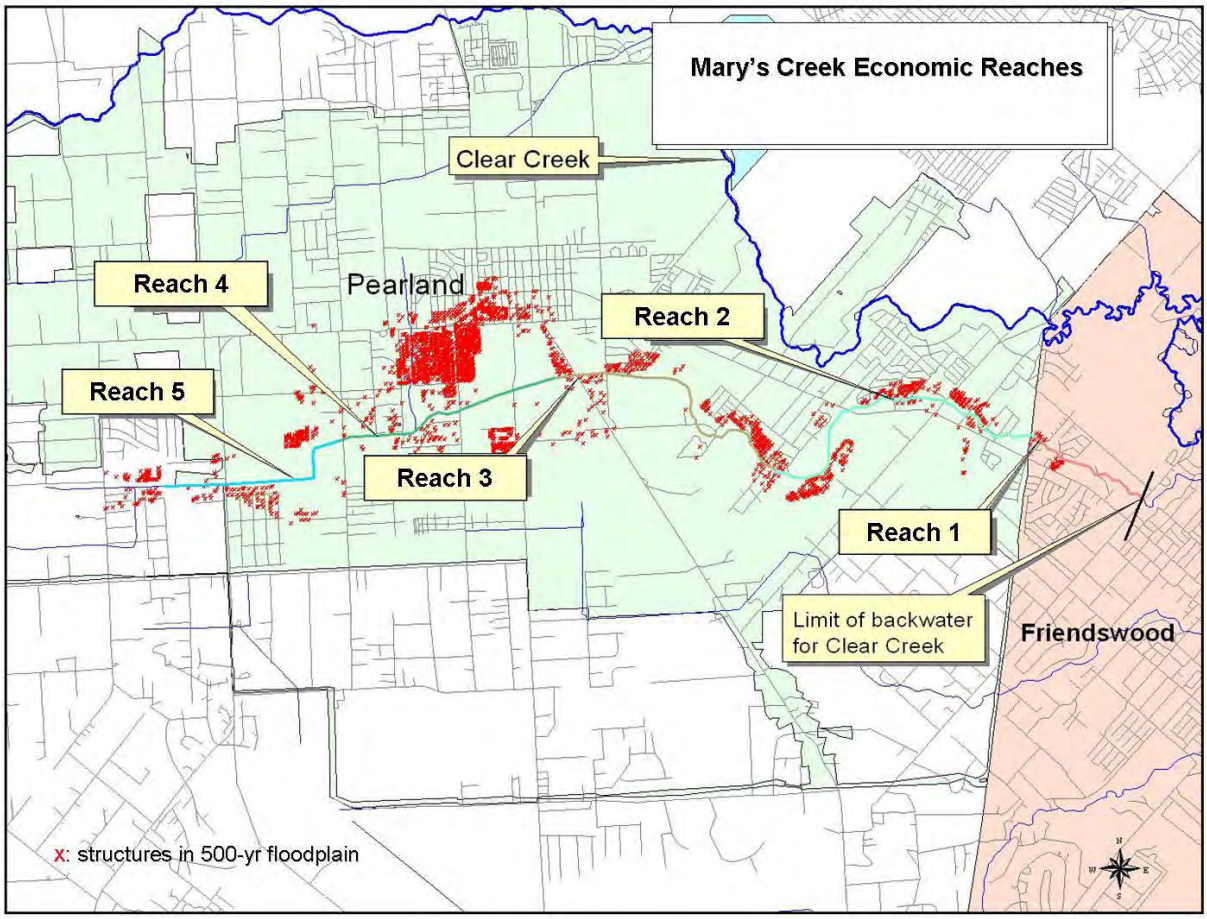


Figure 17
Marys Creek Economic Reaches With
Structures in 0.2 percent (500-year) Annual Exceedance Probability Event

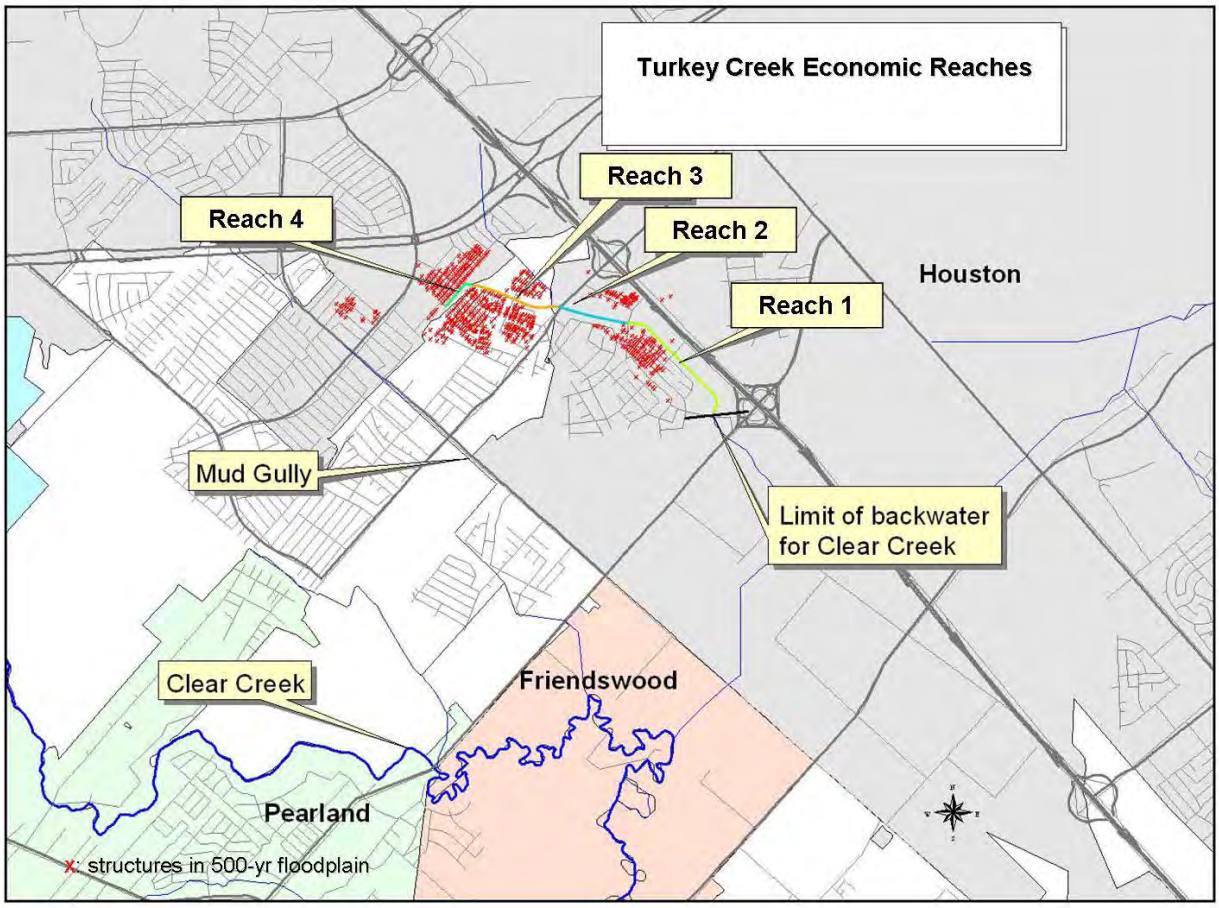


Figure 18
Turkey Creek Economic Reaches With
Structures in 0.2 percent (500-year) Annual Exceedance Probability Event

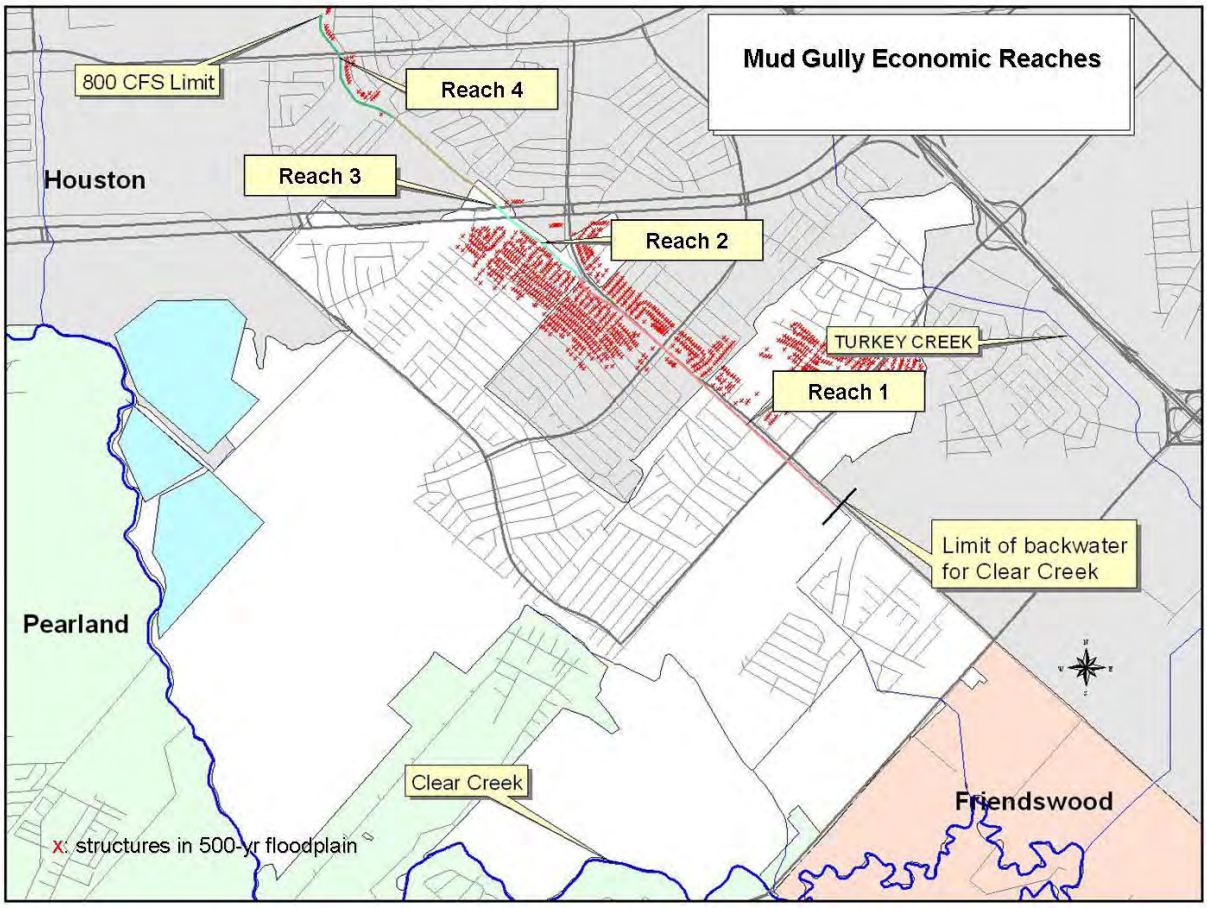


Figure 19
Mud Gully Economic Reaches With
Structures in 0.2 percent (500-year) Annual Exceedance Probability Event

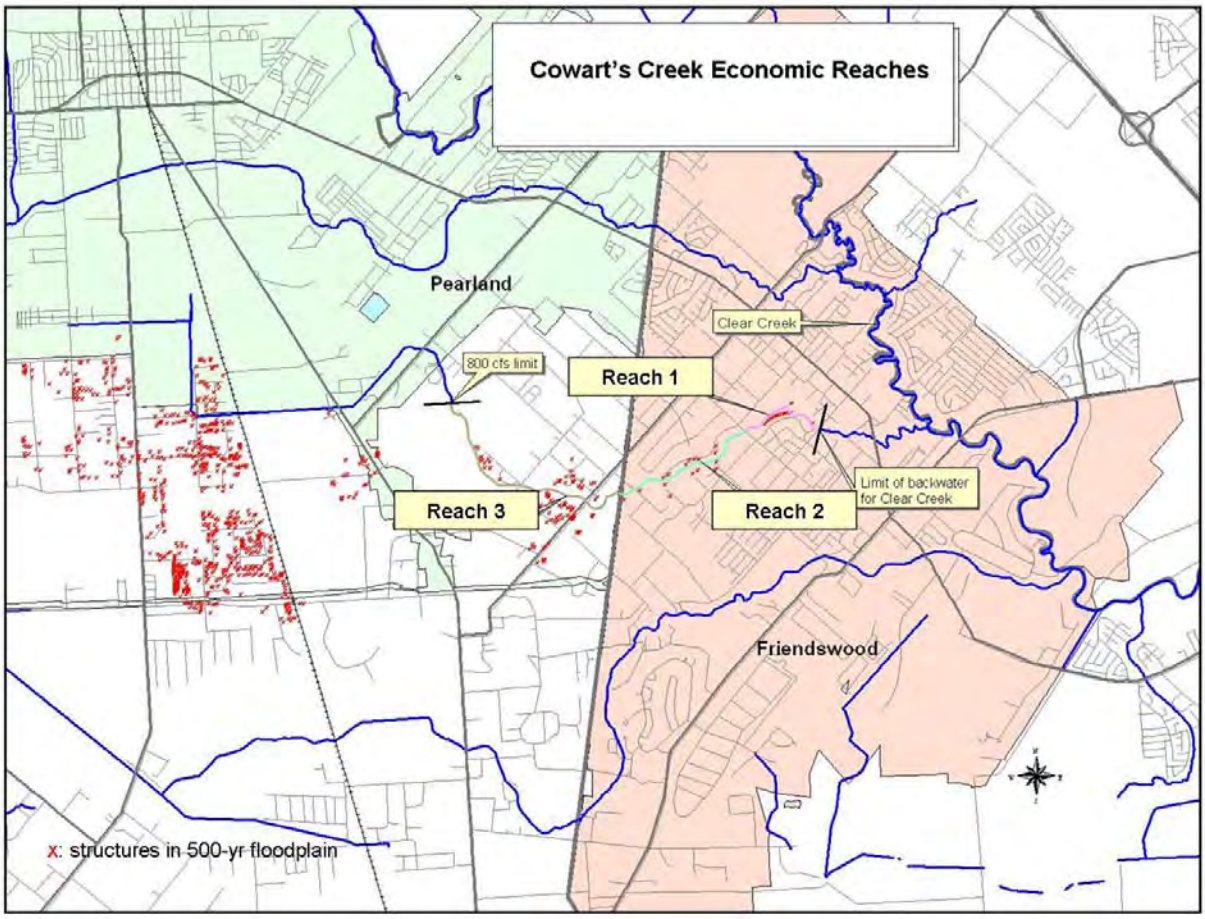


Figure 20
Cowart Creek Economic Reaches With
Structures in 0.2 percent (500-year) Annual Exceedance Probability Event

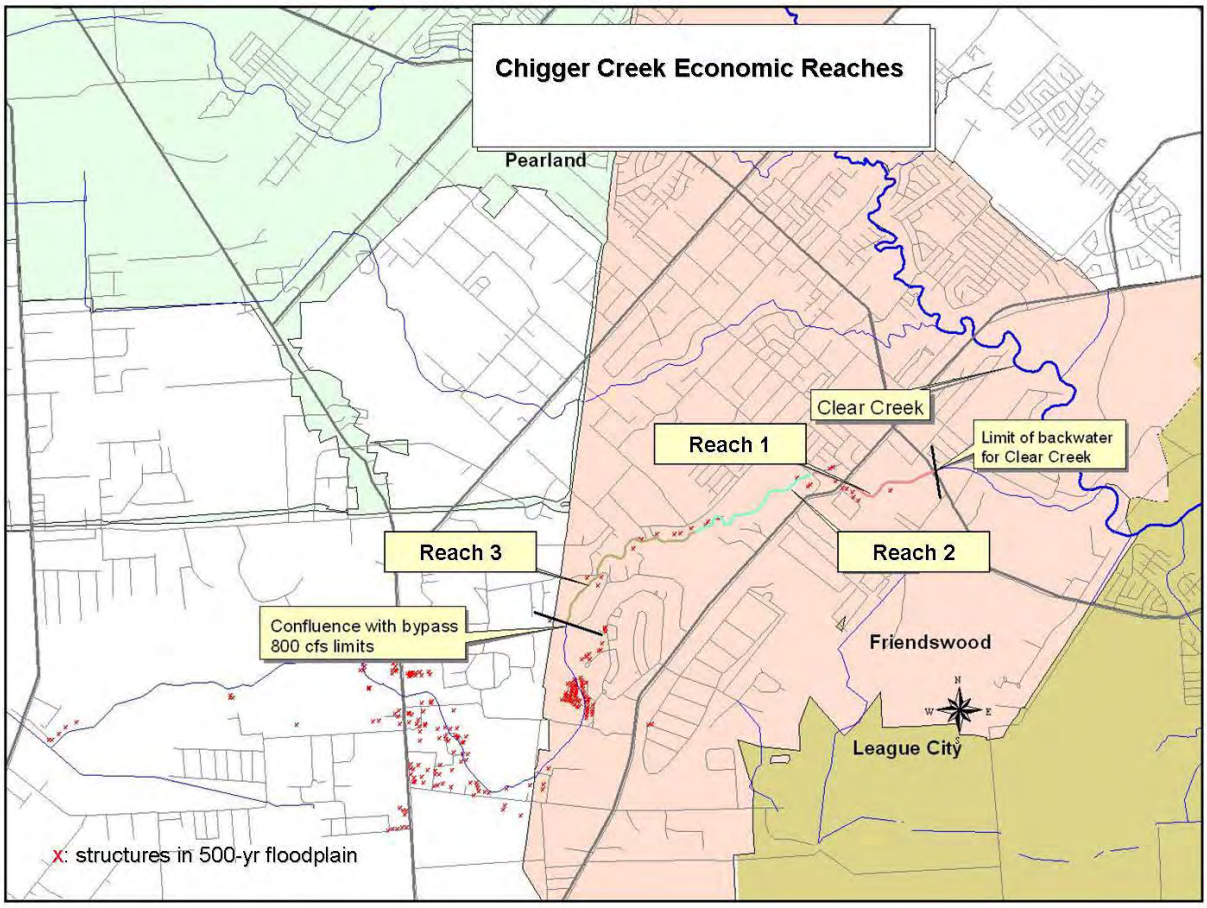


Figure 21
Chigger Creek Economic Reaches With
Structures in 0.2 percent (500-year) Annual Exceedance Probability Event

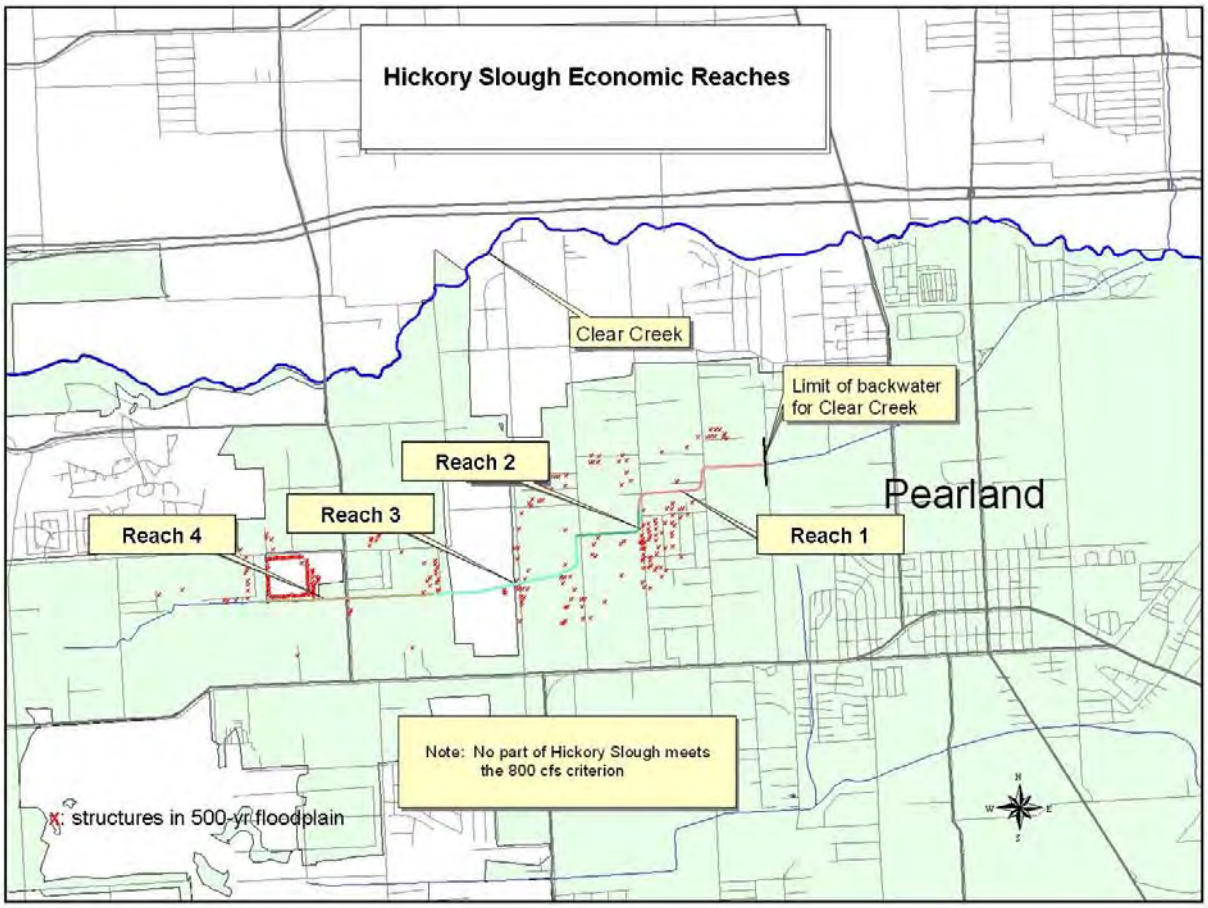


Figure 22
Hickory Slough Economic Reaches With
Structures in 0.2 percent (500-year) Annual Exceedance Probability Event

Table 11
Outline of Second Added Analysis Process

Formulation Sequence	Measure	Number of Sizes	Description of Measure	Select	Measures Already Added
1. Selection and Optimization of Clear Creek Upstream Anchor Component	SuperC	5	Bench-cut conveyance measure on Clear Creek from SH 288 to Bennie Kate Road (Approximately 10.0 miles).	**Yes Size d**	None
	SuperCa + DLS	3	System testing of conveyance measure combined with offline detention near Bennie Kate. Detention site is the existing regional basin site known as David L Smith.	No	None
	SuperCshort	3	Bench-cut conveyance measure on Clear Creek from SH 288 to BNSF RR. (Approximately 6.5 miles).	No	None
	SuperCshort-a + B3	3	System testing of conveyance measure combined with offline detention near Mykawa Road.	No	None
	Buyout of Structures	3	Buyout of structures by incremental floodplain of Clear Creek	No	None
2. Test for Upper Reach Measures	Super C + LD4	3	Linear Detention on Clear Creek from Bennie Kate to Dixie Farm Road	No	**Super Cd**
	Super C + C5	5	Bench-cut conveyance on Clear Creek from Bennie Kate to Dixie Farm Road	No	**Super Cd**
3. Test for measures on Mud Gully and Turkey Creek	**MUC1 + TKC1**	3	Conveyance improvement on Mud Gully (Concrete lined trapezoidal channel from Sagedowne Lane to Astoria Blvd. Approximately 0.8 miles) and Turkey Creek (trapezoidal earthen channel from Dixie Farm Road to Mouth. Approximately 2.4 miles)	**Yes Size b (Mud) and Size d (Turkey)**	**SuperCd**

Table 11 (Continued)
Outline of Second Added Analysis Process

Formulation Sequence	Measure	Number of Sizes	Description of Measure	Select	Measures Already Added
4. Test for measures on Marys Creek	**MAC2**	5	Conveyance improvement on Marys Creek (trapezoidal earthen channel from Harkey Road to SH 35. Approximately 2.1miles)	**Yes Size a**	**SuperCd+ MUC1b+ TKC1d**
5. Test for Clear Creek upper-reach measures	**C5**	5	Bench-cut conveyance improvement on Clear Creek from Bennie Kate to Dixie Farm Road (Approximately 5.1 miles).	**Yes Size d**	**SuperCd + MUC1b+ TKC1d+ MAC2a**
6. Test for additional measures on Mud Gully	Mud Gully Offline Detention	3	Offline detention on Mud Gully (Size c is 857 acre-feet which is the maximum available capacity at the site).	**No**	**SuperCd + MUC1b+ TKC1d + MAC2a+ C5d**
7. Test for additional measures on Chigger Creek	Chigger Creek Offline Detention	3	Offline detention on Chigger Creek.	No	**SuperCd + MUC1b+ TKC1d + MAC2a+ C5d**
8. Test for additional measures on Clear Creek	**Clear Creek Inline** and Offline Detention	3	Inline and offline detention on Clear Creek. Inline detention evaluated utilizing several configurations of roughness to include rough, smooth and average.	**Yes Inline**	**SuperCd + MUC1b+ TKC1d + MAC2a+ CC Inline C5d**
9. Test for additional measures on Marys Creek	Marys Creek Offline Detention	2	Modification of existing offline detention on Marys Creek.	No	**SuperCd + MUC1b+ TKC1d + MAC2a+ CC Inline C5d**

channel construction to facilitate quick movement of water downstream. These measures would not contribute to environmental concerns because the portions of these tributaries identified for inclusion and modification in the project have been previously channelized. All were successful and were added to the model.

The fifth formulation sequence tested for Clear Creek upper-reach measures again. These model runs led to the modification of the previously modeled measure Remove Dredged Material/ Deepen for Conveyance (RDM1) and the identification of Measure C5, a conveyance measure extending from the downstream end of the Super C measure. These combined measures were successful at one size in increasing net excess benefits. This led to the inclusion of C5(d) as a component of the GRP. This measure is a bench cut on the main stem of Clear Creek that extends from Bennie Kate Road (the downstream extent of Super C(d)) to Dixie Farm Road.

The non-Federal Sponsors requested modeling of detention components for inclusion in a Locally Preferred Plan (LPP). Modeling of these features (the sixth through ninth formulation sequences) determined that detention, while not successful on a stand-alone basis, was potentially successful in increasing net excess benefits as part of an overall system. With the new modeling results, the GRP was modified to include one detention component: inline detention on Clear Creek. Offline detention on Chigger Creek was also considered, but did not generate benefits. The offline detention on Marys Creek consists of two existing detention facilities that have already been constructed by the project partners. Although the basins were evaluated at their current sizes and at larger and smaller sizes, current sizes were found to be most cost effective relative to additional flood risk management benefits.

Each of the measures identified in the formulation sequences were combined to form the GRP. In addition to these flood risk management measures, the project team also looked at potential wetland creation and/or rehabilitation, reestablishment of oxbows, floodplain preservation, marsh rehabilitation, step pool creation, riparian habitat preservation, wetland functions at detention facilities, and recreation. These features were incorporated into the plan to minimize impacts, where possible, and were also considered during development of the mitigation plan.

Description of the GRP

Based on the results of the first-added and second-added analyses (phases II and III), a series of conveyance and detention measures along the main stem of Clear Creek and three of its tributaries were identified to form the GRP. These measures include two conveyance features on the main stem of Clear Creek (Super C(d) and C5(d)) and additional conveyance features on the following tributaries: Turkey Creek (TKC1d), Mud Gully (MUC1b), and Mary's Creek (MAC2a). An in-line detention feature on the mainstem of Clear Creek is also included in the

GRP (CC Inline). Offline detention features were removed from the GRP Alternative based on plan refinements and following additional cost/benefit evaluations. Each of the measures that make up the GRP is described in detail in the following subsections.

Excavated material from construction and maintenance activities would need to be placed in upland confined placement areas. Approximately 375.8 acres of placement areas would be identified outside of the 500-year floodplain in areas suitable for placement of excavated material associated with the project.

As part of the environmentally sensitive design, the GRP Alternative encompasses avoidance and minimization measures including rehabilitating 122 acres and reestablishing 33 acres of floodplain forest (155 total acres, which includes 7.5 acres of wetlands). In addition, as part of compensatory mitigation, the GRP Alternative will rehabilitate and/or reestablish an additional 31 acres of floodplain forest.

Clear Creek Main Stem Measures - Conveyance measures along Clear Creek are divided into two main sections: SH 288 to 4,000 feet downstream of Bennie Kate Road (Super C(d)) and 4,000 feet downstream of Bennie Kate to Dixie Farm Road (C5(d)). Also included are inline detention measures.

Super C(d) Section: This flood risk management measure provides conveyance improvement on Clear Creek from SH 288 to 4,000 feet downstream of Bennie Kate Road. The conveyance feature includes construction of 10.8 miles of high-flow channel along Clear Creek in Harris and Brazoria counties. The high-flow channel would be constructed by excavating a shallow, wide flood bench on either side of the existing channel (Figure 23). The existing channel would be preserved to convey low flows. The flood bench would have a total bottom width of 200 feet. The flood bench areas would consist of grassy, parklike areas with trees planted on the side slopes at a density of approximately 14 trees per acre. These areas would be periodically mowed to maintain the parklike setting. An additional 30-foot right-of-way would be outside of, and on both sides of, the high-flow bench. This right-of-way would be utilized to construct backslope drains to prevent erosion during high flows, while acting as a buffer to preserve and rehabilitate existing or reestablish floodplain forest. As shown on Figure 23, these features combine to require an overall project right-of-way measuring approximately 300 feet in width.

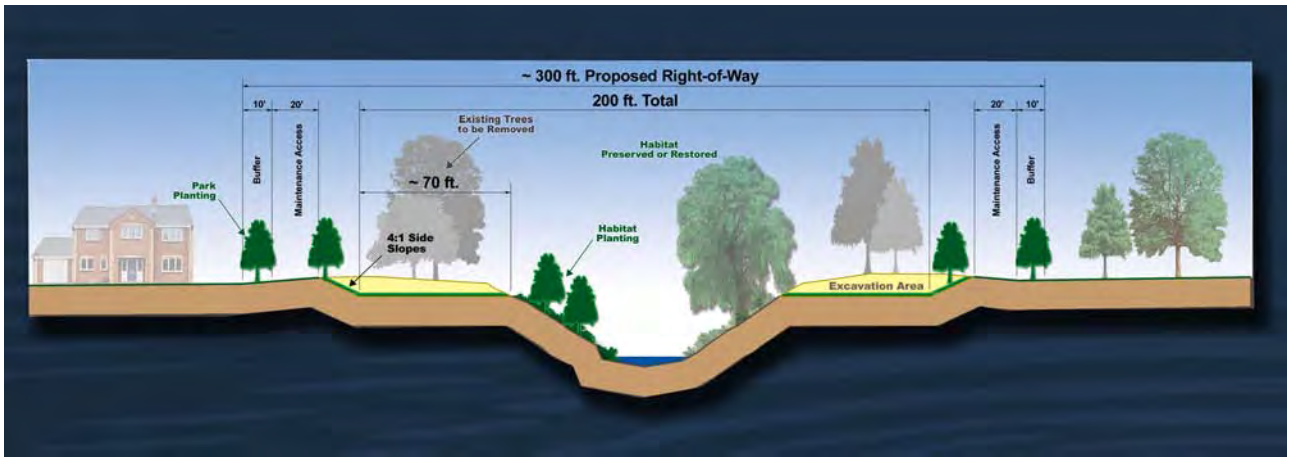


Figure 23
Cross-Section of Measure Identified as Super C(d)

As noted above, the existing Clear Creek channel would be preserved for low-flow conveyance. In addition, a 65-foot corridor of floodplain forest along the low-flow channel would be preserved and rehabilitated or reestablished. Where the channel maintains some sinuosity and floodplain forest, these areas would be preserved and rehabilitated. In areas where the channel has been previously channelized and cleared of trees, floodplain forest would be reestablished through plantings. In some areas, the high-flow channel would diverge from the low-flow channel. In these instances, the low-flow channel and resulting isolated lands or "island" between the low-flow and high-flow channels would be preserved; floodplain forest would be preserved and rehabilitated or reestablished, as necessary. The result would be a low-flow channel from SH 288 to Bennie Kate Road with an uninterrupted riparian corridor of floodplain forest, which would provide a continuous shaded watercourse.

C5(d) Section: From approximately 4,000 feet downstream of Bennie Kate Road to Dixie Farm Road, this flood risk management measure provides conveyance via construction of 4.4 miles of high-flow channel. Similar to that described for the Super C(d) Section, the high-flow channel would be created by constructing a shallow, wide flood bench on either side of the existing channel. The existing low-flow channel would be preserved to convey low flows and floodplain forest along the low-flow channel would be preserved and rehabilitated to provide a 65-foot riparian corridor along the length of the conveyance feature. The flood bench would have a total bottom width of 90 feet (Figure 24). Bench areas would be maintained as grassy, parklike settings with trees planted on the side slopes at a density of 14 trees per acre. The 30-foot-wide right-of-way outside of and on either side of the high-flow bench would be used for construction of backslope drains to prevent erosion and to create a buffer preserving and rehabilitating floodplain forest, as described for the Super C(d) Section. These features would combine to create an overall right-of-way measuring approximately 180 feet in width.

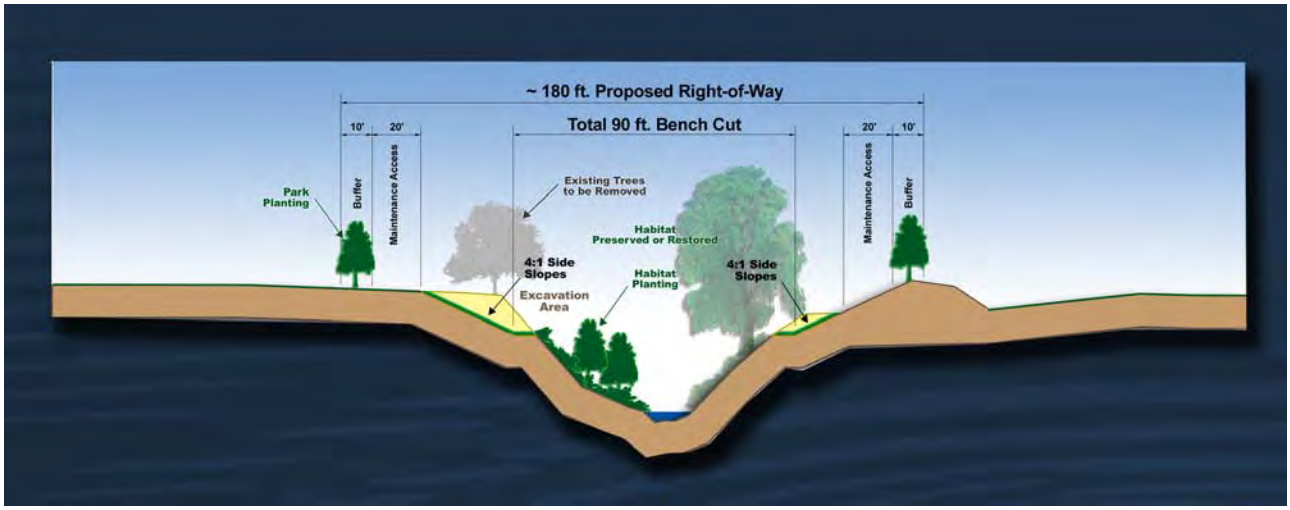


Figure 24
Cross-Section of Measure C5(d)

Inline Detention Measures: These measures would provide detention for up to 485 acre-feet of water within limited segments of the proposed Clear Creek conveyance measures, as described above. Construction of these measures would require deepening the high-flow channel in areas where the high-flow channel diverges from the low-flow channel, thus allowing for additional storage with no impact to the low-flow channel (Figure 25). Gravity flow would be utilized to return temporarily stored waters to the low-flow channel.

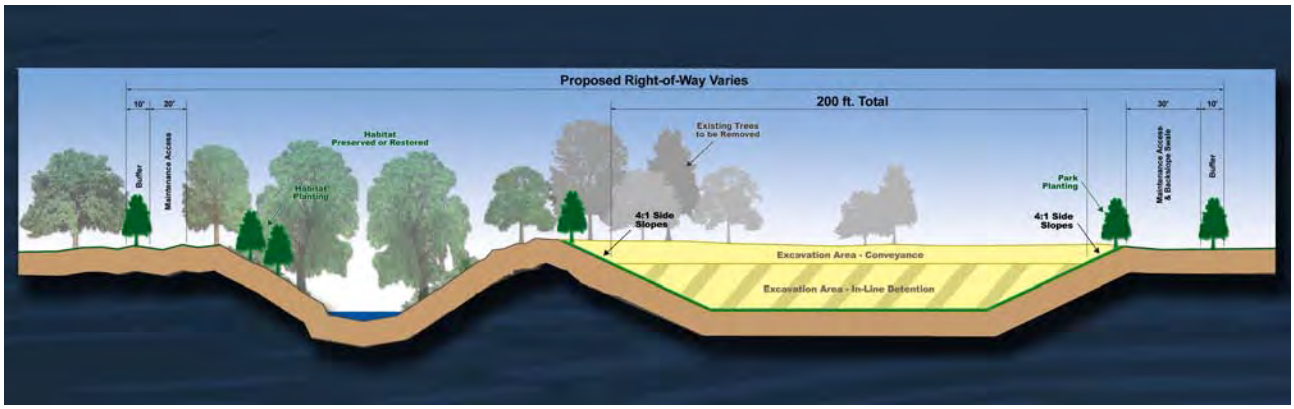


Figure 25
Cross-Section of Inline Detention Measure

<u>Turkey Creek Conveyance</u> - This measure would provide improved conveyance via construction of a 2.4-mile earthen, grass lined channel on Turkey Creek from Dixie Farm Road to the confluence with Clear Creek. From Dixie Farm Road to 2,000 feet downstream of Well School, the channel bottom width would be 20 feet, and the remaining channel to the confluence with Clear Creek would have a bottom width of 25 feet (Figure 26). An additional 60-foot right-

of-way (30 feet on each side of the channel) would be required for maintenance access and construction of backslope drains to prevent erosion caused from sheet flows into the channel.

Figure 26
Turkey Creek Conveyance Measure Cross-Section

Mud Gully Conveyance - The flood risk management measure proposed for Mud Gully includes conveyance improvements along 0.8 mile of Mud Gully from Sagedowne to Astoria. The existing channel would be concrete lined to maintain stability of side slopes with a bottom width of 45 feet (Figure 27). No right-of-way is needed, as this section of Mud Gully is located immediately between the northbound and southbound lanes of Beamer Road.

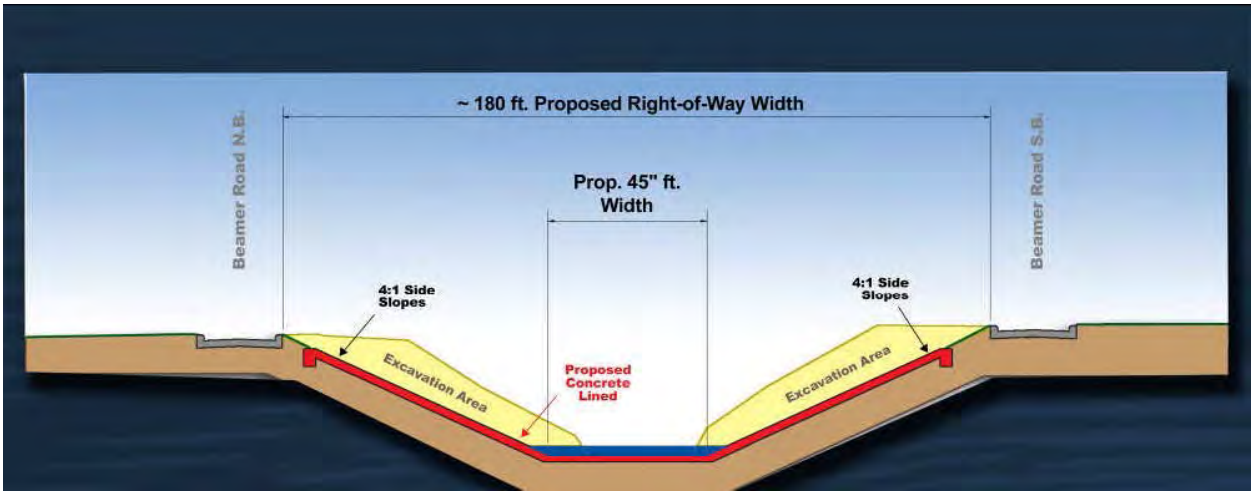


Figure 27
Mud Gully Conveyance Measure Cross-Section

Marys Creek Conveyance - Similar to Mud Gully, flood risk management measures for Marys Creek include conveyance features. The conveyance measure would involve construction of a grass-lined trapezoidal channel (Figure 28) along 2.1 miles of Marys Creek. From Harkey Road

to 3,940 feet upstream of McClean Road, the channel bottom width would be 15 feet, and from that point to 100 feet downstream of McClean Road, it would be 27.5 feet wide. Downstream of McClean Road to SH 35, the channel bottom width would be 35 feet. A 30-foot right-of-way would be needed on both sides of the channel for maintenance access and backslope drains to prevent erosion.

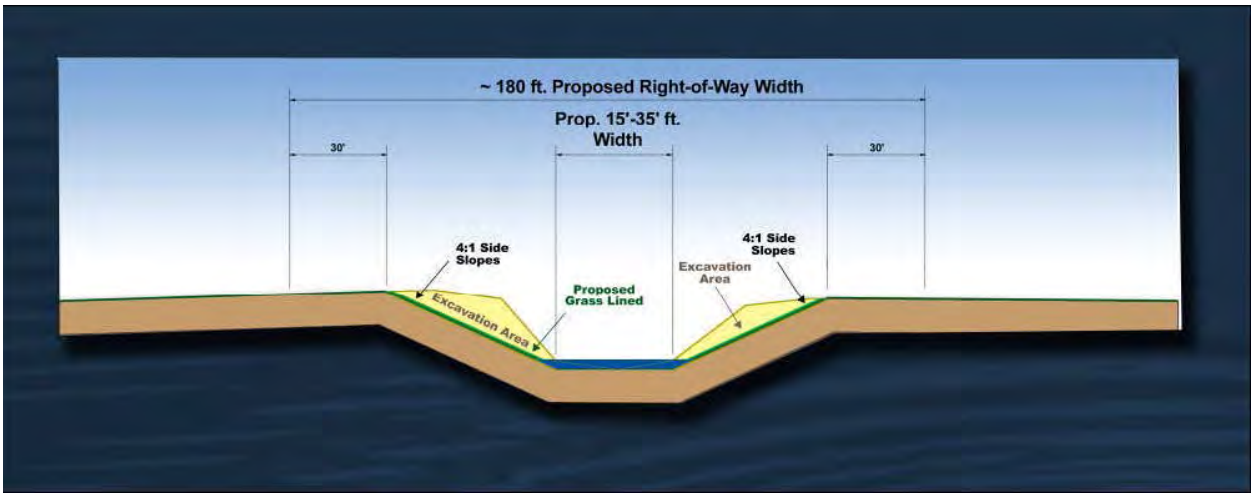


Figure 28
Marys Creek Conveyance Measure Cross-Section

GRP Alternative with Nonstructural Buyout Components

Two additional alternatives were considered that combined the GRP with the 20 percent and 10 percent AEP buyout nonstructural alternatives. As described for the Nonstructural Alternatives section, three levels of participation in the buyout program were assumed. Because participation is often reduced with a plan that combines structural components with buyouts, the assumed levels of participation used in the analysis of these two alternatives were 25 percent (low), 50 percent (most likely), and 75 percent (high).

GRP Alternative with 20 Percent AEP Buyouts - This alternative includes the GRP with additional buyouts in the 20 percent (5-year) AEP floodplains. The most likely number (50 percent) of homes to be removed or bought out under this scenario is approximately 14.

GRP Alternative with 10 Percent AEP Buyouts - This alternative includes the GRP with additional buyouts in the 10 percent (10-year) AEP floodplains. The most likely number (50 percent) of homes to be removed or bought out under this scenario is approximately 68.

VI. ECONOMIC EVALUATION

Various structural and nonstructural solutions to flooding were considered to mitigate flood damages in the study area. These include construction of detention basins, channel modifications, watershed management, bridge replacements, floodplain buyout, raising-in-place, etc., and several combinations of the aforementioned.

Each alternative project condition was analyzed with risk and uncertainty using the HEC-FDA program in the same manner as the FWOP condition. Economic benefits from each alternative were computed and compared to the FWOP condition. The aim of the economic analysis was to select a plan that maximized net benefits. A detailed discussion of the analytical process followed throughout the study is provided in Enclosure 2 to the Economic Appendix.

ANALYSIS OF ALTERNATIVES

Structural Analysis

The analysis of structural measures took place in phases over the study period. Each measure was optimized and incrementally justified. In this way, poor performing and less beneficial measures were eliminated from further consideration. The resultant optimized structural alternative is the GRP alternative, which was carried forward to the final array.

In addition, analysis of two legacy plans, namely the SPA and the AFP, took place. The AFP includes conveyance improvement from Mykawa Road to Clear Lake plus the Second Outlet Channel and Gate Structure. The Second Outlet and Gate Structure were developed as part of the AFP to mitigate flows into Clear Lake from the enlarged channel upstream. As previously mentioned, the Second Outlet and Gate structure have been constructed and are considered sunk costs with no benefits being claimed in this analysis.

The SPA was developed in 1997 as an alternative to the AFP. This alternative reduced the size of the proposed Federal alternative channel and included a bypass channel near the Friendswood area.

Nonstructural Analysis

Nonstructural measures were investigated early in the first-added measures phase of the study and were not deemed feasible. However, with the many changes and updates made over time, further in-depth analysis including the tributaries was deemed necessary. Also, nonstructural measures were further analyzed in addition to structural measures in two additional alternatives considered that combined the GRP, the 20 percent and 10 percent AEP buyout nonstructural alternatives. However, these two additional alternatives were not incrementally justified when compared with the GRP alone and were not carried forward into the economic comparison of alternatives. The detailed nonstructural analysis results are shown in Enclosure 4 of the Economic Appendix.

COMPARISON OF ALTERNATIVES

Based upon the results of the first-added and second-added measures analysis, the optimized plan unfolded as the analysis took place. Several combinations of measures meet the objective of positive net benefits. However, with each step of the analysis a combination of measures producing greater net benefits than the previous was revealed until the GRP was identified. In addition, two other plans were carried forward from previous studies, including the AFP and the SPA. Incremental analysis was conducted throughout the analysis, resulting in the final array of alternatives being considered.

Table 12 shows the damages reduced by each of the alternatives above under 2020 conditions. Damage reductions for the plans are between -$1.8 million and $19.0 million. Net economic benefits are between -$21.6 million and $9.1 million. The plan that reasonably maximizes net benefits is the GRP, which is, therefore, carried forward as the NED plan.

This NED plan includes both conveyance and inline detention flood risk management measures on the main stem of Clear Creek as well as several tributaries. Conveyance measures on Clear Creek include high-flow benches adjacent to the low-flow creek (which will be allowed to return to a natural state). Inline detention is also proposed for the main stem of Clear Creek. Conveyance on Marys Creek, Turkey Creek and Mud Gully include trapezoidal channel rectification ranging from 15 to 45 feet in width.

Table 12

Comparison of Alternatives

Average Annual Damages, 2020 Condition

(Values in 1000s, Oct 2011 Price Levels, 4.0%)

Alternative	Average Annual Damages 2020	Average Annual Damage Reduction	Average Annual Cost	Net Excess Benefits	Benefit-to-Cost Ratio
Without Project	$38,338.0				
Authorized Federal Plan	$29,756.5	$8,581.5	$18,356.5	-$9,775.0	0.47
Sponsor Preferred Alternative	$40,162.2	-$1,824.2	$19,784.1	-$21,608.3	-0.09
GRP Alternative	$19,274.0	$19,064.0	$9,962.9	$9,101.1	1.91

* Note - Average annual damages (2020 condition) are shown rather than AAE values. Future condition H&H runs were not provided for the AFP and SPA Alternatives due to lack of feasibility of the alternatives.

The largest feature of the project is the conveyance components proposed for the main stem of Clear Creek. These features are designed to maintain a natural low-flow channel that will minimize impacts of the project while facilitating the reduction of flood damages through the construction of high-flow benches. The only detention feature included in the plan is made up of linear detention located in the footprint of the high-flow bench cut conveyance feature, but only when the high-flow bench leaves the footprint of the natural low-flow channel. In the footprint of the low-flow channels, habitat already existing will remain while any areas not currently forested will be planted in an attempt to create a shaded stream habitat. The benches will be unvegetated and easier to maintain, reducing Operations and Maintenance expenses.

DETAILED ASSESSMENT OF THE NED PLAN

Capital Investment within the Various Floodplains for the NED Plan

Table 13 displays a summary of the number of structures and the distribution of capital investment within eight median discharge AEP floodplains of the main stem and tributaries of Clear Creek based on first floor elevations with the NED plan in place in the 2020 condition. As can be noted from Table 13, approximately 90 percent of the structures inventoried within the estimated existing median 0.2 percent AEP (500-year) floodplain are residential. In total the 0.2 percent AEP floodplain on the main stem and tributaries contains over 4,200 structures valued at over $427 million dollars, at October 2011 price levels.

In a comparison of Table 13 and Table 1, previously presented for the FWOP condition in 2020, the 1 percent AEP (100-year) floodplain with the NED plan in place contains about 1,600 structures (Table 13) while the FWOP condition contains over 3,700 structures (Table 1), resulting in a reduction of over 2,100 structures with the NED plan. Using the same tables for the 0.2 percent AEP (500-year) floodplain of the entire study area, the FWOP condition contains approximately 7,300 structures (Table 1) while the NED plan includes 4,275 structures (Table 13), effectively removing over 3,000 structures from inundation. This is a reduction of over 40 percent of the structures inundated by the 0.2 percent AEP event in the near-term condition.

Similarly to Table 13, Table 14 displays the structure inventory and distribution of capital investment within the eight existing median discharge AEP floodplains for the main stem and tributaries for the NED 2070 condition. As with the 2020 condition, the 2070 condition also reveals the majority of structures in the 0.2 percent AEP floodplain to be residential, representing

Table 13
Cumulative Distribution of Structures by Type by Flood Event
Summary of Main Stem and All Tributaries
Cumulative Totals Based on First-Floor Elevations and NED Plan 2020 Condition
(Dollar Values in $1,000s, Oct 2011 Price Levels)

Structure Type/Flood Event	50% AEP Floodplain (2-Year)	20% AEP Floodplain (5-Year)"	10% AEP Floodplain or (10-Year)	4% AEP Floodplain (25-Year)	2% AEP Floodplain (50-Year)	1% AEP Floodplain (100-Year)	0.4% AEP Floodplain (250-Year)	0.2% AEP Floodplain (500-Year)
Residential								
Number of Structures	1	39	188	421	901	1,343	2,540	3,824
Value of Structures	$95	$4,989	$21,411	$43,711	$91,780	$134,054	$253,477	$382,584
Value of Contents	$48	$2,494	$10,706	$21,905	$45,839	$67,448	$128,239	$194,864
Percent of Structures Inundated/Zone	25%	53%	76%	77%	81%	84%	87%	89%
Commercial								
Number of Structures	3	34	53	106	171	213	305	371
Value of Structures	$34	$467	$2,187	$8,441	$15,274	$17,815	$23,245	$25,993
Value of Contents	$1	$268	$838	$4,294	$9,034	$10,070	$14,766	$18,957
Percent of Structures Inundated/Zone	75%	46%	21%	19%	15%	13%	10%	9%
Industrial								
Number of Structures	0	0	3	8	15	22	36	44
Value of Structures	$0	$0	$93	$1,943	$4,586	$6,258	$7,556	$9,675
Value of Contents	$0	$0	$63	$3,690	$5,739	$8,043	$10,976	$14,634
Percent of Structures Inundated/Zone	0%	0%	1%	1%	1%	1%	1%	1%
Public								
Number of Structures	0	1	5	10	19	23	32	36
Value of Structures	$0	$16	$1,156	$5,764	$6,396	$7,210	$8,710	$8,762
Value of Contents	$0	$6	$378	$825	$1,168	$1,650	$2,443	$2,464
Percent of Structures Inundated/Zone	0%	1%	2%	2%	2%	1%	1%	1%
Total								
Number of Structures	4	74	249	545	1,106	1,601	2,913	4,275
Value of Structures	$129	$5,471	$24,848	$59,858	$118,036	$165,337	$292,988	$427,014
Value of Contents	$48	$2,768	$11,985	$30,714	$61,781	$87,211	$156,423	$230,919
Percent of Structures Inundated/Zone	100%	100%	100%	100%	100%	100%	100%	100%

Note: Individual numbers may not sum to totals due to rounding.

Table 14
Cumulative Distribution of Structures by Type by Flood Event
Summary of Main Stem and All Tributaries
Cumulative Totals Based on First-Floor Elevations and NED Plan 2070 Condition
(Dollar Values in $1,000s, Oct 2011 Price Levels)

Structure Type/Flood Event	50% AEP Floodplain (2-Year)	20% AEP Floodplain (5-Year)"	10% AEP Floodplain or (10-Year)	4% AEP Floodplain (25-Year)	2% AEP Floodplain (50-Year)	1% AEP Floodplain (100-Year)	0.4% AEP Floodplain (250-Year)	0.2% AEP Floodplain (500-Year)
Residential								
Number of Structures	4	54	239	615	1,116	1,597	3,249	4,386
Value of Structures	$273	$7,237	$25,931	$63,946	$111,043	$159,151	$317,597	$444,086
Value of Contents	$136	$3,619	$12,965	$32,361	$55,658	$80,585	$161,547	$225,788
Percent of Structures Inundated/Zone	40%	57%	73%	78%	82%	84%	89%	90%
Commercial								
Number of Structures	6	35	76	138	200	246	349	406
Value of Structures	$57	$468	$2,781	$10,207	$17,413	$20,815	$25,235	$38,745
Value of Contents	$17	$269	$1,227	$5,250	$9,942	$11,231	$16,459	$72,201
Percent of Structures Inundated/Zone	60%	37%	23%	18%	15%	13%	10%	8%
Industrial								
Number of Structures	0	5	8	17	19	25	35	40
Value of Structures	$0	$93	$189	$4,463	$5,771	$6,930	$9,221	$10,266
Value of Contents	$0	$63	$128	$5,404	$6,545	$8,499	$12,108	$15,037
Percent of Structures Inundated/Zone	0%	5%	2%	2%	1%	1%	1%	1%
Public								
Number of Structures	0	1	6	16	20	28	35	42
Value of Structures	$0	$16	$1,173	$6,024	$6,503	$7,855	$8,762	$8,926
Value of Contents	$0	$6	$384	$982	$1,208	$1,986	$2,464	$2,525
Percent of Structures Inundated/Zone	0%	1%	2%	2%	1%	1%	1%	1%
Total								
Number of Structures	10	95	329	786	1,355	1,896	3,668	4,874
Value of Structures	$330	$7,814	$30,074	$84,640	$140,730	$194,750	$360,816	$502,024
Value of Contents	$153	$3,956	$14,705	$43,997	$73,353	$102,303	$192,578	$315,550
Percent of Structures Inundated/Zone	100%	100%	100%	100%	100%	100%	100%	100%

Note: Individual numbers may not sum to totals due to rounding.

approximately 90 percent. For the 2070 condition, the 0.2 percent AEP floodplain contains over 4,800 structures valued at over $502 million dollars.

For comparison, Table 2 previously presented the structure inventory for the FWOP 2070 condition. In a comparison of Table 14 and Table 2, the 1 percent AEP (100-year) floodplain with the NED plan in place contains almost 1,900 structures while the FWOP condition contains almost 4,900 structures, resulting in a reduction of approximately 3,000 structures with the NED plan. Using the same tables for the 0.2 percent AEP (500-year) floodplain of the entire study area, the FWOP condition contains approximately 8,400 structures while the NED plan includes almost 4,900 structures, effectively removing over 3,500 structures from inundation. This is also a reduction of over 40 percent of the structures inundated by the 0.2 percent AEP event in the near-term condition.

Single Occurrence Damages for the NED Plan

Damages expected to accrue from various flood events along the main stem and tributaries of Clear Creek for the NED Plan are displayed in Table 15. These values represent damages expected for individual events under the with-project, near-term, hydrologic condition and include structure and content damages as well as other benefit categories. Similarly, Table 16 displays the summary of single occurrence damages by event for the main stem and tributaries in the future hydrologic condition.

In the with-project 2020 condition, a 1 percent AEP event is expected to cause approximately $86 million in damages to structures and contents, representing over 50 percent reduction in damages when compared to the FWOP condition 1 percent AEP event. The value of properties located in the 1 percent AEP floodplain is on the order of $252 million. Damages to structures and contents as a percent of total value of the structures and contents are approximately 46 percent. The average value of the residual floodplain properties in the 1 percent AEP floodplain is $100,000.

In the with-project 2070 condition, a 1 percent AEP event is expected to cause approximately $96 million in damages to structures and contents. The value of properties located in the 1 percent AEP floodplain is on the order of $194 million. Damages to structures and contents as a percent of total value of the structures and contents are approximately 44 percent. The average value of the residual floodplain properties in the 1 percent AEP floodplain is $102,000.

Table 15
Single Occureence Damages by Event
NED Plan, 2020 Condition
Summary of Clear Creek Main Stem and All Tributaries
(Dollar Values in $1,000s, Oct 2011 Price Level)

	Annual Exceedance Probability Events							
Damage Category	50% or "2-Year"	20% or "5-Year"	10% or "10-Year"	4% or "25-Year"	2% or "50-Year"	1% or "100-Year"	0.4% or "250-Year"	0.2% or "500-Year"
Residential	$304.6	$4,438.7	$13,834.4	$30,035.6	$56,281.1	$80,848.7	$139,144.0	$201,533.3
Public	$0.1	$1.5	$2.2	$5.8	$18.7	$31.5	$1,445.9	$1,751.4
Commercial	$1.9	$58.9	$281.2	$880.6	$2,102.0	$3,267.8	$5,415.6	$7,413.4
Industrial	$0.0	$0.9	$12.5	$91.1	$857.2	$1,427.0	$3,369.8	$5,462.2
Damages to Structures, Contents	$306.6	$4,500.0	$14,130.3	$31,013.0	$59,258.9	$85,575.0	$149,375.2	$216,160.3
Postdisaster Recovery Costs	$260.8	$1,929.3	$5,142.5	$9,514.5	$15,986.4	$21,919.9	$37,673.7	$53,302.3
Utilities	$9.8	$72.5	$193.6	$358.2	$601.8	$825.2	$1,418.3	$2,006.7
Vehicles	$0.7	$105.3	$692.4	$1,650.0	$3,175.5	$5,594.8	$10,949.1	$17,995.9
Roads	$309.1	$552.6	$863.3	$1,346.7	$1,829.2	$2,251.1	$2,998.1	$4,194.9
Total Damages by Event	$887.1	$7,159.6	$21,022.1	$43,882.4	$80,851.9	$116,165.9	$202,414.4	$293,660.1
Percent Distribution by Event								
Residential	34.3%	62.0%	65.8%	68.4%	69.6%	69.6%	68.7%	68.6%
Public	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.7%	0.6%
Commercial	0.2%	0.8%	1.3%	2.0%	2.6%	2.8%	2.7%	2.5%
Industrial	0.0%	0.0%	0.1%	0.2%	1.1%	1.2%	1.7%	1.9%
Postdisaster Recovery Costs	29.4%	26.9%	24.5%	21.7%	19.8%	18.9%	18.6%	18.2%
Utilities	1.1%	1.0%	0.9%	0.8%	0.7%	0.7%	0.7%	0.7%
Vehicles	0.1%	1.5%	3.3%	3.8%	3.9%	4.8%	5.4%	6.1%
Roads	34.8%	7.7%	4.1%	3.1%	2.3%	1.9%	1.5%	1.4%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Note: Individual numbers may not sum to totals due to rounding.

Table 16
Single Occureence Damages by Event
NED Plan, 2070 Condition
Summary of Clear Creek Main Stem and All Tributaries
(Dollar Values in $1,000s, Oct 2011 Price Level)

	Annual Exceedance Probability Events							
Damage Category	50% or "2-Year"	20% or "5-Year"	10% or "10-Year"	4% or "25-Year"	2% or "50-Year"	1% or "100-Year"	0.4% or "250-Year"	0.2% or "500-Year"
Residential	$151.3	$5,073.3	$16,116.4	$36,038.1	$60,986.6	$89,729.5	$162,074.3	$215,700.2
Public	$0.0	$18.5	$110.0	$317.0	$682.2	$1,034.6	$1,472.0	$1,763.9
Commercial	$1.0	$55.8	$323.3	$1,093.4	$2,267.6	$3,545.9	$6,102.4	$8,507.9
Industrial	$0.0	$1.5	$36.8	$234.8	$717.7	$1,316.1	$3,330.7	$5,001.1
Damages to Structures, Contents	$152.3	$5,149.2	$16,586.4	$37,683.3	$64,654.1	$95,626.1	$172,979.4	$230,973.1
Postdisaster Recovery Costs	$217.0	$2,214.0	$5,962.6	$10,679.4	$16,843.6	$24,253.7	$44,310.2	$56,594.5
Utilities	$8.1	$83.3	$224.5	$402.0	$634.1	$913.1	$1,668.1	$2,130.6
Vehicles	$0.3	$114.7	$715.2	$1,813.7	$3,581.8	$6,091.8	$13,261.5	$20,204.6
Roads	$343.1	$620.0	$993.7	$1,456.6	$1,912.3	$2,354.5	$3,355.7	$4,366.0
Total Damages by Event	$720.7	$8,181.2	$24,482.4	$52,035.0	$87,625.9	$129,239.2	$235,574.9	$314,268.8
Percent Distribution by Event								
Residential	21.0%	62.0%	65.8%	69.3%	69.6%	69.4%	68.8%	68.6%
Public	0.0%	0.2%	0.4%	0.6%	0.8%	0.8%	0.6%	0.6%
Commercial	0.1%	0.7%	1.3%	2.1%	2.6%	2.7%	2.6%	2.7%
Industrial	0.0%	0.0%	0.2%	0.5%	0.8%	1.0%	1.4%	1.6%
Postdisaster Recovery Costs	30.1%	27.1%	24.4%	20.5%	19.2%	18.8%	18.8%	18.0%
Utilities	1.1%	1.0%	0.9%	0.8%	0.7%	0.7%	0.7%	0.7%
Vehicles	0.0%	1.4%	2.9%	3.5%	4.1%	4.7%	5.6%	6.4%
Roads	47.6%	7.6%	4.1%	2.8%	2.2%	1.8%	1.4%	1.4%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Note: Individual numbers may not sum to totals due to rounding.

Average Annual Equivalent Damages for the NED Plan

Tables 17 through 20 show the AAE damages reduced for the NED Plan for the main stem and tributaries inventoried. Also shown are the probabilities that annual damages exceed indicated values for the 0.75, 0.50, and 0.25 probabilities. To illustrate, for Reach 8 on the main stem, equivalent annual damages reduced are $625,000 with the NED plan in place. For the same reach there is a 75 percent probability that the damages reduced (or benefits) exceed $249,000, a 50 percent probability that the benefits exceed $440,000, and a 25 percent probability that the benefits exceed $770,000.

For the main stem, the greatest reductions in damages are realized in Reaches 8 through 11 (with reductions ranging from 65 to 78 percent). Additional significant reductions in damages on the main stem are realized in Reaches 15 through 18 with reductions ranging from 40 to 65 percent.

On Mud Gully, the NED Plan reduces damages significantly in the all of the four reaches with reductions ranging from over 56 percent to 96 percent from the FWOP condition (Table 18). For Turkey Creek, damages are reduced significantly in all reaches with percent reductions ranging from 78 percent to 94 percent (Table 19). On Marys Creek, the greatest reduction in damages with the NED Plan in place occurs in Reaches 3 and 4 ranging from 48 to 81 percent. (Table 20).

Reduction in flood damages resulting from the implementation of the NED Plan is expected to result in residual AAE damages of $19.7 million. When compared with the FWOP condition, this is a $22.9 million reduction in AAE damages.

Figures 29 through 32 graphically illustrate the reduction in AAE damages for each of the Main Stem (Figure 29), Mud Gully (Figure 30), Turkey Creek (Figure 31), and Marys Creek (Figure 32). Cowart and Chigger Creeks are not shown graphically since there is no damage reduction expected to these two tributaries with the NED plan in place.

Consideration of Induced Flooding Effects

Conveyance measures work to reduce flooding by increasing flow capacity and reducing storage. This generally results in higher flood flows (i.e. induced flooding) in the adjacent, downstream reach. The resulting increase in damage can offset economic benefits to the upstream reach. Even when the downstream reach is undeveloped, there is still an impact since property values

Table 17
Equivalent Annual Damages Reduced and Distributed for the NED Plan
Clear Creek Main Stem
Dollar Values in 1,000s, Oct 2011 Price levels, Discount Rate of 4.0%, 50-Year Period of Analysis

REACH	LOWER LIMIT NEAR	UPPER LIMIT NEAR	EQUIVALENT ANNUAL DAMAGE			Percent Reduction	PROBABILITY DAMAGE REDUCED EXCEEDS INDICATED VALUES		
			Total Without Project	Total With Project	Damage Reduced		0.75	0.50	0.25
1	GALVESTON BAY	ROSEWOOD	$116	$116	$0	0.4%	$3	-$1	$0
2	ROSEWOOD	BAL HARBOR	$93	$93	$1	0.7%	$0	$1	$0
3	BAL HARBOR	FM 270	$99	$94	$5	4.9%	$2	$2	$6
4	FM 270	SH 3	$129	$121	$9	6.7%	$3	$5	$12
5	SH 3	IH 45	$0	$0	$0	3.7%	$0	$0	$0
6	IH 45	W BAY AREA BLVD	$196	$181	$15	7.7%	$7	$12	$19
7	W BAY AREA BLVD	FM 528	$909	$612	$297	32.6%	$177	$254	$352
8	FM 528	WHISPERING PINES	$970	$344	$625	64.5%	$249	$440	$770
9	WHISPERING PINES	NEAR MARY'S CRK	$759	$220	$538	71.0%	$206	$397	$679
10	NEAR MARY'S CRK	FM 2351	$1,538	$353	$1,185	77.1%	$596	$953	$1,428
11	FM 2351	NEAR TURKEY CRK	$235	$52	$182	77.6%	$60	$117	$214
12	NEAR TURKEY CRK	DIXIE FARM RD	$103	$113	-$10	-9.4%	-$8	-$14	-$24
13	DIXIE FARM RD	COUNTRY CLUB DR	$865	$789	$77	8.8%	-$40	-$64	-$101
14	COUNTRY CLUB DR	BENNIE KATE	$212	$164	$48	22.5%	-$5	-$3	-$9
15	BENNIE KATE	SH 35	$5,658	$3,505	$2,153	38.1%	$961	$1,418	$1,988
16	SH 35	MYKAWA	$829	$294	$535	64.5%	$228	$408	$676
17	MYKAWA	STONE RD	$2,963	$1,091	$1,872	63.2%	$952	$1,562	$2,410
18	STONE RD	SH 288	$5,249	$3,154	$2,095	39.9%	$1,121	$1,763	$2,814
19	SH 288	ALMEDA SCHOOL RD	$242	$240	$2	0.7%	$2	$4	$4
TOTAL			$21,165	$11,537	$9,628	45.5%	$4,511	$7,252	$11,239

Note: Individual numbers may not sum to totals due to rounding.

Table 18
Equivalent Annual Damages Reduced and Distributed for the NED Plan
Mud Gully
Dollar Values in 1,000s, Oct 2011 Price levels, Discount Rate of 4.0%, 50-Year Period of Analysis

REACH	LOWER LIMIT NEAR	UPPER LIMIT NEAR	EQUIVALENT ANNUAL DAMAGE			Percent Reduction	PROBABILITY DAMAGE REDUCED EXCEEDS INDICATED VALUES		
			Total Without Project	Total With Project	Damage Reduced		0.75	0.50	0.25
1	90 DEGREE TURN SW	HALL RD	$2,384	$1,076	$1,308	54.9%	$493	$849	$1,348
2	HALL RD	BELTWAY 8	$1,489	$606	$883	59.3%	$315	$476	$707
3	BELTWAY 8	KINGSPOINT	$149	$51	$98	65.6%	$20	$36	$60
4	KINGSPOINT	UPPER LIMIT	$520	$20	$500	96.2%	$8	$16	$27
TOTAL			$4,542	$1,753	$2,789	61.4%	$837	$1,376	$2,143

Note: Individual numbers may not sum to totals due to rounding.

Table 19
Equivalent Annual Damages Reduced and Distributed for the NED Plan
Turkey Creek
Dollar Values in 1,000s, Oct 2011 Price levels, Discount Rate of 4.0%, 50-Year Period of Analysis

REACH	LOWER LIMIT NEAR	UPPER LIMIT NEAR	EQUIVALENT ANNUAL DAMAGE			Percent Reduction	PROBABILITY DAMAGE REDUCED EXCEEDS INDICATED VALUES		
			Total Without Project	Total With Project	Damage Reduced		0.75	0.50	0.25
1	START	NYACK	$1,328	$84	$1,245	93.7%	$267	$472	$763
2	NYACK	SCARSDALE	$742	$92	$650	87.6%	$137	$253	$424
3	SCARSDALE	BELTWAY 8	$671	$114	$557	83.0%	$133	$218	$338
4	BELTWAY 8	SAGEDOWNE	$1,518	$332	$1,186	78.1%	$288	$445	$656
TOTAL			$4,259	$622	$3,638	85.4%	$825	$1,388	$2,181

Note: Individual numbers may not sum to totals due to rounding.

Table 20
Equivalent Annual Damages Reduced and Distributed for the NED Plan
Marys Creek
Dollar Values in 1,000s, Oct 2011 Price levels, Discount Rate of 4.0%, 50-Year Period of Analysis

REACH	LOWER LIMIT NEAR	UPPER LIMIT NEAR	EQUIVALENT ANNUAL DAMAGE			Percent Reduction	PROBABILITY DAMAGE REDUCED EXCEEDS INDICATED VALUES		
			Total Without Project	Total With Project	Damage Reduced		0.75	0.50	0.25
1	EDGEWOOD DR.	COUNTY LINE	$84	$81	$3	3.5%	$31	$44	$63
2	COUNTY LINE	LONGHERRIDGE DR	$1,604	$1,084	$521	32.5%	$187	$396	$1,072
3	LONGHERRIDGE DR.	AT&SF RR	$3,009	$1,568	$1,441	47.9%	$596	$1,143	$2,066
4	AT&SF RR	HARKEY RD	$5,525	$1,028	$4,497	81.4%	$2,817	$4,617	$7,346
5	HARKEY RD	CHARLES AVE	$1,807	$1,474	$333	18.4%	-$343	-$310	-$251
TOTAL			$12,030	$5,235	$6,795	56.5%	$3,287	$5,891	$10,295

Note: Individual numbers may not sum to totals due to rounding.

Figure 29
Clear Creek Main Stem
Equivalent Annual Damages by Reach
(Values in Thousands, Oct 2011 Prices, 4%)

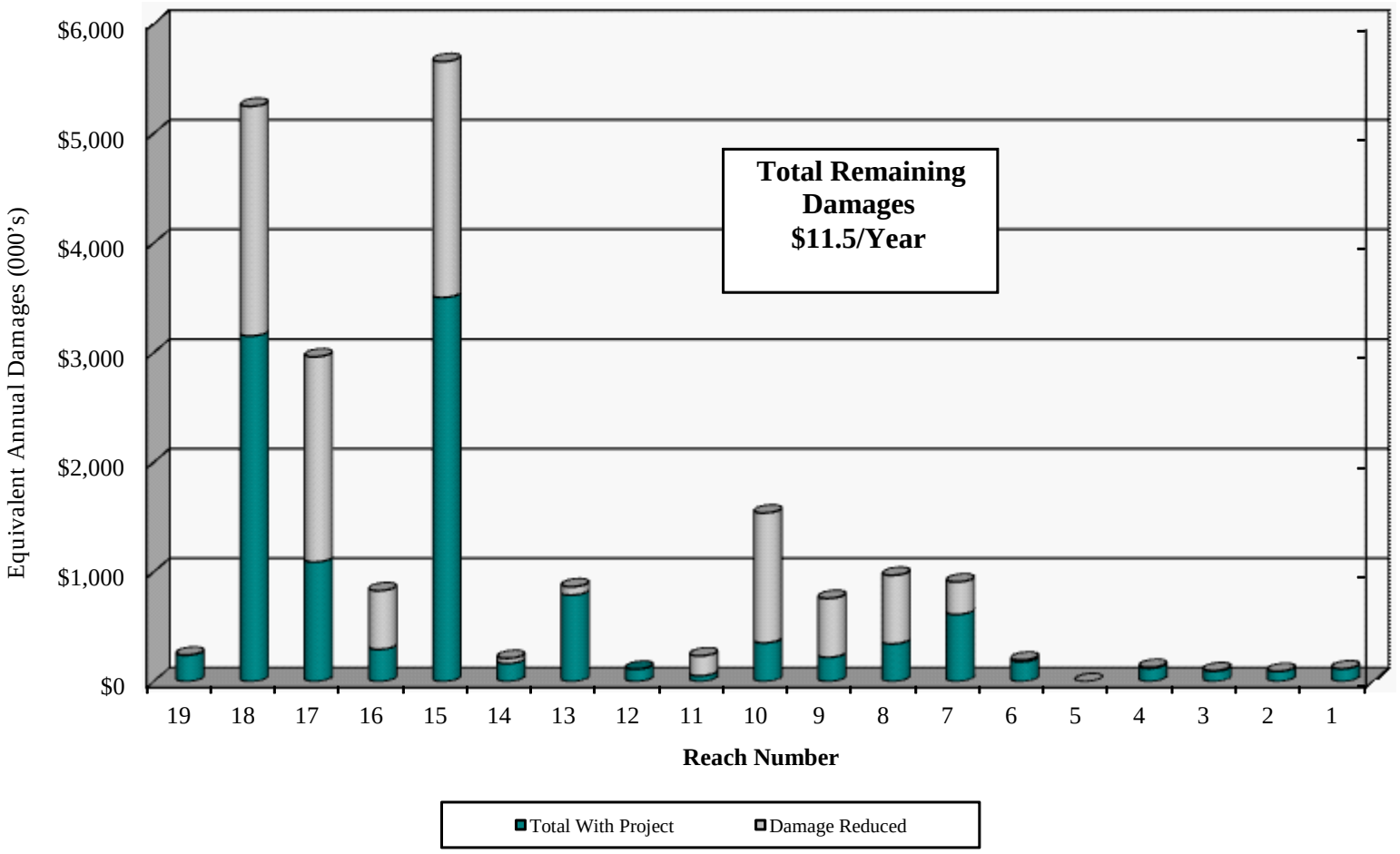


Figure 30
Mud Gully
Equivalent Annual Damages by Reach
(Values in Thousands, Oct 2011 Prices, 4%)

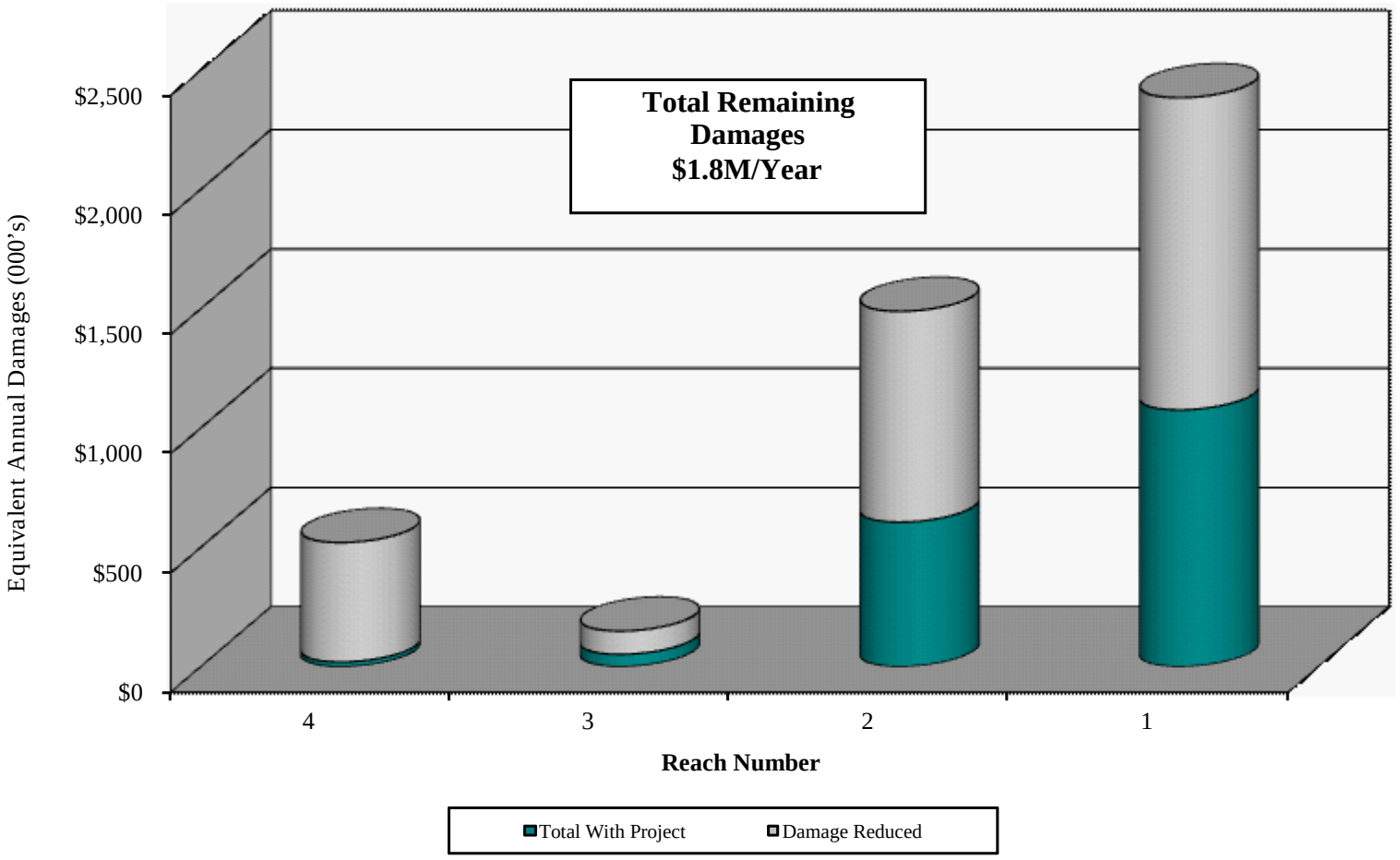


Figure 31
Turkey Creek
Equivalent Annual Damages by Reach
(Values in Thousands, Oct 2011 Prices, 4%)

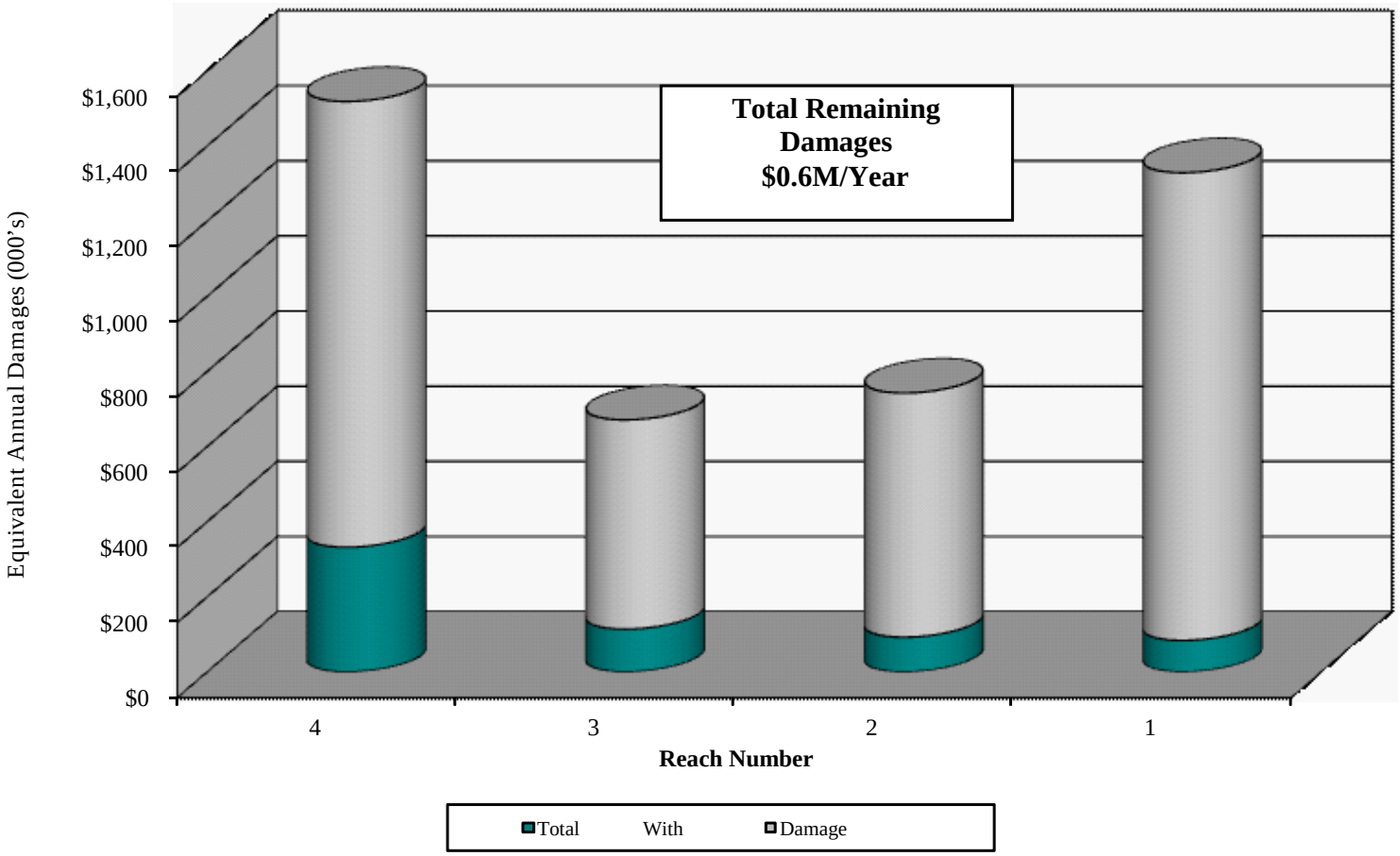
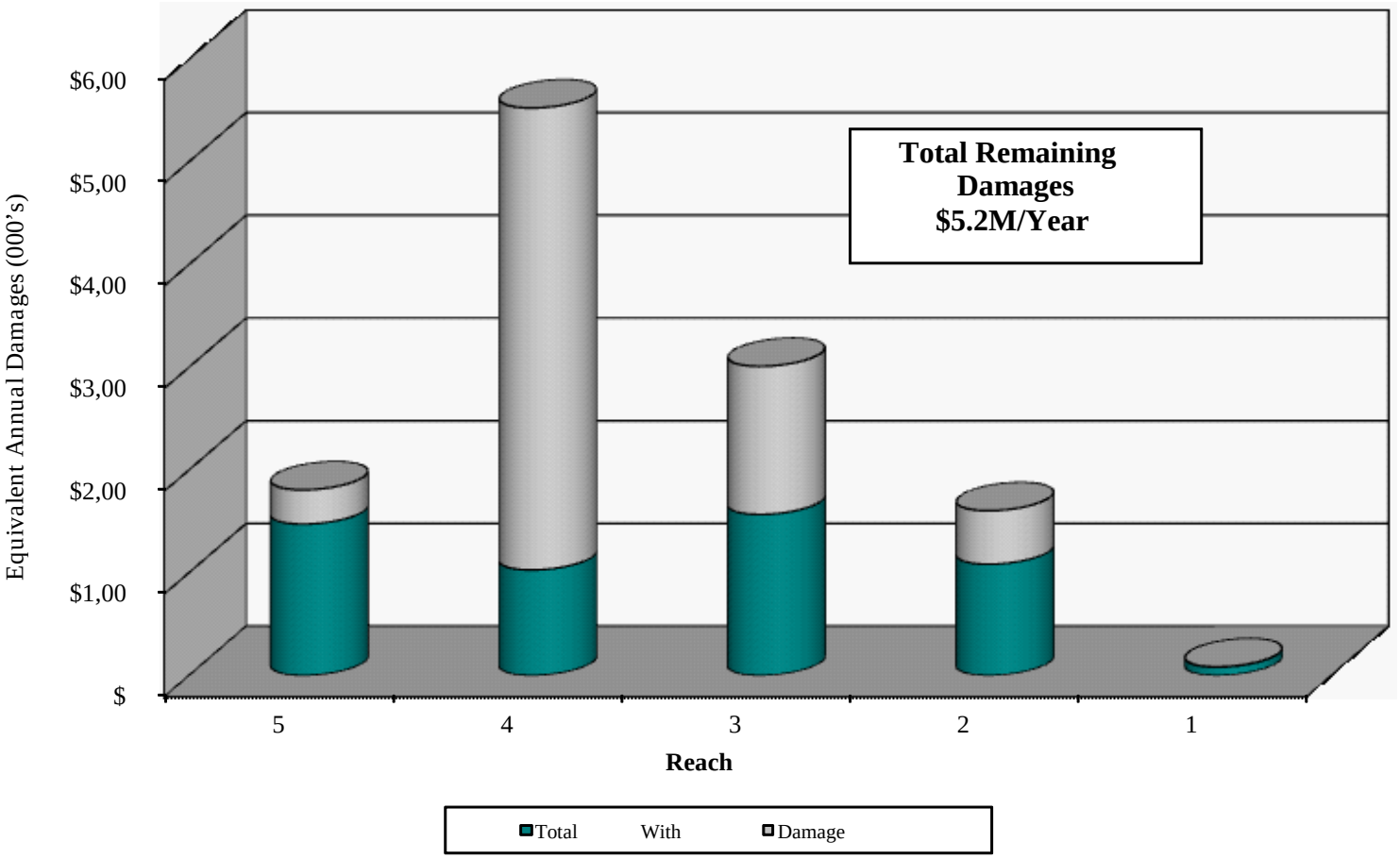


Figure 32

Mary's Creek
Equivalent Annual Damages by Reach
(Values in Thousands, Oct 2011 Prices, 4%)



are affected. Harris County and some other entities generally prohibit projects that cause induced flooding.

The GRR NED formulation was predicated on economic optimization without the constraint that induced flooding must be mitigated. Components were selected and sized to optimize net benefits. Investigation of the water surface elevations reveals that there is a maximum of 0.15 feet (less than 2 inches) of induced flooding in the Clear Creek watershed with the NED plan in place. This is well within one standard deviation of uncertainty in water surface elevations (one standard deviation is generally on the order of 0.75 feet) and, therefore, the induced damages for the NED plan are considered statistically insignificant. Since induced damages are statistically insignificant (meaning there is no statistical basis indicating that induced damages actually exist), a real estate analysis was not undertaken.

Savings in National Flood Insurance Administration Costs

Benefits can be derived from a reduction in administrative costs to the NFIP if implementation of a plan removes structures from the existing 1 percent AEP (100-year) floodplain. According to FEMA, the average cost of administering a flood insurance policy was $192 for Fiscal Year 2006 (Economic Guidance Memorandum (EGM) 06-04 "National Flood Insurance Program Operating Costs, Fiscal Year 2006," April 6, 2006). This is the latest estimate available for NFIP operating costs.

Based on hydrologic stages for a median 1 percent AEP flood under the NED plan, an estimated 1,602 structures are physically located within the improved floodplain of main stem and tributaries of Clear Creek under the 2020 condition.

As previously stated, participation rates in the NFIP vary by county with an estimated 70 percent participation in Brazoria County, 70 percent in Galveston County (Galveston County Engineer, April, 2006), and 60 percent in Harris County (Harris County Engineer in consultation with NFIP Regional Manager, April 2007). Based on this information, a total of 1,050 structures within the 1 percent chance floodplain hold NFIP policies with the NED Plan in place. The total estimated cost of administering policies for the 100-year floodplain with the NED Plan in place is $201,500. The total annual cost of administering policies for the structures under the FWOP condition was estimated to be approximately $472,500. The difference, or reduction in NFIP costs, represents a project benefit and is estimated at $271,000.

LOCALLY PREFERRED PLAN

Economic evaluation of plans during the analytical process resulted in selection the GRP as the NED Plan. This alternative has no adverse economic impacts downstream and meets the non-Federal Sponsor's criteria of no increase in water surface elevations. In addition, the plan was formulated to alleviate the environmental issues the sponsors had with the AFP. As a result, the sponsor was no longer interested in pursuing the SPA and no additional locally preferred plans were investigated or recommended.

RECOMMENDED PLAN

The Recommended Plan for Clear Creek, Texas is the NED Plan. This Recommended Plan includes remaining construction for the project and does not include the sunk costs, which include costs for the GRR and the previously constructed second outlet and gated structure. A detailed description of the plan's components is included in Section VIII – Description of the Recommended Plan of this report. Table 21 presents the summary of the benefits and costs of the Recommended Plan at the current discount rate of 4.0 percent. Detailed calculations for interest during construction and operations and maintenance costs are shown in the Economic Appendix. The Recommended Plan has a BCR of 2.3 at 4.0 percent.

SECTION 575 ANALYSIS

Section 575 of WRDA 1996 provides that "during an evaluation of economic benefits and costs for projects set forth in subsection (b) that occurs after the date of the enactment of this Act, the Secretary shall not consider flood control works constructed by non-Federal interests within the drainage area of such projects prior to the date of such evaluation in the determination of conditions existing prior to construction of the project." Section 354 of WRDA 99 amended Section 575 to remove nonstructural actions from considerations and add Clear Creek to the authorization. The WRDA 99, Section 575 (b), as amended, provides that:

> *(b) SPECIFIC PROJECTS. –The projects to which subsection (a) apply are—*
> *(1) the project for flood control, Buffalo Bayou Basin, Texas, authorized by Section 203 of the Flood Control Act of 1954 (68 Stat. 1258);*
> *(2) the project for flood control, Buffalo Bayou and tributaries, Texas, authorized by section 101(a) of the Water Resources Development Act of 1990 (104 Stat. 4610);*

(3) the project for flood control, Cypress Creek, Texas, authorized by section 3(a)(13) of the Water Resources Development Act of 1988 (102 Stat. 4014); and
(4) the project for flood control, Clear Creek, Texas, authorized by section 203 of the Flood Control Act of 1968 (82 Stat. 742).

Table 21
Summary of the Recommended Plan
Average Annual Equivalent Values
(50-year Period of Analysis, dollar values in thousands, October 2011 Price Levels)

NED Average Annual Impacts	Discount Rate 4.000%
Without-Project Conditions:	
Flood Damages	$42,587.0
NFIP Costs	$472.5
Subtotal Without-Project	$43,059.5
NED Plan Conditions:	
Flood Damages	$19,748.0
NFIP Costs	$201.5
Subtotal Without-Project	$19,949.5
Total Annual Benefits	$23,110.0
Project First Costs:	$189,135.0
Annual Costs:	
Interest and Amortization	$8,804.3
Interest During Construction	$276.0
OMRR&R	$1,060.7
Total Annual Project Costs	$10,140.9
Benefit/Cost Ratio	2.3

Note: Individual numbers may not sum to totals due to rounding.

To meet the intent of the legislation, the FWOP condition for Clear Creek (main stem and tributaries) was formulated without consideration of ongoing construction and property relocations within the study area. Only after the Federal NED plan was developed and fully

evaluated was additional analysis performed, testing the effect of activities by non-Federal interests. Two activities had the potential for altering either the hydrologic or economic profile of the study area—the construction of detention basins on Marys Creek and the purchase and demolition of 163 properties along the main stem of Clear Creek following Tropical Storm Allison, which occurred in June 2001. FEMA's HMGP and the HCFCD funded the buyouts.

Section 575 Implementation Guidance states that the following steps should be applied in the order presented to any current and future analyses:

1) Exclude non-Federal flood control works completed prior to the evaluation of benefits and costs from the existing and future "without-project" condition descriptions.

2) Exclude the same completed non-Federal flood control works from the "with-project" conditions for each alternative considered.
3) Combine the completed non-Federal flood control works with the recommended Federal project to form a total project. Identify the total project output.

4) Reexamine and possibly modify the design and operation of the recommended Federal project to more efficiently achieve the total project output.

Since there are two separate water bodies on Clear Creek affected by Section 575, it is necessary to analyze them in two parts.

Main Stem Section 575 Analyses

Of the structures inventoried, 163 residential structures have been purchased and removed from the floodplain under the FEMA's HMGP on the main stem of Clear Creek. Under authority of Section 575, WRDA 96, as amended, those properties remain in the structure inventory for Federal project justification. The Section 575 analysis for the FEMA buyouts is shown in Table 22.

The removal of 163 damageable properties from the 0.2 percent AEP floodplain of the main stem of Clear Creek reduced residual damages in the with-project condition by $948,000 on an AAE

Table 23
Section 575 Analysis
Average Annual Equivalent Damages
Clear Creek Main Stem
(October 2011 Price Levels, 50-year Period of Analysis, 4 Percent Discount Rate, dollar values in thousands)

				ANALYSIS WITHOUT NON-FEDERAL PROJECTS IN PLACE		ANALYSIS WITH BOTH FEDERAL AND NON-FEDERAL PROJECTS IN PLACE				
REACH	LOWER LIMIT NEAR	UPPER LIMIT NEAR	Without Project	NED Plan	Damage Reduced	Without Project (w/ non-Fed project)	NED plan (w/ non-Fed project)	Damage Reduced	Change in Benefits with non-Fed project	Percent Change in Residual Damages w/ and w/o non-Fed project
1	GALVESTON BAY	ROSEWOOD	$116	$116	$0	$116	$116	$0	$0	0%
2	ROSEWOOD	BAL HARBOR	$93	$93	$0	$93	$93	$0	$0	0%
3	BAL HARBOR	FM 270	$99	$94	$5	$99	$94	$5	$0	0%
4	FM 270	SH 3	$129	$121	$8	$129	$121	$8	$0	0%
5	SH 3	IH 45	$0	$0	$0	$0	$0	$0	$0	0%
6	IH 45	W BAY AREA BLVD	$196	$181	$15	$170	$157	$13	-$2	-13%
7	W BAY AREA BLVD	FM 528	$909	$612	$297	$867	$588	$279	-$18	-4%
8	FM 528	WHISPERING PINES	$970	$344	$626	$775	$225	$550	-$76	-35%
9	WHISPERING PINES	NEAR MARY'S CRK	$759	$220	$539	$577	$161	$416	-$123	-27%
10	NEAR MARY'S CRK	FM 2351	$1,538	$353	$1,185	$654	$103	$551	-$634	-71%
11	FM 2351	NEAR TURKEY CRK	$235	$52	$183	$202	$42	$160	-$23	-19%
12	NEAR TURKEY CRK	DIXIE FARM RD	$103	$113	-$10	$91	$100	-$9	$1	-12%
13	DIXIE FARM RD	COUNTRY CLUB DR	$865	$789	$76	$621	$561	$61	-$15	-29%
14	COUNTRY CLUB DR	BENNIE KATE	$212	$164	$48	$212	$164	$48	$0	0%
15	BENNIE KATE	SH 35	$5,658	$3,505	$2,153	$5,444	$3,349	$2,095	-$58	-4%
16	SH 35	MYKAWA	$829	$294	$535	$829	$294	$535	$0	0%
17	MYKAWA	STONE RD	$2,963	$1,091	$1,872	$2,963	$1,091	$1,872	$0	0%
18	STONE RD	SH 288	$5,249	$3,154	$2,095	$5,249	$3,154	$2,095	$0	0%
19	SH 288	ALMEDA SCHOOL RD	$242	$240	$2	$242	$240	$2	$0	0%
TOTAL			$21,164	$11,536	$9,628	$19,332	$10,652	$8,680	-$948	-8%
		First Costs of Construction (Main Stem Only)			$126,538			$126,538		
		AAEV Cost at 4.0%, 50-yrs (includes IDC & O&M)			$7,186			$7,186		
		Net Benefits			$2,442			$1,494		
		B/C Ratio (Main Stem Only)			1.3			1.2		

Note: Individual numbers may not sum to totals due to rounding.

basis and increased the benefits "attributable to the total Federal/non-Federal actions" by 8 percent. The BCR of the main stem portion of the Recommended Plan with the non-Federal project in place is 1.2, compared to the BCR of the main stem portion of the Recommended Plan without the non-Federal project in place ratio of 1.3. The non-Federal project (FEMA buyout) on the main stem augments the Recommended Plan by reducing residual damages and increasing benefits. Additional modification to the design and operation of the recommended Federal plan is not required.

Marys Creek Section 575 Analysis

During the study of this project, offline detentions on Marys Creek were constructed by the non-Federal Sponsor. These detentions, named SWEC and West Marys Detentions, were initially analyzed for inclusion in the Federal plan, so the detention sizes were optimized (see Attachment 2 of the Economic Appendix). The detentions were eventually dropped from analysis and analyzed as Section 575 projects. Analysis of the effect of the construction of these detentions on the Federal plan is shown in Table 23. As can be seen from the table, the Marys Creek detentions further reduces residual damages along Marys Creek on an AAE basis of $1.1 million and increased benefits "attributable to the total Federal/non-Federal actions" by 16 percent.

The BCR of the Marys Creek portion of the Recommended Plan with the non-Federal project is 5.9, compared to the BCR of the Recommended Plan without the non-Federal project in place ratio of 7.0. The non-Federal project (detentions) impacts the Recommended Plan by simultaneously reducing residual damages and decreasing benefits.

These detentions were successful in reducing benefits but the sponsor will receive no credit for their construction since these features were completed prior to completion of the study. Therefore, these detention features were not included in the final plan. Since the Recommended Plan (with the detention on Marys Creek) has a very robust BCR, additional modification to the design and operation of the recommended Federal plan is not required.

Table 23
Section 575 Analysis
Average Annual Equivalent Damages
Marys Creek

(October 2011 Price Levels, 50-year Period of Analysis, 4 Percent Discount Rate, dollar values in thousands)

				ANALYSIS WITHOUT NON-FEDERAL PROJECTS IN PLACE		ANALYSIS WITH BOTH FEDERAL AND NON-FEDERAL PROJECTS IN PLACE				
REACH	LOWER LIMIT NEAR	UPPER LIMIT NEAR	Without Project	NED Plan	Damage Reduced	Without Project (w/ non-Fed project)	NED plan (w/ non-Fed project)	Damage Reduced	Change in Benefits with non-Fed project	Percent Change in Residual Damages w/ and w/o non-Fed project
1	EDGEWOOD DR.	COUNTY LINE	$84	$81	$3	$113	$72	$41	$38	-11%
2	COUNTY LINE	LONGHERRIDGE DR	$1,604	$1,084	$520	$2,001	$1,013	$989	$469	-7%
3	LONGHERRIDGE DR.	AT&SF RR	$3,009	$1,568	$1,441	$2,111	$1,203	$908	-$534	-23%
4	AT&SF RR	HARKEY RD	$5,525	$1,028	$4,497	$4,348	$725	$3,622	-$875	-29%
5	HARKEY RD	CHARLES AVE	$1,807	$1,474	$333	$1,509	$1,366	$143	-$190	-7%
TOTAL			$12,030	$5,235	$6,795	$10,082	$4,380	$5,703	-$1,093	-16%
		First Costs of Construction (Mary's Creek Only)			$20,765			$20,765		
		AAEV Cost at 4.0%, 50-yrs (includes IDC & O&M)			$967			$967		
		Net Benefits			$5,828			$4,736		
		B/C Ratio (Mary's Creek Only)			7.0			5.9		

Note: Individual numbers may not sum to totals due to rounding.

ABILITY TO PAY ANALYSIS

In accordance with ER 1165-2-121, an ability-to-pay analysis was conducted for the Clear Creek GRR flood risk management project. The ability-to-pay test determines the eligibility of the non-Federal Sponsors to qualify for a reduction in the amount they are required to cost share. To qualify for a reduction, the results of both the benefit and income portions of the two-fold, ability-to-pay test must fall within the specified guidelines.

The benefits' test determines the maximum reduction, called the "benefits based floor" (or BBF), in the level of non-Federal cost sharing for any project. The factor is determined by dividing the BCR by four. If the factor (expressed as a percentage) is less than the standard level of cost sharing, the project may be eligible for a reduction in the non-Federal share to this BBF. The standard-level cost share for a flood control project authorized before WRDA 1986 is 25 percent. The Recommended Plan's BCR of 2.3 was divided by four to yield a BBF of 58 percent. Therefore, the non-Federal sponsor does not qualify for a reduction in the non-Federal share under this benefits' test.

The income test determines qualification for the reduction calculated in the benefit step. Qualification depends on the measure of current economic resources of both the project area and the state in which the project is located.

In accordance with the factors released in EGM 08-05, the income index factor for the State of Texas is 93.38 and for the counties of Galveston, Harris and Brazoria, the index factors are 96.69, 118.36, and 87.13, respectively. The Eligibility Factor (EF) for a flood damage mitigation project is calculated according to the following formula:

$$EF = a - b_1*(\text{State Factor}) - b_2*(\text{Area Factor})$$

Where: $a = 18.12$
$b_1 = .078$
$b_2 = .156$

When a project area, as determined by the location of the project's beneficiaries, includes more than one county, calculation of a composite project area index is necessary by taking a weighted average of the county index numbers, the weights being equal to the relative levels of benefits received in each county. The composite area index for the Clear Creek study area is 102.14.

Utilizing the above formula and the composite area index, an EF of the Clear Creek Recommended Plan is -5.10. An EF less than zero indicates ineligibility for a reduction in construction cost sharing.

As stated previously, a BBF factor for the Recommended Plan was calculated at 58 percent. To qualify for a reduction, the BBF factor must be less than the standard level of cost sharing. According to ER-1165-2-121 paragraph 5a(2), the project and sponsors do not meet the criteria for a reduction in cost sharing. This project does not meet either of the tests; therefore, the sponsors must pay the standard percentage of the total project first cost.

ECONOMIC BENEFIT UPDATE PLAN

In accordance with ER 1105-2-100, a plan is included to update the economic benefits of the project every three years after project approval. Only the important economic variables are considered for update.

As part of this economic update, changes to floodplain development will not be considered due to the fact that the study area participates in floodplain development restrictions, thus, inhibiting any development from occurring below the FEMA 1 percent AEP (100-year) floodplain. Structure values for residential, commercial, industrial, and public categories will be updated by creating a random sample of inventoried structures and valuing these structures using off-the-shelf valuation software. The resultant index will be used to update all structure values. Automobile values will be updated using the latest published values (for average mid-sized sedans). The NFIP benefit category will be updated using the latest available EGM. Finally, utilities, roads, and post disaster recovery benefit categories will be updated using the most appropriate Consumer Price Index factor.

VII. RISK AND UNCERTAINTY ANALYSIS

OVERVIEW

This chapter outlines the approach being taken for the Clear Creek GRR for evaluating risks, uncertainties, and consequences inherent in evaluation of alternatives and identification of the recommended plan. This approach involves a two-step process: 1) application of the USACE Risk and Uncertainty Analysis procedures assessing and incorporating uncertainty in the technical evaluation process; and 2) the evaluation and selection of a recommended plan that takes into account a wide array of economic, environmental, technical, and societal risk factors.

GUIDANCE AND CONCEPTS

Risk and uncertainty is an important part of the USACE planning process and feasibility analyses. The "Economic and Environmental Principles for Water and Related Land Resources Implementation Studies," established pursuant to WRDA 1965 (Pub. L. 89-80), as amended (42 U.S.C. 1962 a-2 and d-1), require that areas of risk and uncertainty be identified and clearly described so that public investment decisions can be informed by the degree of reliability of estimated costs, benefits and effectiveness of alternative plans. This approach captures and quantifies the extent of risk and uncertainty in the various planning and design components of a project. The total effect of risk and uncertainty on the project's design and viability can be examined and conscious decisions made reflecting an explicit trade-off between risks and costs.

More recently, risk-informed decision making was emphasized in the Campaign Plan (USACE, February 2011) in an effort to transform the USACE planning, design, construction, and operation and maintenance principles and decision-making processes. USACE has committed to developing and employing risk and reliability-based approaches that evaluate the consequences of design, construction and management decisions, especially as they affect risks to human health and safety. The Campaign Plan includes efforts to employ risk-based concepts in planning, design, construction, operations and major maintenance, as well as effective communicate risk and public involvement risk reduction strategies.

Risk and uncertainty arise from measurement errors and the underlying variability of complex natural, social and economic situations. Plans may be subject to measurement errors if the data are imperfect or the analytical tools are crude. Some future demographic, economic, hydrologic and meteorological events are essentially unpredictable because they are subject to random influences. However, in some cases, the randomness can be approximated by developing a probability distribution using a historical database that is applicable to the future. If there is no

such historical database, the probability distribution of random future events can be described subjectively, based upon the best available insight and judgment (ER 1105-2-100.E-4.a(3)). The latter case could also be applied to situations in which there is uncertainty as to whether historical conditions can be reliably applied to the future. This is likely the case with environmental parameters affected by global warming, such as sea level rise. None of the historical databases in use today can reliably be used to predict future conditions in which the rates of change are clearly diverging from historical precedents (IPCC, 2007).

The degrees of risk and uncertainty also will differ among various aspects of a project and will vary by time. Obviously, high levels of risk associated with project elements that could adversely affect human health and safety are not acceptable; while it might be acceptable to trade lower economic costs for higher levels of risk for project elements that do not affect human health or safety. In relation to time, components that may be relatively certain at the beginning of a project may be relatively uncertain at the end of the period of analysis.

A variety of specific technical terms and concepts that are employed in risk and uncertainty analysis are described below:

1) "Risk" is the probability that a hazardous outcome will occur as a consequence of uncertainty. It is "conventionally defined as those (situations) in which the potential outcome can be described in reasonably well known probability distributions" (ER 1105-2-100.E-4.a.(1)). These distributions are generally based upon well-established, empirical data (historical or experimental). The best-known examples of this concept are applied in flood risk management projects; i.e., it is known that a river will flood to a specific elevation on the average of once in 20 years. When applied to ecological modeling and impact analysis, risk should be viewed as an inevitable consequence of the uncertainties inherent in the current state of knowledge of ecological systems.

2) "Uncertainty" is a measure of imprecision of knowledge of parameters and functions used to describe the hydraulic, hydrologic, geotechnical, ecological, and economic aspects of a project. "In situations of uncertainty, potential outcomes cannot be described in objectively known probability distributions. . . . Because there are no known probability distributions to describe uncertain outcomes, uncertainty is substantially more difficult to analyze than risk" (ER 1105-2-100.E-4.a.(2)).

3) "Risk-based analysis" is defined as "an approach to evaluation and decision making that explicitly . . . incorporates consideration of risk and uncertainty to compare plans in terms of likelihood and variability of physical performance, economic success and residual risk (ER 1105-2-100.2-4.g)." Analytical evaluation is sometimes restricted by a lack of data

and understanding of biological and physical processes, effectively limiting risk considerations to more subjective comparisons.

4) "Sensitivity analysis" is a technique that varies assumptions of economic, demographic, environmental, and other factors and examines the effects of varying these assumptions on outcomes of benefits and costs (ER 1105-2-100.E-4.b.(1)(b)(6).

5) "Residual risk" is a concept best understood in relation to flood risk management studies; i.e., residual risk is the flood risk that remains after a proposed project is implemented; or, in other words, the residual damages and potential loss of life due to exceedance of design capacity. For navigation studies, one type of residual risk might be risk that benefits are foregone in those situations where locally preferred plans are selected over the NED Plan.

The USACE has developed a risk management model detailed in Figure 33. The steps in this model include:

1) Establish Decision Context - This task establishes the decision context in which a risk management decision will be made. It includes defining the management problem and establishing the measurable objectives of the activity to which the risk management process is being applied. Decision-making criteria, evident uncertainties, and the questions to be answered in subsequent analytical steps are identified in this step.

2) Identify Risks - Identify the risks relevant to the decision context. This means identifying but not yet quantifying the consequences (positive or negative) and likelihoods and how they will be expressed. It includes asking and answering "what can go wrong" and "how can it happen" about the problem setting.

3) Analyze Risks - Estimate the consequences and likelihoods of the risks identified in the previous step. At the same time recognize and report decision-critical uncertainties and incorporate them as a source of risk. The consequence and likelihood for each risk may be combined to produce an estimated level of risk. Alternative management strategies are analyzed in this step. This is often the principle analytical step in the risk management process.

4) Evaluate Risks - Risk management alternatives are evaluated and compared to identify the best solution. This evaluation includes consideration of the risk and other values important to the decision. The evaluation will consider the cost to reduce increments of risk; who bears the risk; what risks are managed, reduced, borne, transferred, and so on.

5) Risk Management Decision - A decision is made to accept or take action to manage the identified risks. If action is taken, a risk management strategy is developed and implemented. Desired and measurable outcomes of the management strategy are identified at this step so the success of the plan can be monitored and evaluated. To the extent there is significant analytical uncertainty, the risk management strategy will include an adaptive management plan to reduce such uncertainties over time and, as needed, modify the execution of the actions taken.

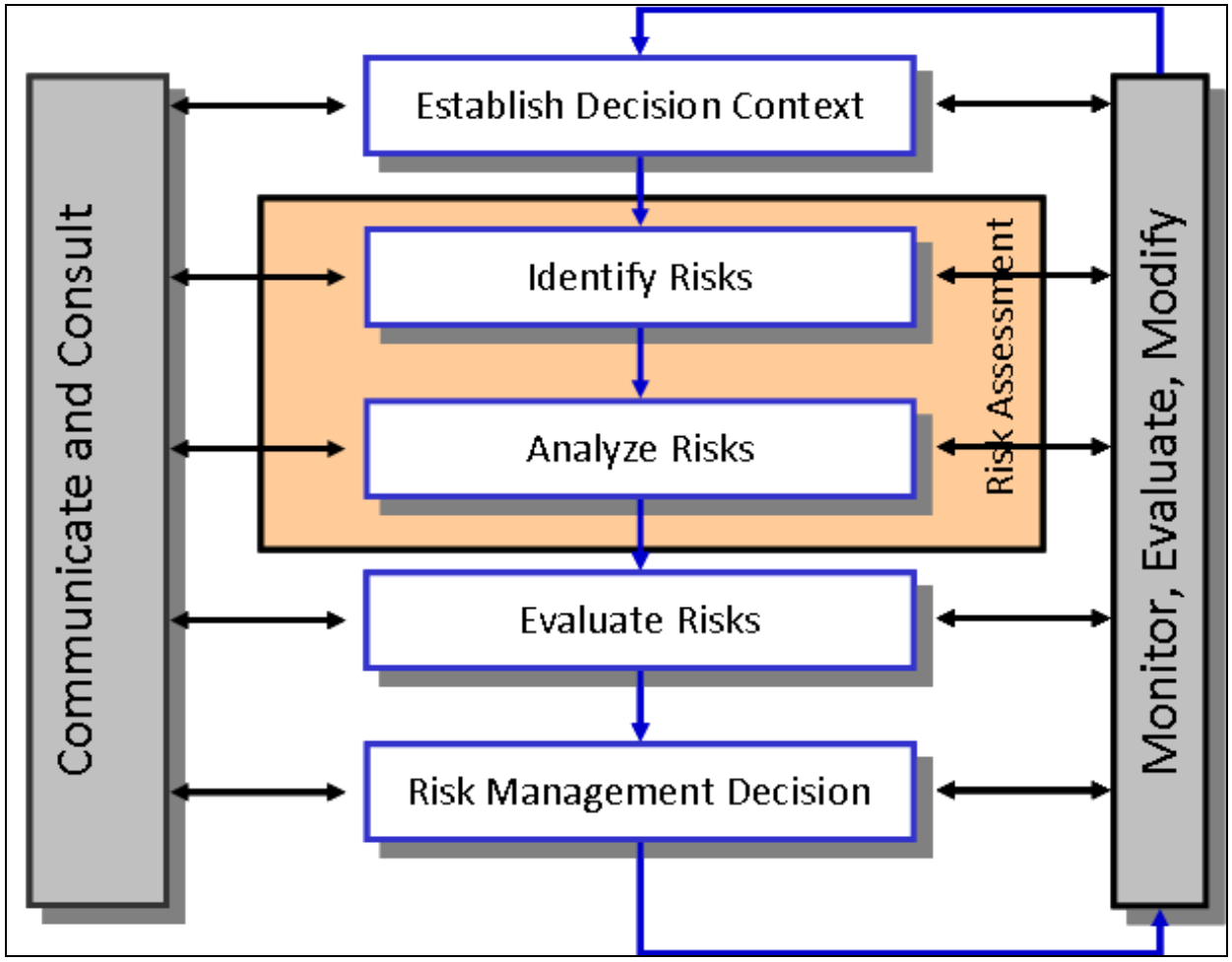


Figure 33
USACE Risk Management Model

The steps detailed in the model are described below as they specifically relate to the steps taken and tools utilized for the Clear Creek GRR.

Establish Decision Context

The main task in this step is defining the management problem. The problem, as detailed earlier in this report, is flood risk that remains throughout the Clear Creek watershed and the objectives that have been established to help identify measures that will remove some of this risk. The largest uncertainty in any flood risk management project, and an important part of the USACE planning process, is the forecasting of future conditions. In order to evaluate the risks and benefits of alternatives over the period of analysis, a forecast is created based on historical and existing information as well as quantitative and qualitative assumptions about what may happen within the study area in the future. One method is to identify the 'most likely' future, or the best guess about what may happen, based on observed variables and assumptions of both natural and human behaviors. Another method is to conduct scenario planning, where multiple future scenarios are created in order to evaluate what would happen if observed variables or assumptions do not happen as projected. Scenario planning attempts to answer the 'what if' questions that arise when making forecasting assumptions and predictions. For the Clear Creek GRR, the "most likely future" method was chosen due to the size, scope, and complexity of the overall analysis.

Identify Risks

After the identification of the most likely FWOP scenario for the Clear Creek watershed, the next step was the evaluation of alternatives using H&H, economic and ecological models. There are two levels of risk when utilizing these tools in making decisions during a flood risk management analysis. The first is the accuracy and reliability of the tools themselves and the second is the risk of not reducing or actually increasing flood risk or environmental impacts with the decisions that come from these tools.

To increase accuracy and reliability, the rainfall-runoff model (HEC-1) and hydraulic models (HEC-RAS) for the GRR were created using newly acquired data. These models benefit from modern technologies such as GIS, Global Positioning System surveys, and improved modeling software. This information is fed into the economic model (HEC-FDA) which is used to determine damages for different flood levels.

Efforts were made to obtain historic flood damage information for the study area; however, no reliable information exists. This is true in most any flood situation, as estimates of damage are anecdotal and unsubstantiated estimates by local officials. There is no true quantification of flood damages following a flood event, only off-the-cuff estimates that cannot be used to substantiate a rigorous analysis. Also, damage dollar estimates for individual events tend to

cross over several watersheds so utilizing estimates from a single event are difficult at best. USACE attempted to evaluate further historical information but was unable to capture damages from historical events and the uncertainty associated with them.

Additionally in the last few years, storms have been more intense but there is uncertainty as to whether this trend continue and if so, at what rate. Additional attempts to quantify or describe this uncertainty would add little to determining the feasibility of the project. USACE considered doing sensitivity analyses to capture the changes in rainfall depths/storms over the next 50 years but ultimately did not quantify such changes.

The ecological model utilized was a community-based HEP model. The HEP model benefitted from input of numerous resource agencies that were part of the ICT developed for the project.

To reduce risk associated with decision making, the team utilized national and regional experts including the non-Federal Sponsors, model development teams, and resource agencies. Coordination with the non-Federal Sponsors responsible for watershed management for Clear Creek and its tributaries, as well as numerous other floodplain managers from the communities surrounding the water bodies, occurred on a monthly basis. Also, USACE experts on modeling, as well as resource agency representatives with vast knowledge of the habitats in the watershed, were part of the team evaluating impacts and potential mitigation.

Analyze Risks

While this section will paint a broad picture of the application of techniques used to analyze risk and uncertainty, the GRR, Economic Appendix, and the Supplemental Draft EIS go into greater detail on how each discipline addressed these issues.

ENGINEERING DATA AND MODELS

Risk and Uncertainty Parameters

The flood damage analysis program HEC-FDA requires input parameters that describe the error functions associated with the HEC-1 results (flow frequency) and HEC-RAS results (stage discharge). Derivation of risk and uncertainty parameters followed guidance in Engineering Manual (EM) 1110-2-1619 and is described in detail in the July 2003 without-project report. The values must be entered into the HEC-FDA program for each economic reach.

H&H Modeling

Importing Water Surface Profiles for Risk Analysis - Water surface profiles from HEC-RAS or HEC-2 backwater models were imported to HEC-FDA for each scenario modeled. The profiles are stored in the HEC-FDA project database. HEC-FDA will not execute properly if there is a stage dip in the stage discharge functions at index locations, i.e. a flow increase results in a lower stage. For the roughly 350 cross-sections in the mainstream hydraulic model, there are generally about 14 sections where this will occur. Thus, all computed profiles were routinely screened by importing the raw results to a spreadsheet and adjusting out any dips. The total adjustment needed was generally less than a few hundredths of a foot.

Exceedance Probability Functions for Risk Analysis – HEC-FDA retrieves the flow frequency data for each reach from the imported water surface profiles as the risk parameters are input. The "Graphical from WSP" method in HEC-FDA was used to assign the exceedance probability functions. This insured that the functions would closely reflect the hydrologic modeling results. The "Synthetic from WSP" method is easier to code, but that method forces the data to a Log-Pearson function. Since the basin is urbanized and because flood risk management measures were being tested, it was concluded that a forced Log-Pearson function was not appropriate. For the graphical method procedure, a 0.999 frequency value was added for each reach to extend the lower end of the function. The corresponding flow value was set at half of the input value for the 50 percent chance event.

Stage Discharge Functions for Risk Analysis - HEC-FDA retrieves the stage discharge data for each reach from the imported water surface profiles as the risk parameters are input. To resolve the complete stage discharge function, HEC-FDA inserts a zero-flow coordinate and sets the corresponding stage equal to the channel invert at the reach index location. However, the channel inverts for the first 11 reaches of Clear Creek are below sea level, so the zero-flow condition would occur near sea level, not at the invert elevation of the channel. To correct this anomaly, the stage discharge functions were edited for these first 11 reaches and the zero-flow stage was changed to +1.0 foot.

Hydrologic Engineering Center Review of H&H Modeling - A review was performed by the Hydrologic Engineering Center on the risk and uncertainty and the H&H modeling for the project. During the review, compliance with established policy principles and procedures, utilizing justified and valid assumptions was generally verified. This included review of: assumptions, methods, procedures, and material used in analyses; alternatives evaluated; the appropriateness of data used and level obtained; and reasonableness of the results, including whether the product meets the customer's needs consistent with law and existing USACE policy.

Any revisions to H&H models and analyses of the system will be completed during the Preconstruction, Engineering, and Design (PED) phase. During this phase, design-level modeling will include additional investigation of the backwater effects on the tributaries using unsteady-state HEC-RAS. This modeling should include updated topography, reevaluated Manning's n values and updates to software and methodology changes used for modeling. Additional details on the H&H modeling and the Hydrologic Engineering Center review are included in the Engineering Appendix.

Sedimentation – Previous studies, field observations, and historical data indicate Clear Creek and its tributaries have not experienced significant sediment and erosion issues within the study limits. Soils within the project vicinity consist of clays resistant to erosion. Additionally, discussions with local drainage districts have indicated that sediment has not presented any serious problems for Clear Creek over the life of the present channel. Velocities will be generally the same for the with- or without-project conditions based on H&H models. No significant changes in sediment deposition are anticipated because there is little change in the hydraulic characteristics in the creek between the with- and without-project conditions and the alignment of the stream remains relatively unchanged. Temporary erosion controls will be utilized during the construction of the project to minimize siltation. Permanent erosion control measures will also be designed and maintained as part of this project to minimize siltation. Detailed design and location of temporary and permanent erosion control devices will be determined during PED.

However, an additional review of the analysis for sedimentation was performed by sedimentation experts from the PCX for Flood Risk Management. This review consisted of field visits, sedimentation estimates using the box method, soil assessment in the watershed, and discussions with local experts and determined that sedimentation will not be a problem for the project. Additional information on sedimentation is included in the Engineering Appendix.

COST ENGINEERING

Contingencies for all contracts were developed using the Cost and Schedule Risk Analysis (CSRA) process and the Crystal Ball software.

ECONOMIC DATA AND MODELS

The HEC-FDA model is employed in this analysis because its risk-based analysis methods for flood risk management studies meet the requirements of EM 1110-2-1419 and ER 1105-2-101. HEC-FDA Version 1.2.5 is a certified model and appropriate for this application. The analytical method explicitly incorporates descriptions of uncertainty within key parameters and functions into project benefit and performance analyses. Uncertainty was captured for the key economic

parameters of depth-percent damage functions, structure values, utility damages, post disaster recovery costs, and first floor elevations.

ECOLOGICAL MODELING

Campaign Plan Directive

An analysis of risk and uncertainty associated with the Floodplain Forest community-based habitat suitability index (HSI) model application to the Clear Creek GRR was performed in consideration of recommendations contained in the Campaign Plan directive (USACE, February 2011). This analysis facilitated risk-informed decision-making regarding the levels of ecological impacts and resulting recommended compensatory mitigation that was established using the models. The analysis allows decision makers to evaluate uncertainties associated with impact predictions, and understand how different predictable outcomes would affect the cost of the mitigation plan.

Types of Risk Associated with Predictive Ecological Modeling

Risks to human health and safety associated with ecological impacts evaluated by the model are small. The primary impact of the recommended plan is a direct impact associated with the loss of 278 acres of floodplain forest due to conveyance improvements.

Floodplain forest hydrologic parameters (hydroregime, sinuosity, substrates, roughness, etc.) would not be greatly affected as the system was already stressed and would continue as such; water depth would increase as a matter of conveyance designs. Ongoing urban encroachment in conjunction with project implementation would cause further fragmentation of floodplain forest leading to constrictions in habitat core areas and increases in overall habitat edges, which, in turn, would affect patch sizes, distances between patches, and impervious surfaces. This loss of vegetative structure and spatial complexity would leave the remaining floodplain forest susceptible to disease and incursions of nonnative species and exotics leading to increased competition and a general loss of the native-based, functioning community.

Where practicable, floodplain forest restoration (e.g. adding patches, expanding core areas, increasing native species through native tree planting schemes, and intensive maintenance) was designed into the recommended plan to minimize the declining trends in floodplain forest to some degree and return the system to a more natural, shaded, riverine complex. The proposed compensatory mitigation plan would further offset the declining trends in both floodplain forest and contribute to the long-term sustainability of the floodplain forest by increasing overall vegetative integrity, spatial complexity, and connectivity of the communities' landscape mosaics.

The amount of recommended mitigation is based upon the amount that needs to be preserved and/or restored or created in order to fully compensate for adverse changes in the spatial and functional complexity of Clear Creek's floodplain forest communities over the 50-year period of analysis.

The primary risks associated with ecological modeling for the Clear Creek GRR relate to the accuracy of the impact assessment and the cost of mitigation.

Although the USACE – Galveston District went to great lengths to avoid and minimize impacts under the recommended plan, impacts were still anticipated (106 average annual habitat units (AAHUs) for floodplain forests). These impacts must be fully compensated for (in-kind), and as such, a suite of mitigation plans afforded full compensation in a cost-effective and incrementally effective manner. An extensive evaluation of mitigation measure alternatives and a cost effectiveness/incremental cost analysis, described in Appendix A of the Supplemental Draft EIS, have identified the Best Buy combination of recommended mitigation measures. By focusing on each cost analysis result in turn, the results indicate a combination of several proposed mitigation measures, when implemented together, fully compensate for the impacts in a cost effective, incrementally effective manner.

Uncertainties Associated with Predictive Ecological Modeling

There are two types of uncertainty that have been identified for the predictive ecological modeling conducted in this study: (1) uncertainty associated with model quality and performance and (2) uncertainty associated with model predictions. Extensive technical and peer review of the Floodplain Forest model have been completed to ensure they are technically sound and defensible.

Sensitivity Analyses of the Floodplain Forest Model Predictions

Sensitivity analysis of the Floodplain Forest Community HSI Model employed the use of a "one-at-a-time parameter sensitivity assessment" of the model's individual variables to generate a range of potential outcomes and quantify the uncertainty of the model's output. Every variable in the floodplain forest model was subjected to a 20 percent increase (and decrease) in its mean to calculate the "best" and "worst" possible HSI values as a quantification of the degree of certainty associated with the model's results. Overall, the model's uncertainty is relatively low with results vary as much as 9 percent over and as low as 17 percent below the HSI (on average). A second sensitivity analysis on the use of rounded means was run and revealed that rounding did not significantly affect the outcomes but, in fact, improved the ability of the users to forecast the future ecosystem responses to proposed alternative designs.

Additional analyses resulted in a number recommendation for users of the model with regard to robust collection and subsequent handling, management and assessment of variable data for input into the model analyses. Users are cautioned to take particular care to note the sensitivities and potential variability of particular model parameters and their mathematical relationships in driving the model outcomes.

A complete technical discussion of the sensitivity analysis and the potential errors and their impacts on the conclusions drawn from the model's outputs may be found in Chapter 4 of the model documentation report (Burks-Copes and Webb, 2010).

EVALUATE RISKS

All of the previously mentioned risk factors were folded into the analysis performed at every level including initial screening, first- and second-added analysis as well as selection of the recommended plan. Probabilistic evaluations were also performed during the economic analysis to help determine the likelihood of reaching certain damage levels for certain events.

RISK MANAGEMENT DECISION

The combinations of all of the evaluated measures that have become part of the recommended plan reduce flood risk within the watershed while also minimizing environmental impacts. The determinations made have been done so with an acceptable level of uncertainty. As far as the risk assessment, the proposed project does not remove all of the risk but only a portion. This fact is clearly communicated throughout the report. The non-Federal Sponsors are taking steps through additional structural and nonstructural projects to continue to reduce risk in the watershed. These risk factors are and will continue to be evaluated by the CCSC through development of the Watershed Management Plan in accordance with Policy Guidance Letter (PGL) 52, a guidance letter that provides policy on Section 202 (c), Flood Plain Management Plans, of the WRDA of 1996. This guidance letter requires non-Federal interests to prepare a floodplain management plan designed to reduce the impacts of future flood events.

Other parts of the model include "Communicate and Consult" as well as "Monitor, Evaluate, and Modify". The GRR team has utilized a very aggressive communication strategy, making the entire process very transparent to the public. Through monthly communication with the CAC, townhall meetings at key decision points in the process, and the utilization of a DVD presentation on the process, the team has continually communicated information on risk associated with taking no steps as well as implementation of the Federal project.

To insure proper monitoring the non-Federal Sponsors, in cooperation with the CAC, have begun development of a Watershed Management Plan to address the requirements of PGL 52, insuring that steps taken on a local level do not negatively impact the Federal project. Also, due to new requirements, an adaptive management plan has been developed for the environmental mitigation. This plan will make certain that steps can be taken to insure success of the mitigation, should it be determined that problems exist after construction.

VIII. DESCRIPTION OF RECOMMENDED PLAN

The GRP/NED Alternative was identified as the recommended plan. The recommended plan completes construction of the authorized project. This plan is composed of numerous conveyance and detention components that create a system that reduces flood damages in the upper extent (upstream of FM 2351) of the Clear Creek watershed while producing statistically insignificant increases in flood surface elevations. The plan also utilizes environmental features that enhance acceptability of the project by the surrounding communities but, due to the lack of a cost-share sponsor, no ecosystem restoration components were evaluated or proposed for approval. This recommended plan does not include the cost of previously constructed components. Figure 34 details all of the project components associated with the recommended plan.

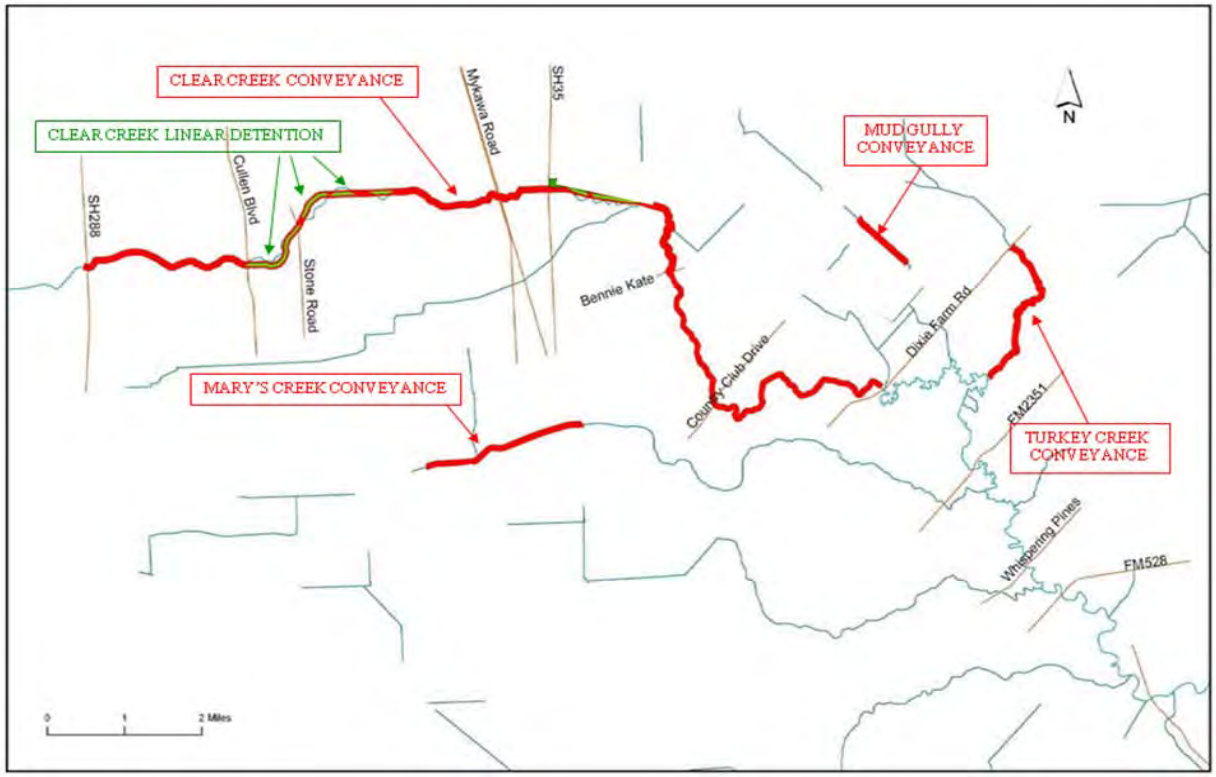


Figure 34
Conveyance and Detention Components of
Clear Creek Recommended Plan

The existing Second Outlet and Gate Structure between Clear Lake and Galveston Bay will be operated by HCFCD to ensure that the project will not induce flood damages on the lake community by keeping water levels in the lake from increasing. The standard operating

practices currently used for the gates will continue to be utilized to maintain the appropriate lake levels.

The largest feature of the project is the conveyance components proposed for the main stem of Clear Creek. The largest portion of this feature is an approximately 10-mile conveyance measure, which includes a 200-foot bottom width bench cut from SH 288 to approximately 4,000 feet downstream of Bennie Kate Road (Figure 35). Conveyance improvement continues downstream of the 200-foot wide bench cut but is reduced in size and extends from 4,000 feet downstream of Bennie Kate Road to Dixie Farm Road. In this reach, the feature is a 90-foot wide bench cut (Figure 36). Both of these features are designed to maintain a natural low-flow channel that will minimize impacts of the project while facilitating the reduction of flood damages through the construction of high-flow benches. In the footprint of the low-flow channels, habitat already existing will remain while any areas not currently forested will be planted in an attempt to create a shaded stream habitat. These forested, low-flow channels are design features and were developed as a result of the Environmental Operating Procedures. They are not designated as mitigation but due to their nature, reduce the amount of mitigation necessary to offset total project impacts. The benches will be unvegetated and easier to maintain, reducing operations and maintenance expenses. Trees will also be planted at a rate of 14 per acre on the side slopes of the bench as well as in a 10-foot buffer on both sides of the feature for aesthetic purposes.

The only detention feature included in the plan is made up of linear detention located in the footprint of the high-flow bench cut conveyance feature, but only when the high-flow bench leaves the footprint of the natural low-flow channel (Figure 37). A plan view representation of this can be seen in Figure 38. This linear detention will generate approximately 500 acre-feet of additional detention.

Additional conveyance is located on three tributaries to Clear Creek. The first is on Marys Creek. Marys Creek is a previously impacted creek with little habitat value (Figure 39). This feature is a trapezoidal, grass-lined channel modification that ranges in bottom width from 15 to 35 feet and extends from Harkey Road to SH 35 (Figure 40).

The recommended plan also incorporates conveyance improvements on Mud Gully. This feature would extend from Sagedowne to Astoria on Mud Gully a distance of one mile (Figure 31). This section of the waterbody has undergone significant modification in the past and has a limited footprint available for changes to occur. The Gully is located between the northbound and southbound lanes of Beamer Road (Figure 41), and because of this limitation, the feature has been designed as a concrete-lined channel (Figure 42).

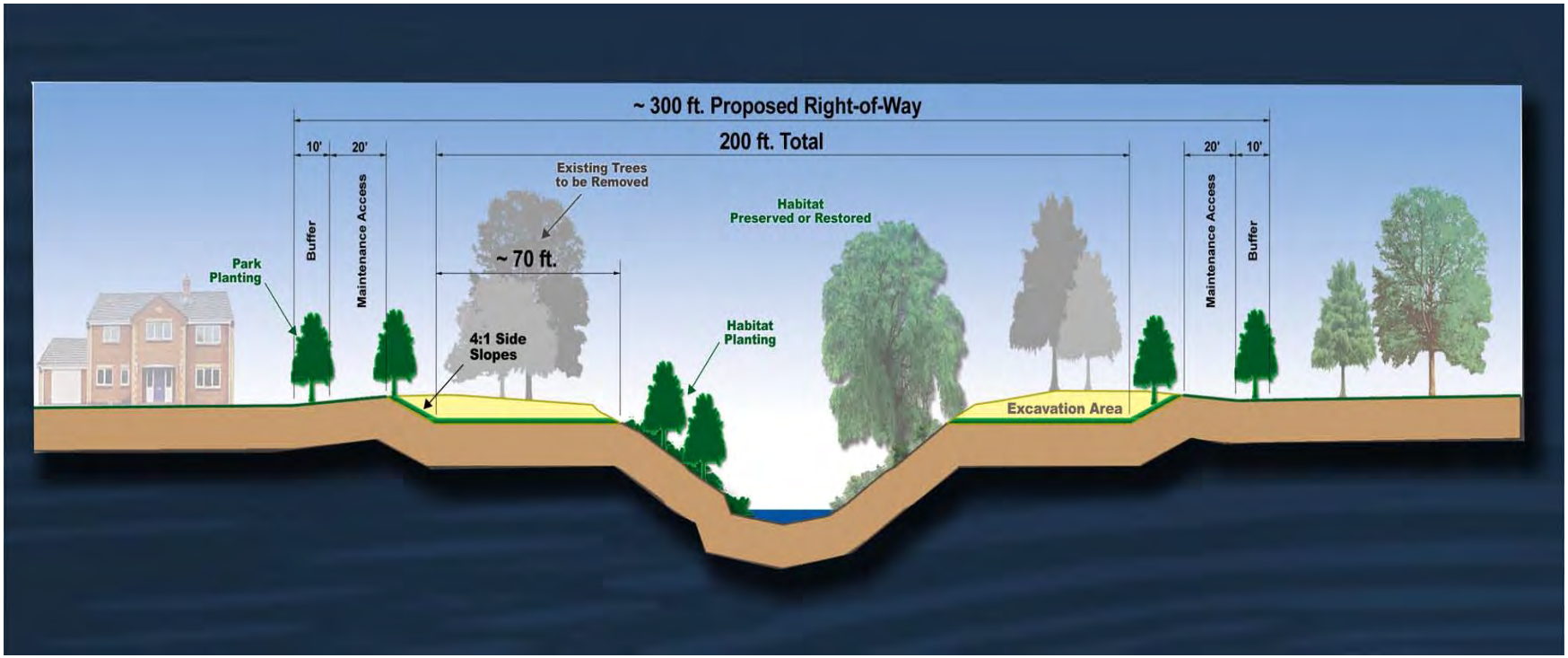


Figure 35
Clear Creek Mainstem Conveyance Feature
From SH 288 to Bennie Kate Road

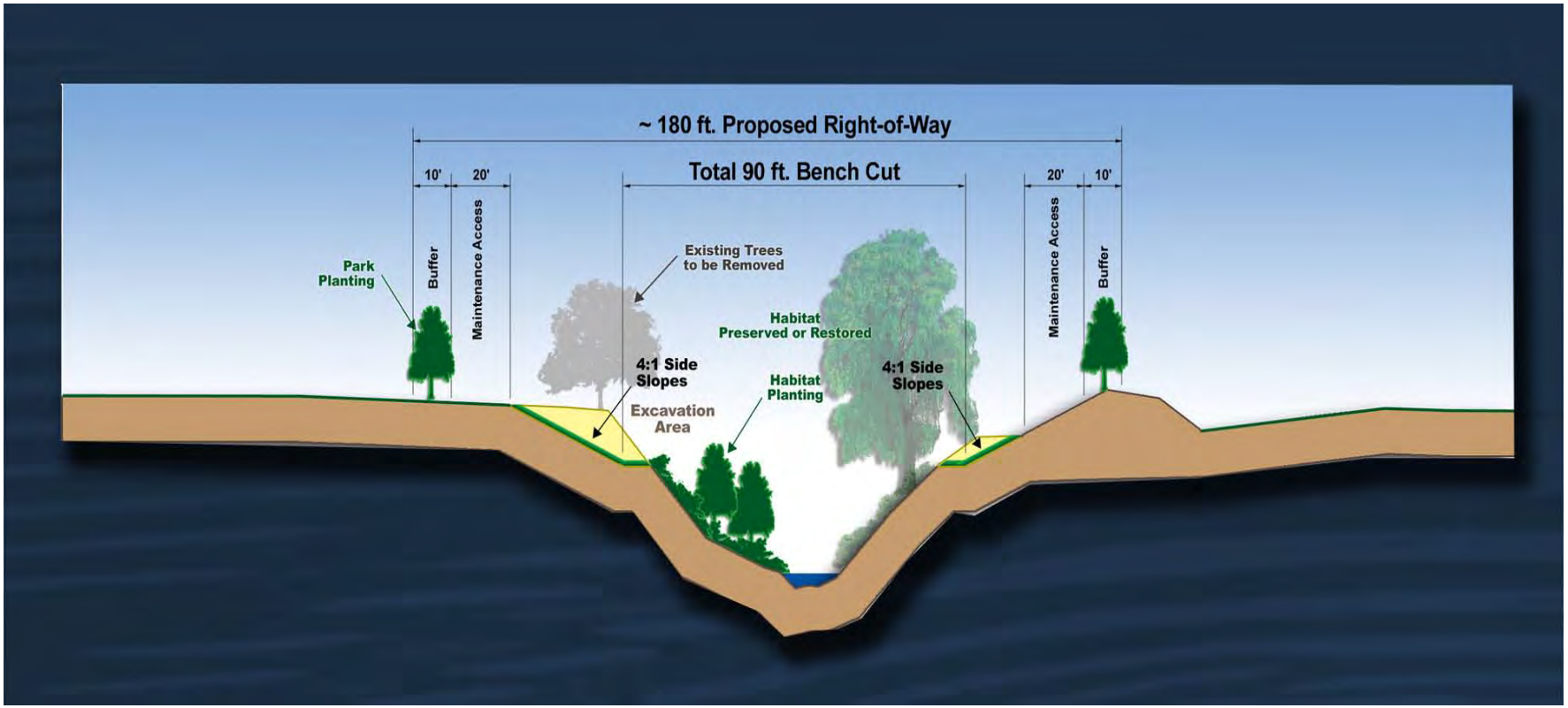


Figure 36
Clear Creek Mainstem Conveyance Feature
From Bennie Kate Road to Dixie Farm Road

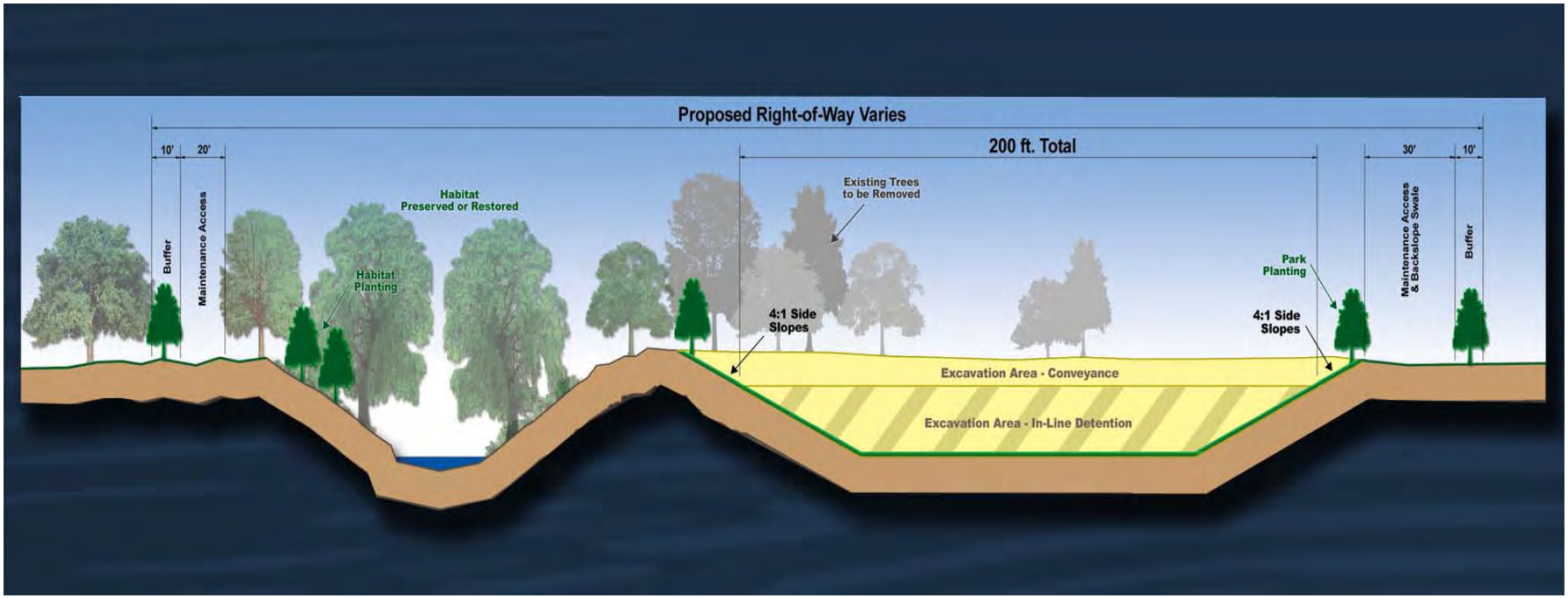


Figure 37
Cross-Section of High-Flow Bench When Not Within Same Footprint as Low-Flow Channel
(Hatched X-Section Is Detention Capacity)

Figure 38
Plan View Example of Areas Including Inline Detention
On Main Stem of Clear Creek

Figure 39
Marys Creek Downstream of Harkey Road

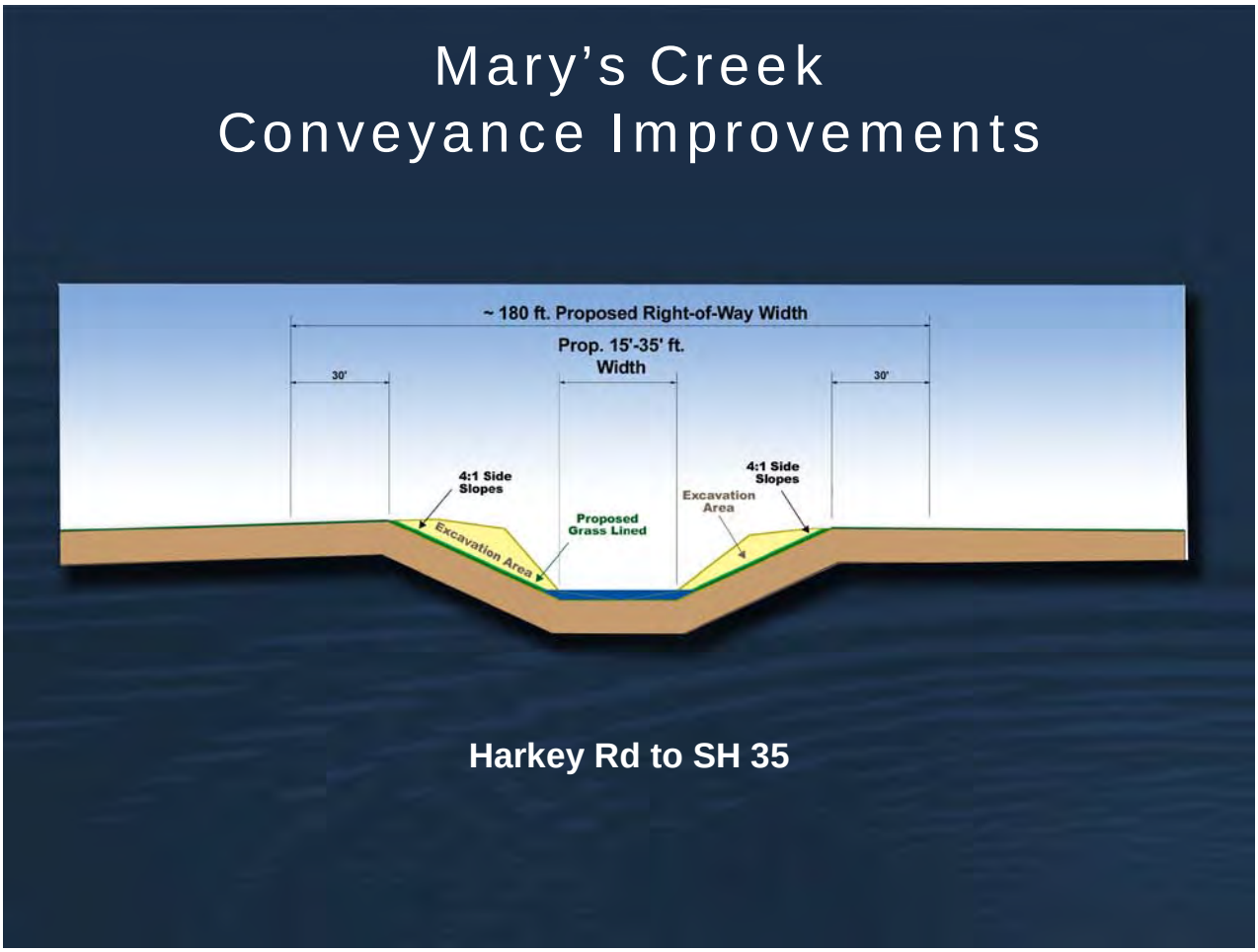


Figure 40
Cross-Section of Marys Creek Conveyance Feature

Figure 41
Mud Gully Downstream of Sagedowne Road

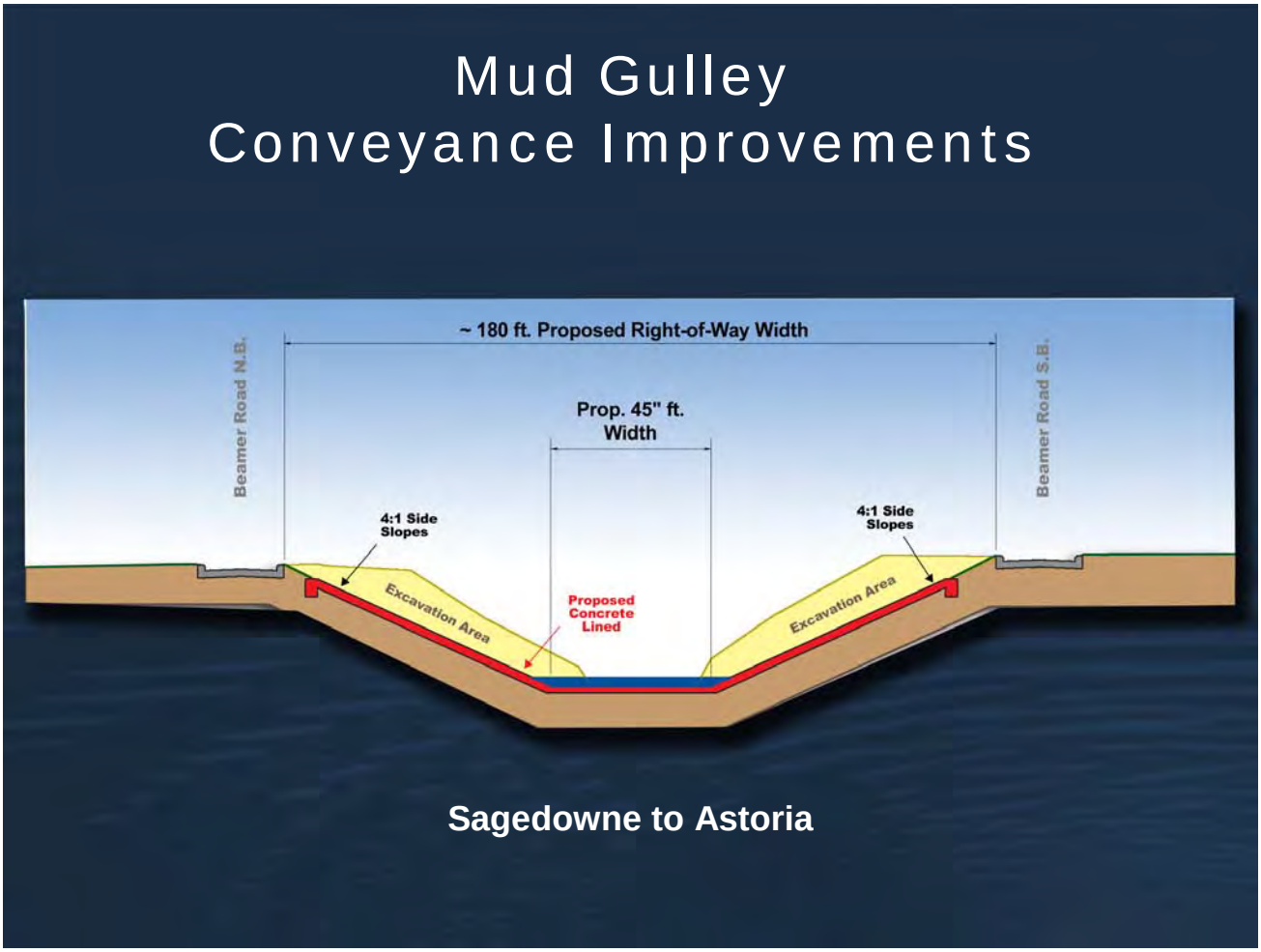


Figure 42
Cross-Section of Mud Gully Conveyance Feature

Superfund sites (Brio Refinery and Dixie Oil Processors) are located just downstream of the conveyance improvement on Mud Gully. The potential discharge of affected groundwater has been contained through corrective action by the responsible parties and the TCEQ. Remedial action at both sites involved the construction of a soil cap over the residual waste, significantly reducing the potential for direct contact with surface waters and sediments. Subsequently, the concentrations of pollutants in the waters and sediment of Mud Gully and Clear Creek have decreased significantly. Construction of the project would reduce the surface flood elevations in the area, further reducing the potential for flood waters to impact to the sites during major flood events.

The final project component is located on Turkey Creek, another tributary to Clear Creek (Figure 43). This feature is approximately 2.5 miles in length and would extend from Dixie Farm Road to Turkey Creek's confluence with Clear Creek. The feature would also be a grass-lined trapezoidal channel with a bottom width ranging from 20 to 25 feet.

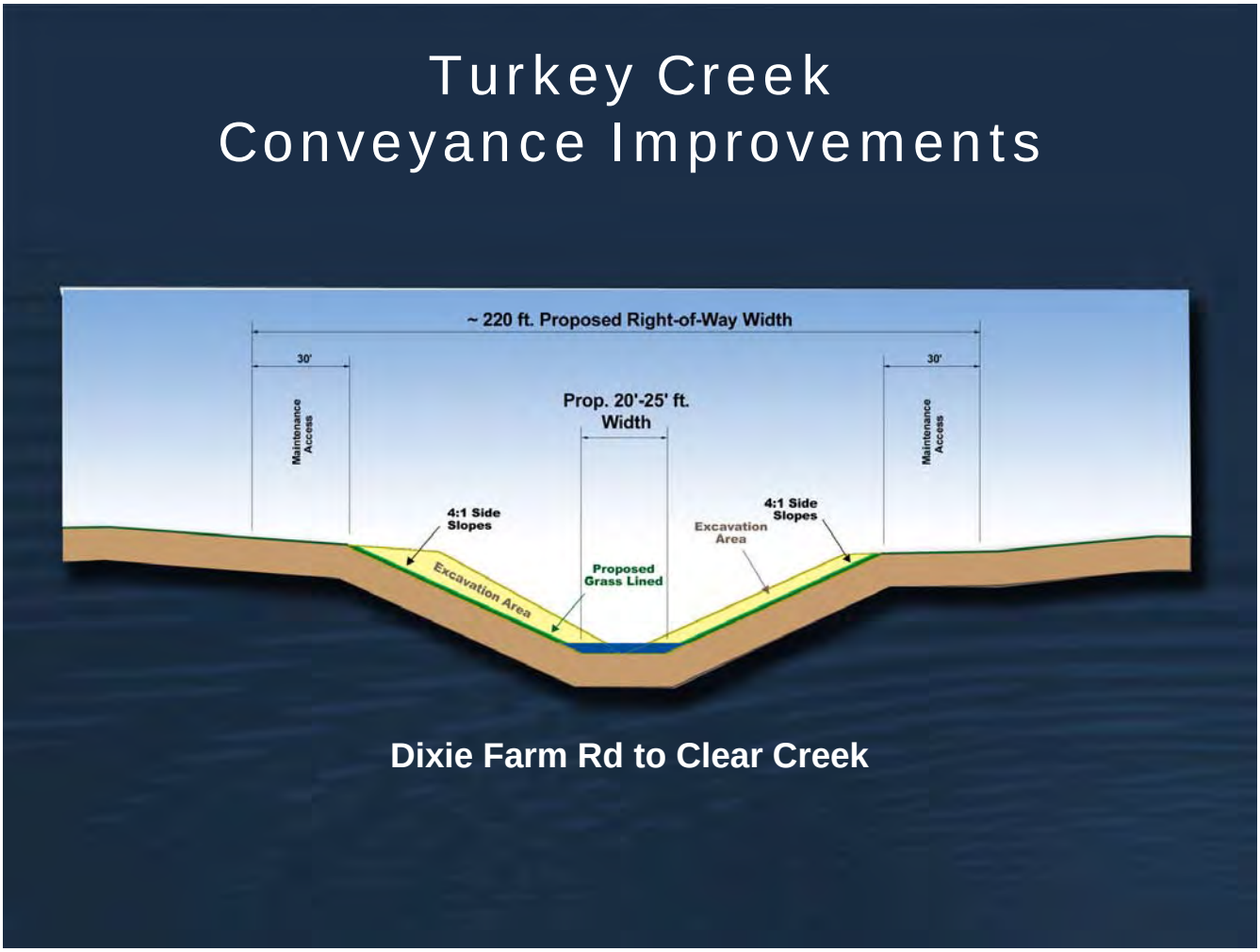


Figure 43
Cross-Section of Turkey Creek Conveyance Improvement

MITIGATION REQUIREMENTS

Due to design features incorporated into the recommended plan, the amount of mitigation necessary to offset impacts is lower than the mitigation needed if these environmental features were not included. Environmental features include the vegetated low-flow channels and reintroduction of low-flow channels into historic locations. These features help return the creek to a shaded and more sinuous nature, allowing for higher dissolved oxygen totals and cover for both land and aquatic species.

To compensate for unavoidable impacts resulting from construction of project features, potential mitigation measures were evaluated. Subsequently an Ecosystem Assessment Team (E-Team) was formed to oversee the development and application of a HEP model to evaluate ecological effects of the Clear Creek alternatives. Selection of mitigation features was conducted by the E-

Team through the development of HSI modeling using the HEP. Variables included in the model were selected based on their potential to capture changes to ecosystem integrity within a water, soils, habitat structure, and/or landscape context in response to land and water management activities with the study area. The E-Team defined the study area for assessment of impact and mitigation alternatives as the 0.2 percent AEP (500-year) floodplain, and for evaluation purposes, divided the study area into seven reaches. Three priority ecosystem habitats were identified by the E-Team for assessment: floodplain forest, wet coastal prairie, and tidal marsh. However, because no impacts to wet coastal prairie and tidal marsh are expected, these habitats were not included in final modeling.

The primary impact of the recommended plan is the loss of 278 acres of floodplain forest over the period of analysis. These adverse effects are caused by the changes in landforms, hydrologic characteristics, and vegetative cover associated with conveyance improvements and storage features of the project. As part of the project features, green design elements were incorporated into the recommended plan providing for the rehabilitation of 122 acres and reestablishment of 33 acres of floodplain forest in the project area. While this habitat acreage is not part of the compensation requirements for the project, it has been considered in the determination of the evaluations of impacts from the project.

Using the habitat models, the No-Action Alternative, future with-project, and mitigated future with-project conditions were determined. The ecological value of the forest floodplain impacts from the recommended plan has been determined to be 106 AAHUs. A total of 27 different mitigation measures were evaluated. Eventually, 12 mitigation components were identified for additional evaluation. The E-Team culled measures that did not meet the in-kind mitigation requirements or address the spatial connectivity and complexity requirements; plans were refined to optimize outputs, where possible. In some instances, proposed measures required buyouts that potentially provided ancillary flood risk management benefits. Many of these were dropped from consideration due to considerable costs involved and the fact that they were politically infeasible. The final array of mitigation features evaluated included 12 measures, spanned 4 environmental reaches, and offered a range of AAHU outputs at varying degrees of costs, which were sufficient to offset losses. These were carried forward into cost effective and incremental cost comparisons.

Cost effective analyses identified the least-costly plans for each level of output. The three criteria used for identifying non-cost effective plans or combinations include:

1) The same level of output could be produced by another plan at less cost.
2) A larger output level could be produced at the same cost.
3) A larger output level could be produced at the least cost.

Thirty-two combinations of measures for floodplain forest were identified as cost effective. Incremental cost analysis compared the incremental costs for each additional unit of output for all of the combinations evaluated. This led to the development of an incremental cost-per-habitat unit. The plan with the lowest incremental cost-per-unit over the No-Action Alternative was the first incremental Best Buy plan. Plans that had higher incremental costs-per-unit for a lower level of output were eliminated. The next step was to recalculate the incremental cost-per-unit for the remaining plans. This process was reiterated until the lowest incremental cost-per-unit for the next level of output was determined. The intent of the incremental analysis was to identify large increases in cost relative to output. Nine combinations of designs for the floodplain forest are shown in Table 24.

Table 24
Incremental Cost Per Output for Cost Effective Mitigation Plans

Potential Mitigation Plans for the Floodplain Forest Community	Reaches Affected	Average Annual Habitat Units (AAHUs)	Costs ($1000)	Average Cost ($1000)	Incremental Cost ($1000)	Incremental Outputs (AAHUs)	Incremental Cost Per Output ($1000)
No Action	--	0	0	0	0	0	0
C1	4 and 5	131	242,835	1,854	242,835	131	1,854
C1 + D	4 and 5	310	1,585,895	5,116	1,343,060	179	7,503
C1 + D + I	2, 4 and 5	356	2,036,596	5,721	450,701	46	9,798
C1 + D + G + I	2, 4 and 5	421	2,748,462	6,528	711,866	65	10,952
C1 + D + G + I + A2a	2, 4, 5, and 6	441	2,973,676	6,743	225,214	20	11,261
C2 + D + G + I + A2a	2, 4, 5, and 6	461	3,350,486	7,268	376,810	20	18,841
C2 + D + F + G + I + A2a	2, 4, 5, and 6	560	5,265,200	9,402	1,914,714	99	19,341
C2 + D + E + F + G + I + A2a	2, 3, 4, 5, and 6	608	6,455,377	10,617	1,190,177	48	24,795
C2 + D + E + F + G + I + A1a + A2a	2, 3, 4, 5, and 6	616	6,885,782	11,178	430,405	8	53,801

Through use of the cost effectiveness/incremental cost effectiveness analysis, a mitigation plan successful at compensating for all of the with-project environmental impacts was developed incorporating the measures as follows:

- Restoration of the low-flow channel to mimic the known sinuosity in 1955 on the main stem of Clear Creek by reconnecting remnant oxbows between Country Club Drive and Dixie Farm Road (Figure 44). These oxbows were cutoff as a result of past channelization activities. This would be accomplished by modifying portions of the existing conveyance feature, diverting water into the oxbows under low-flow conditions, and maintaining high-flow conditions to guarantee flood protection for the area. Dredged material stockpiled along the north bank of the creek would be removed, and the existing cleared overbank areas along the channel would be densely planted to restore the existing floodplain forest to a desired state. Approximately 31 acres of floodplain forest would be restored.


Country Club Drive
Dixie Farm Road
FM 518
Key's Creek
HARRIS
CHAMBERS
FORT BEND
BRAZORIA
GALVESTON
Key
Road
Stream
Project Footprint
Mitigation Features:
Mitigation Site C1
N
W
E
S
0
1,000
2,000
Feet
Figure 44
Compensatory
Mitigation
Clear Creek
Flood Risk Management Project
Prepared for: USACE
Job No.: 100002202
Scale: 1in = 1000 ft
Prepared by: GR
Date: 3/23/2010
File: N:/Clients/U_Z/USACE/Projects/Clear_Crk/044188600/figures/mitigation/Mitigation_C1.mxd

RECOMMENDED PLAN COST SUMMARY

The costs for the Recommended Plan are summarized in Table 25. The Total First Cost is $189,135,000. Table 26 displays the cost and benefit analysis for the Recommended Plan which results in a BCR of 2.3 at the current 4 percent interest rate. These costs do not include the sunk costs for the project from the previous construction of the second outlet and gated structure. The sunk costs are combined with the recommended plan costs to make the Modified Authorized Project which is presented in the Plan Implementation Section of this report.

Project cost share requirements are detailed in Table 27. As stated earlier, the sponsors are responsible for costs associated with LERRD which totals $66,522,000.

Table 28 details the Fully Funded Project Cost, which includes both contingency and escalation. Escalation is calculated by using mid-point of the proposed construction contracts.

Table 25
Cost Summary
For Recommended Plan
Clear Creek, Texas
(October 2011 Price Levels)

Construction Item	Cost ($)
Land and Damages	43,735,000
Elements	
Relocations	24,744,000
Fish & Wildlife Facilities	16,587,000
Channels & Canals	79,094,0000
Cultural Resource Preservation	1,895,000
Subtotal	122,320,000
Engineering & Design	16,639,000
Construction Management (E&D, S&A)	6,441,000
Total First Cost of Recommended Plan	189,135,000

Table 26
Equivalent Annual Benefits and Costs
For Recommended Plan
Clear Creek, Texas
(October 2011 Price Levels, 50-year Period of Analysis, 4 Percent Discount Rate, dollar values in thousands)

	Costs
Investment Costs	
Total Project Construction Costs	$189,135,000
Interest During Construction	$5,929,000
Total Investment Costs	$194,064,000
Average Annual Costs	
Interest and Amortization of Initial Investment	$9,080,300
OMRR&R	$1,060,700
Total Average Annual Costs	$10,141,000
Average Annual Benefits	$23,110,000
Net Annual Benefits	$12,969,000
Benefit-Cost Ratio	2.3

Table 27
Cost Sharing
For Recommended Plan
Clear Creek, Texas
(October 2011 Price Levels)

Item	Federal Cost ($)	Non-Federal Cost($)	Total Cost ($)
Flood Risk Management (FRM)			
LERRD	0	66,522,000	66,522,000
Flood Risk Management	105,974,000	0	105,974,000
Subtotal	105,974,000	66,522,000	172,496,000
Engineering and Design	16,639,000	0	16,639,000
FRM Subtotal	122,613,000	66,522,000	189,135,000
Associated Costs	0	0	0
Total Recommended Plan with Associated Costs	122,613,000	66,522,000	189,135,000

Table 28
Fully Funded Project Cost
For Recommended Plan
Clear Creek, Texas
(October 2011 Price Levels)

Construction Item	Cost ($)
Land and Damages	46,878,000
Elements	
Relocations	26,763,000
Fish & Wildlife Facilities	17,986,000
Channels & Canals	86,920,000
Cultural Resource Preservation	2,015,000
Subtotal	133,684,000
Engineering & Design	19,551,000
Construction Management (E&D, S&A)	7,832,000
Total Fully Funded Cost (Recommended Plan)	207,945,000

IX. PLAN IMPLEMENTATION

The intent of the GRR was to re-evaluate the unconstructed portion of the authorized Clear Creek Project, and to recommend a plan which, when combined with the constructed components, would result in a Modified Authorized Project. The total cost of the Modified Authorized Project would include the cost of the newly formulated portion added to all previous actual construction costs. This includes the actual costs of the second outlet and gated structure, associated lands, easements, rights of way, relocations, and disposal areas, and finally all costs for conducting the GRR. The Modified Authorized Project will serve as a basis for modifying the existing Local Cooperation Agreement between the Corps and the non-Federal sponsors.

DIVISION OF PLAN RESPONSIBILITIES/COST SHARING REQUIREMENTS

The non-Federal Sponsor is responsible for all LERRD uncontaminated with hazardous and toxic wastes and a minimum cash contribution amounting to 5 percent of the flood control features of Total Project First Costs. For projects authorized on or before October 12, 1996, if the value of LERRD plus cash is less than 25 percent of Total Project First Costs, the non-Federal Sponsor is responsible for providing additional cash to total 25 percent of Total Project First Costs. The maximum non-Federal contribution will not exceed 50 percent of Total Project First Costs.

Total project first cost for the Modified Authorized Project is $243,623,000 (Table 29). This cost includes the total first cost for the newly formulated portion of $189,135,000, which would require seven separate contracts for complete construction. It also includes the sunk costs, including the cost of the GRR and construction of the second outlet and gated structure, which total $54,488,000.

A Memorandum of Agreement among the USACE, the State Historic Preservation Officer (SHPO), and the Advisory Council on Historic Preservation (ACHP) is in place to ensure compliance with Section 106 of the National Historic Preservation Act. A new Programmatic Agreement (PA) is currently being coordinated with the SHPO, the ACHP, and the Project Sponsors. This PA was prepared to include the Project Sponsors and to guide implementation of the proposed Clear Creek Project. Final analysis for cultural resources has been deferred until PED and will be performed under either the existing MOA or the new PA. Based on this the costs identified for cultural resources in the current cost estimate include additional surveys, as well as rough estimates for what may be necessary for mitigation. The costs for mitigation are not expected to exceed 1 percent of Total Project First Costs; however, this will be determined during PED.

Table 29
Cost Summary
For Modified Authorized Project
Clear Creek, Texas
(October 2011 Price Levels)

Construction Item	Cost ($)
01 Land and Damages	43,735,000
Elements	
02 Relocations	24,744,000
06 Fish & Wildlife Facilities	16,587,000
09 Channels & Canals	79,094,000
18 Cultural Resource Preservation	1,895,000
Subtotal	122,320,000
30 Engineering & Design	16,639,000
31 Construction Management (E&D, S&A)	6,441,000
Total First Cost of Newly Formulated Portion	189,135,000
Sunk Cost (previously constructed project and GRR)	54,488,000
Total First Cost of Modified Authorized Project	243,623,000

Table 30 summarizes the benefits and costs for the Modified Authorized Project. Table 30 presents the summary at the current discount rate of 4.0 percent and the rate of 7.0 percent. The Modified Authorized Project has a BCR of 1.8 at 4.0 percent and a BCR of 1.1 at 7.0 percent.

Project cost share requirements using the project total first costs are detailed in Table 31. The sponsor is required to provide all lands, easements, rights-of-way, relocations, and disposal areas. In addition, the sponsor must provide a cash contribution equaling 5 percent of the total project cost.

Table 32 details the cost sharing for the fully funded project cost for the Modified Authorized Project, which includes both contingency and escalation. Escalation is calculated by using mid-point of the proposed construction contracts.

Table 30
Equivalent Annual Benefits and Costs
For Modified Authorized Project
Clear Creek, Texas
(October 2011 Price Levels, 50-year Period of Analysis,
4 Percent Discount Rate, dollar values in thousands)

	Costs
Investment Costs	
Total Costs of Newly Formulated Portion	$189,135,000
Sunk Costs	$54,488,000
Total Investment Costs	$243,623,000
Average Annual Costs	
Interest and Amortization of Initial Investment	$11,692,100
OMRR&R	$1,060,700
Total Average Annual Costs	$12,752,800
Average Annual Benefits	$23,556,000
Net Annual Benefits	$10,803,200
Benefit-Cost Ratio	1.8
Benefit-Cost Ratio (computed at 7%)[1]	1.1

[1] Per Executive Order 12893

Table 31
Total First Costs
Cost Sharing
For Modified Authorized Project
Clear Creek, Texas
(October 2011 Price Levels)

Item		Federal Cost ($)	Non-Federal Cash ** ($)	Non-Federal LERRD ($)	Total Cost ($)
Flood Risk Management (FRM)*					
01	Lands & Damages - Non-Federal (100%)	0	0	51,147,000	51,147,000
01	Lands & Damages (Federal Review)	306,000	24,000		330,000
02	Relocations - Non-Federal (100%)	0	0	32,404,000	32,404,000
02	Relocations - GH&H Rail Road Bridge	2,010,000	0		2,010,000
02	Relocations -BN&SF Rail Road Bridge	1,958,000	0		1,958,000
02	Relocations (Federal Review)	134,000	11,000		145,000
06	Fish & Wildlife Services	15,540,000	1,305,000		16,845,000
09	Channels & Canals	80,512,000	6,739,000		87,251,000
18	Cultural Resources	1,949,000	163,000		2,112,000
30	Engineering & Design	23,700,000	1,959,000		25,659,000
30	Engineering and Design (GRR)	15,394,000	1,231,000		16,625,000
31	Construction Management	6,586,000	551,000		7,137,000
Total Modified Authorized Project Costs		148,089,000	11,983,000	83,551,000	243,623,000

* FRM Cost Shared 75/25 based on 1986 Authorization
** Non-Federal cash is based on minimum 5% of TPCS (excluding the RR Bridges)

Table 32
Cost Sharing
Fully Funded Project Cost
For Modified Authorized Project
Clear Creek, Texas
(October 2011 Price Levels)

	Item	Federal Cost ($)	Non-Federal Cash ** ($)	Non-Federal LERRD ($)	Total Cost ($)
Flood Risk Management (FRM)*					
01	Lands & Damages - Non-Federal (100%)	0	0	54,290,000	54,290,000
01	Lands & Damages (Federal Review)	305,000	25,000		330,000
02	Relocations - Non-Federal (100%)	0	0	34,176,000	34,176,000
02	Relocations - GH&H Rail Road Bridge	2,010,000	0		2,010,000
02	Relocations -BN&SF Rail Road Bridge	2,205,000	0		2,205,000
02	Relocations (Federal Review)	134,000	11,000		145,000
06	Fish & Wildlife Services	16,847,000	1,397,000		18,244,000
09	Channels & Canals	87,817,000	7,260,000		95,077,000
18	Cultural Resources	2,062,000	170,000		2,232,000
30	Engineering & Design	26,406,000	2,165,000		28,571,000
30	Engineering and Design (GRR)	15,394,000	1,231,000		16,625,000
31	Construction Management	7,876,000	652,000		8,528,000
	Total Modified Authorized Project Costs	161,056,000	12,911,000	88,466,000	262,433,000

* FRM Cost Shared 75/25 based on 1986 Authorization

** Non-Federal cash is based on minimum 5% of TPCS (excluding the RR Bridges)

The Fully Funded Cost Allocation for the Modified Authorized Project is detailed in Table 33. The non-Federal cash calculations use the total cost for the Modified Authorized Project to account for the additional cash contribution needed to reach the 5 percent required cash from the non-Federal sponsor. Additionally, the non-Federal sponsor's cost share (LERRD and cash) for this total project cost, including the previously constructed portions, is required to be at least 25 percent of the total costs. Table 33 shows that the non-Federal cost (non-Federal LERRD and non-Federal cash) will be $101,377,000 or almost 39 percent of the $262,433,000 total.

Table 33
Cost Allocation
Fully Funded Project Cost
For Modified Authorized Project
Clear Creek, Texas
(October 2011 Price Levels)

Year	Total Project Cost ($)	Non-Federal LERRD($)	Scheduled Construction ($)	%	Non-Federal Cash ($)*	Federal Cash ($)
Construction Prior to GRR	37,863,000	17,029,000	20,834,000	11.98	1,415,000	19,419,000
GRR thru 2012	16,310,000		16,310,000	9.38	894,000	15,416,000
2013**	1,367,000		1,367,000	0.79	396,000	971,000
2014	1,790,000		1,790,000	1.03	137,000	1,653,000
2015	62,418,000	36,696,000	25,722,000	14.79	1,970,000	23,752,000
2016	66,076,000	13,281,000	52,795,000	30.35	4,044,000	48,751,000
2017	42,335,000	20,141,000	22,194,000	12.76	1,700,000	20,494,000
2018	30,449,000	1,319,000	29,130,000	16.74	2,062,000	27,068,000
2019	1,913,000		1,913,000	1.10	147,000	1,766,000
2020	1,912,000		1,912,000	1.10	146,000	1,766,000
Total Modified Authorized Project Costs	262,433,000	88,466,000	173,967,000		12,911,000	161,056,000

* 5% of Total Cost of Modified Authorized Project less BN & SF Railroad Bridge ($2,205,000) and GH&H RR Bridge ($2,010,000) which are 100% Federal Costs

** N-F includes share plus $315,000 shortage

X. SUMMARY OF COORDINATION, PUBLIC VIEWS AND COMMENTS

Public input has been important in the overall planning process to assure that plans considered and developed were compatible with community and regional objectives. The primary purposes of public involvement are: (1) to allow the public the opportunity to provide timely information to the USACE so that developed plans will reflect their preferences to the greatest extent possible and (2) to provide a method by which the USACE can inform the public so that those who choose to participate in the project formulation and the planning process can do so with a relatively complete understanding about the issues, opportunities, and consequences associated with a study.

The various measures used during this study to assure open, two-way public communication included public notices, newsletters, media interviews, and meetings with various interested parties. Coordination began in the spring of 2001 when the Clear Creek Project Team held three Public Scoping Meetings to solicit oral and written comments from citizens regarding flood risk management solutions. These meetings were held in Friendswood (March 15, 2001), League City (May 3, 2001) and Pearland (May 9, 2001). They were well attended and the Project Team collected more than 100 comments. Consolidated comments from these meetings can be viewed on the project web site (www.clearcreekproject.com).

A Feasibility Scoping Meeting was held on June 25, 2002. The conference was attended by staffs of the HCFCD, Galveston County Consolidated Drainage District, USACE - Southwestern Division, USACE - Galveston District, and HQUSACE.

Studies were coordinated with USFWS, TPWD, TCEQ, NMFS, SHPO, and other Federal and State resource agencies. To assist in evaluation of environmental impacts, an ICT was developed to ensure that the best available knowledge was utilized in developing the assumptions used in the habitat modeling.

Two public open houses were held February 2004 in Pearland and Friendswood. At these meetings, a video was presented detailing current status of the study and question and answer sessions were held to ensure that the public was updated. Copies of the video were made available to the public by DVD. A side benefit of this effort became evident when the video was played on the Friendswood public access television channel for approximately two months.

Upon identification of the NED Plan, additional presentations were made to the public in each of the municipalities in the watershed. Preliminary information on the plan was presented in order to address concerns because of the controversial nature of the AFP. These meetings were

successful in informing the public of the status of the study and ensuring a regular exchange of information between all parties.

The Draft GRR and Draft SEIS were released for public review in December 2011, and a public meeting and open house was held in January 2012. All comments received during this public review were addressed in the Final SEIS.

Continuous coordination with floodplain administrators throughout the watershed has also been occurring through regular attendance of CCSC meetings. The USACE representatives updated the CCSC on the current status of the study on a monthly basis. The CCSC is also integral to the non-Federal Sponsor's efforts to develop a detailed Floodplain Management Program, in accordance with PGL 52.

XI. RECOMMENDATIONS

I recommend that the Clear Creek, Texas, Flood Risk Management Project, generally as described in this report as the Modified Authorized Project and with such modifications as may be advisable and within statutory discretion, authorized by Section 203 of the Flood Control Act of 1968, be approved and remaining construction implemented to completion. I further recommend the Local Cooperation Agreement (LCA), executed with the non-federal sponsors on June 30, 1986, be amended to establish the scope, non-Federal responsibilities, and cost sharing for the Modified Authorized Project, and to add Brazoria County as a third non-federal sponsor.

The Total Project First Cost of the Modified Authorized Project, including features already constructed and GRR study costs, totals $243,623,000. Total average annual costs for the project are $12,753,000. The Fully Funded Project Cost of the project is $262,433,000.

The Non-Federal sponsor, prior to implementation, shall agree, through the amendment to the LCA, to perform items of local cooperation which may include, if applicable, the following:

a. Provide an amount equal to no less than 25 percent of total project costs allocated to structural flood risk management, as further specified below:

(1) Provide, during construction, a cash contribution no less than 5 percent of total project costs; the 5 percent cash contribution shall be based on the sponsors' shares of total project costs, including the attributed appraised fair market value of channel rights-of-way.

(2) The amount to be provided shall include all lands, easements, rights-of-way, and utility and facility alterations and relocations (excluding railroad bridges) required for the Project;

(3) Provide all lands, easements, and rights-of-way, including suitable borrow and dredged or excavated material disposal areas, and perform or assure the performance of all relocations determined by the Government to be necessary for the construction, operation, and maintenance of the project;

(4) Provide or pay to the Government the cost of providing all retaining dikes, wasteweirs, bulkheads, and embankments, including all monitoring features and stilling basins, that may be required at any dredged or excavated material disposal areas should this have cost-share implications for the construction, operation, and maintenance of the project;

(5) Provide, without cost to the Government all alterations and relocations of building, streets, storm drains, utilities, bridges (excluding railroad bridges) and other structures and improvements made necessary by construction of the project;

(6) Provide, during construction, any additional costs as necessary to make its total contribution equal the percent of project first costs allocated to nonstructural flood control and at least 25 percent but no more than 50 percent of project first costs allocated to structural flood risk management.

(7) Provide any shortfall in non-Federal cash contributions in the first year following execution of the LCA amendment to ensure a proportional cost share.

b. Give the Government a right to enter, at reasonable times and in a reasonable manner, upon land which the non-Federal Sponsor owns or controls for access to the project for the purpose of inspection, and, if necessary, for the purpose of completing, operating, maintaining, repairing, replacing, or rehabilitating the project.

c. Assume responsibility of operating, maintaining, replacing, repairing, and rehabilitating (OMRR&R) the project or completed functional portions of the project, including mitigation features without cost to the Government, in a manner compatible with the project's authorized purpose and in accordance with applicable Federal and State laws and specific directions prescribed by the Government in the OMRR&R manual and any subsequent amendments thereto.

d. Comply with Section 221 of Public Law 91-611, Flood Control Act of 1970, as amended, and Section 103 of the WRDA of 1986, Public Law 99-662, as amended, which provides that the Secretary of the Army shall not commence the construction of any water resources project or separable element thereof, until the non-Federal Sponsor has entered into a written agreement to furnish its required cooperation for the project or separable element.

e. Hold and save the Government free from all damages arising from the construction, OMRR&R of the project and any project-related betterments, except for damages due to the fault or negligence of the Government or the Government's contractors.

f. Keep and maintain books, records, documents, and other evidence pertaining to costs and expenses incurred pursuant to the project to the extent and in such detail as will properly reflect total project costs.

g. Perform, or cause to be performed, any investigations for hazardous substances that are determined necessary to identify the existence and extent of any hazardous substances regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), 42 USC 9601-9675, that may exist in, on, or under lands, easements or rights-of-way necessary for the construction, operation, and maintenance of the project; except that the non-Federal Sponsor shall not perform such investigations on lands, easements, or rights-of-way that the Government determines to be subject to the navigation servitude without prior specific written direction by the Government.

h. Assume complete financial responsibility for all necessary cleanup and response costs of any CERCLA regulated materials located in, on, or under lands, easements, or rights-of-way that the Government determines necessary for the construction, operation, or maintenance of the project.

i. Agree that, as between the Federal Government and the non-Federal Sponsor, the non-Federal Sponsor shall be considered the operator of the project for the purpose of CERCLA liability, and, to the maximum extent practicable, operate, maintain, repair, replace, and rehabilitate the project in a manner that will not cause liability to arise under CERCLA.

j. Prevent obstructions or encroachments on the project (including prescribing and enforcing regulations to prevent such obstructions or encroachments) such as any new developments on project lands, easements, and rights-of-way or the addition of facilities which might reduce the level of protection the project affords, hinder operation and maintenance of the project, or interfere with the proper function.

k. Comply with the applicable provisions of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, Public law 91-646, as amended by title IV of the Surface Transportation and Uniform Relocation Assistance Act of 1987 (Public Law 100-17), and the Uniform Regulations contained in 49 CFR part 24, in acquiring lands, easements, and rights-of-way, and performing relocations for construction, operation, and maintenance of the project, and inform all affected persons of applicable benefits, policies, and procedures in connection with said act.

l. Comply with all applicable Federal and State laws and regulations, including, but not limited to: Section 601 of the Civil Rights Act of 1964, Public Law 88 352 (42 U.S.C. 2000d) and Department of Defense Directive 5500.11 issued pursuant thereto; Army Regulation 600-7, entitled “Nondiscrimination on the Basis of Handicap in Programs and Activities Assisted or Conducted by the Department of the Army”; Section 402 of the

Water Resources Development Act of 1986, as amended (33 U.S.C. 701b-12), requiring non-Federal preparation and implementation of floodplain management plans; and all applicable Federal labor standards requirements including, but not limited to, 40 U.S.C. 3141-3148 and 40 U.S.C. 3701-3708 (revising, codifying and enacting without substantive change the provisions of the Davis-Bacon Act (formerly 40 U.S.C. 276a et seq.), the Contract Work Hours and Safety Standards Act (formerly 40 U.S.C. 327 et seq.) and the Copeland Anti-Kickback Act (formerly 40 U.S.C. 276c)).

m. Provide the non-Federal cost share of that portion of total cultural resource preservation mitigation and data recovery costs attributable to structural and nonstructural flood control that are in excess of one percent of the total amount authorized to be appropriated for structural and nonstructural flood control.

n. Inform affected interests, at least annually, regarding the limitations of the protection afforded by the project.

o. Participate in and comply with applicable Federal floodplain management and flood insurance programs.

p. Publicize floodplain information in the areas concerned and provide this information to zoning and other regulatory agencies for their guidance and leadership in preventing unwise future development in the floodplain and in adopting such regulations as may be necessary to ensure compatibility between future development and protection levels provided by the project.

q. Do not use Federal funds to meet the non-Federal Sponsor's share of total project costs unless the Federal granting agency verifies in writing that the expenditure of such funds is authorized.

r. Agree that any part of the project identified as approved for proposed advanced work for credit under Section 104 of Public Law 99-662 must be compatible with recommended flood control project, and that any credit granted shall not relieve the non-Federal Sponsor of its requirement to pay, in cash, 5 percent of total project costs allocated to structural flood risk management.

The recommendations contained herein reflect the information available at this time and current departmental policies governing formulation of individual projects. They do not reflect program and budgeting priorities inherent in the formulation of a national Civil Works construction program nor the perspective of higher review levels within the Executive Branch. Consequently,

the recommendations may be modified prior to transmittal to the appropriate authority as proposals for implementation funding. However, prior to transmittal to the Congress, the non–Federal Sponsors, the States, interested Federal agencies, and other parties will be advised of any modifications and will be afforded an opportunity to comment further.

Christopher W. Sallese
Colonel, U.S. Army Corps of Engineers
District Commander

10 September 2012
Date