APPENDIX E
FLOOD RISK MANAGEMENT ANALYSIS

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APPENDIX E
Flood Risk Management Analysis

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1.1 PURPOSE

The purpose of this flood risk management (FRM) analysis is to evaluate flooding and related problems in the Dallas Floodway Levee System along the Upper Trinity River watershed in the City of Dallas, Texas. The original project, completed in 1958 entailed channel improvement, floodway clearing, levee strengthening, installation and modification of drainage structures, construction of a pump station, pressure sewers, and sump areas. The improvements provided conveyance of the Standard Project Flood (SPF) within the floodway plus 2 feet of freeboard. Changes in runoff due to upstream development as well as vegetation at the Trinity Forest downstream have diminished the originally authorized FRM benefits providing an opportunity to restore and improve benefits.

1.2 FLOOD RISK MANAGEMENT STUDY AREA

The FRM area is located within the area currently protected by the Dallas Floodway Levee System project along the Trinity River, in Dallas, Texas. This study area is bounded on the upstream by the Loop 12 crossings of the West and Elm Forks and at the downstream end by the existing terminus of the Dallas Floodway Levee System approximated by the abandoned Atchison, Topeka & Santa Fe Railroad Bridge on the Trinity River. This area also expands out to include portions of the 440-foot contour. The southern geographical boundary coincides roughly with IH-30 and the northern boundary by Harry Hines Boulevard (Figure E-1).

1.3 FLOODWAY AND FLOODING HISTORY

In 1908, the upper basin of the Trinity River received ten to 15 inches of rain flooding much of downtown and West Dallas. This event pressed city leaders into finding a solution to the long-standing problem of flooding along the Trinity River. Levees were constructed upstream of the Elm and West Forks confluence by the mid-1920s, but it was not until 1927 that plans were developed calling for 13 miles of levees to be constructed along each side of the river between the Elm and West Forks confluence and the Santa Fe Railroad crossing. Construction began in 1928 and was essentially “completed” in 1931. The project however lacked some of the features in the Levee Improvement District’s original design including two of the seven gravity sluiceways, two of the five pressure sewer systems, and adequate compaction. In 1945, Congress authorized the Corps to participate in the strengthening of the Dallas Floodway Levee System and some channel work with construction beginning in 1953 and being completed in 1960. Included in the construction efforts were pump station improvements, pressure sewers, channel excavation, three-on-one side slopes, and relocation of a portion of the channel to prevent potential toe erosion.

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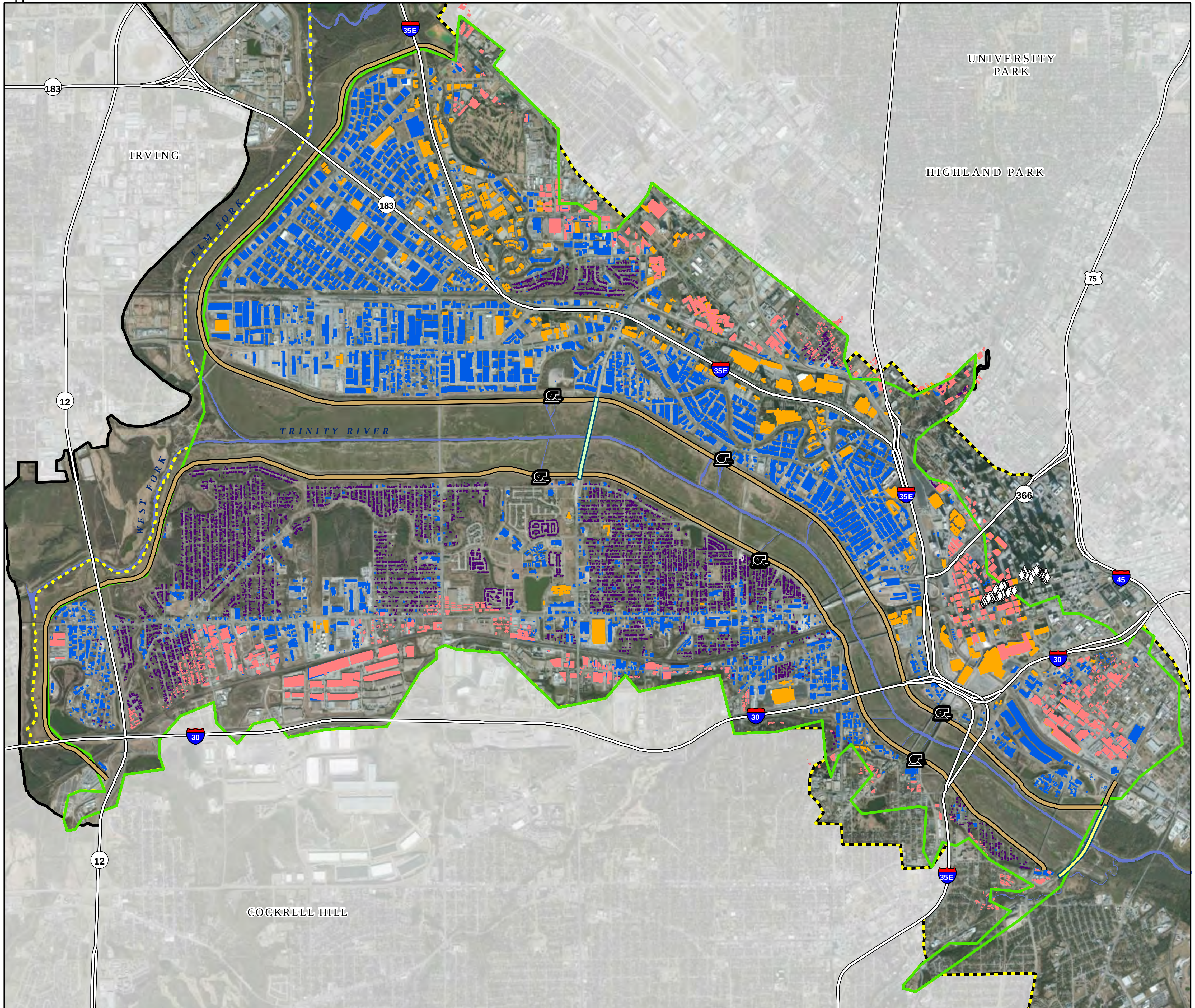
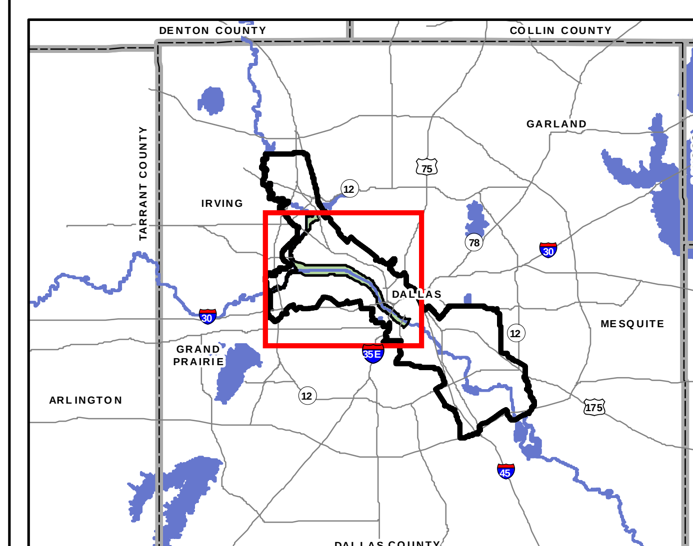


Figure E-1
Dallas Floodway Economic Appendix Map

LEGEND

- Tunnels
- AT&SF Bridge
- Hampton Road Bridge
- Non-Residential Structures
- Residential Structures
- Unique Structures
- Outer Structures
- Trinity Corridor
- FRM Study Area
- Study Area
- Surface Water
- Pumping Plant
- Dallas Floodway Levee System Levee
- Freeway



0 0.5 1 Kilometers

0 0.5 1 Miles

N S

Sources: City of Dallas 2006, 2009a; NCTCOG 2008

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1.4 TOPOGRAPHY

The main stem of the existing Dallas Floodway Levee System is approximately 8 miles long and extends from the DART Bridge at the downstream end to the confluence of the Elm Fork and West Fork at the upstream end. The floodplain on the main stem is bounded by levees on each side. The levees are approximately 30 feet high relative to the bottom of the floodplain. The main stem floodway is generally about 2,900 feet wide between levees at the upstream end and it gradually narrows down to about 1,900 feet wide at the downstream end. The floodway is generally bisected by a low flow channel that is about 200 feet wide. Side channels, which carry sump discharge water, periodically intersect the low flow channel. The floodplain itself has generally mild grades with localized variations in the terrain.

1.5 PROBLEM IDENTIFICATION

Flows along the Trinity River through the study area that might result in frequent flooding events are contained within the floodway. Currently, the computed SPF flow for future hydrologic conditions is 277,000 cubic feet per second (cfs) within the Dallas Floodway, an increase from the original design SPF flow for the Floodway of 226,000 cfs. Hydrology and Hydraulics (H&H) analyses indicate that under existing conditions, there is the potential for significant flood damages during a low-probability event in which flood flows may overtop the channel banks and existing levees, inundating many residential, commercial, and public facilities in the City of Dallas. This event is set at the 0.0364 percent annual chance exceedance (AEP), or the 2,747-year event for the existing condition and the 0.0407 percent AEP or 2,457-year event for the future condition. Table E-1 displays the water surface elevation with its associated discharge at the index point. Table E-1 also includes the stages for the river (exterior) and the stages for both the East and West Levee at the index point.

Table E-1. Water Surface Profile Elevations and Discharges at HEC-FDA Index Point

River Discharge (cfs)	*Exterior Stage*	*East Without Proj. Stage*	*West Without Proj. Stage*	*Existing AEP*	*Future AEP*	*Existing Return Interval (yr)*	*Future Return Interval (yr)*
260,000	424.38	416.36	387.95	0.0469%	0.0524%	2,132	1,908
265,000	424.75	416.98	390.37	0.0435%	0.0486%	2,299	2,058
269,000	425.04	417.22	390.87	0.0409%	0.0458%	2,445	2,183
273,000	425.23	417.47	421.69	0.0386%	0.0432%	2,591	2,315
277,000	425.41	417.71	422.14	0.0364%	0.0407%	2,747	2,457
289,000	426.12	418.93	423.67	0.0307%	0.0344%	3,257	2,907
302,000	426.78	420.12	424.77	0.0257%	0.0288%	3,891	3,472

The following reports were prepared by USACE to further define the flood risk in the study area. This analysis builds upon the findings contained in the following prior reports.

1.5.1 Upper Trinity River – Existing Dallas Floodway Levee System Identification of the NED Plan (1998)

This report identified urbanization as having “increased significantly, thereby increasing the flood flows within the Trinity River watershed,” and further stating that the authorized project was “incapable of containing the current SPF within its levee banks, resulting in a catastrophic failure of the project.”

1.5.2 Periodic Inspection Report #9

A periodic inspection (PI) of the Dallas Floodway project was performed on 3-5 December 2007. Significant deficiencies were documented for the East and West Levee systems including insufficient crest height which renders both the East and West Levees incapable of successfully accommodating the current SPF without overtopping, encroachments and penetrations impacting the integrity and performance of the levees, as well as inhibit access for O&M, surveillance, and flood-fighting purposes, damaged gate closures, unstable structures, severe desiccation cracking of the levees, erosion, vegetation, siltation, and channel instability. Additionally, review of design documentation from the 1950s indicates that the levees were designed for a minimum Factor of Safety. A closeout of PI #9 items is provided in Section 17 of Appendix B.

1.5.3 Base Conditions Risk Assessment

The Risk Management Center (RMC) of USACE conducted a Base Conditions Risk Assessment (BCRA) as part of a national pilot program for the USACE Levee Safety Program. The BCRA was conducted on the East and West Levees. Findings of the initial Draft BCRA report have been adopted for purposes of determining the hydrologic and hydraulic and levee performance under the existing conditions for this study. The two main components of the BCRA are the Potential Failure Mode Analysis (PFMA) and Consequences which includes estimates for Loss of Life (LoL). The BCRA identified six PMFAs that exceeded the Societal Tolerable Risk Guidelines for life safety from ER 1110-2-1156 - Engineering and Design Safety of Dams — Policy and Procedures. These are listed by rank from the highest to the lowest risk in the following order:

- Overtopping erosion of the levee embankments (PFMA #2)
- Overtopping and undermining erosion of the concrete floodwall (PFMA #3)
- Backward erosion piping of a sand layer connected to the river and exposed in a landside sump (PFMA #7)
- Blowout or heave of a clay confining layer in a landside sump followed by backward erosion piping of the underlying sand layer (PFMA #8)
- Global instability of a levee embankment slope that takes out the crest in a single slip through the embankment and foundation (PFMA #13a)
- Progressive instability of a levee embankment slope due to localized slumping, saturation, and more slumping (PFMA #13b)

The first PFM (#2) is the basis for the without project condition and sets the basis on which economic damages are analyzed. This as well as the other PFMs are used as the basis for evaluating potential LoL scenarios.

1.6 FLOOD DAMAGES

1.6.1 Flood Profiles & Reach Delineations

As mentioned previously, water surface profiles were developed representing the river stage and the stages that would impact the protected areas associated with both the East and West Levees. The annual exceedance probabilities range from 0.0469 to 0.0257 percent under the existing condition and 0.0524 to 0.0288 percent for the future condition. These profiles were used to delineate the floodplain limits and determine both the stage-damage and frequency-damage (also referred to as single-occurrence damages) functions.

1.6.2 Data Collection & Refinements

The initial structure file used for the study was compiled in 2004 by TC&B for the USACE. This file was based on a topographical survey conducted in 1991 along the Trinity River for Dallas, Fort Worth, Denton, and other surrounding cities. An architectural-engineering (A-E) firm and the North Central Texas Council of Governments (NCTCOG) collected data on 14,000 structures protected by the Dallas Floodway Levee System and updated the structure database in 1997. The database was amended by the City of Dallas in 2001 based on current aerial photography correcting for errors in building footprints, accounting for demolished structures, and added structures based on new construction. The City also collected information on businesses operating in the tunnel system under the Central Business District and included 2003 tax data from the Dallas Central Appraisal District (DCAD). Additional structures were added based on field verification by TC&B as were a number of mostly public structures including switching stations, recreational facilities, electrical substations, etc. and those identified as being "unique" such as Dallas City Hall, the American Airlines Center, Union Station, Dallas Convention Center, and Parkland Hospital. In 2011, the TC&B database was refined to reflect all changes recorded in the DCAD through 2010. Adjustments were made extending out to the 440-foot contour to ensure a more comprehensive database.

Based on these adjustments, structure file inventories for each of the major damage categories (Table E-2) were developed for analysis. The residential structure inventory contains 5,874 structures; the non-residential contains 2,845; and unique structures total 232. Additionally, 106 businesses located in the downtown tunnels make up the fourth structure inventory. These four structure inventories were combined into one master structure inventory that was then imported into HEC-FDA.

Table E-2. Major Damage Categories

Damage Category	*Activity Description*
Residential	Single and multifamily dwellings
Commercial & Industrial	Retail and wholesale businesses
Public	Public and quasi-public structures
Unique	Structures not fitting USACE depth-damage curves
POV	Personal occupancy vehicles

1.6.3 Privately Owned Vehicles

Damages for automobiles were estimated based on the average number of vehicles per residence characteristic of the study area, and the probability of their being present at the time of a flood. An analysis was made of registered motor vehicles per occupied housing unit for counties within Metropolitan Statistical Areas (MSA) in Texas, using data from the U.S. Census and the Texas State Department of Highways and Public Transportation. The number of registered vehicles per occupied housing unit in MSA clusters around a mean value of 2.48. Given that not all registered motor vehicles are associated with private residences, and some housing units are unoccupied, an average of 2.0 vehicles per residence is assumed for this analysis. Overall, 75 percent (1.5) of vehicles would be impacted by flooding during non-work hours (128 hours per week) and 25 percent (0.5) would be impacted during work hours (40 hours per week). The expected number of vehicles present at any given time that a flood might occur would therefore be:

$$((128/168)*1.5) + ((40/168) 0.5$$

or 1.26 expected vehicles per residence.

Values for vehicles associated with single-family homes as well as multi-family and mobile residences were based on the national average price of new and used vehicles as reported by the U.S. Bureau of Transportation Statistics. Prices for new vehicles are calculated by subtracting CNW Marketing's vehicle leasing data from Bureau of Economic Analysis data combining sales and leases. Used car sales data is derived from sales from franchised dealers, independent dealers and casual sales. The average new and used sales price also includes leased vehicles. The most recent price reported by BTS is $13,105. Under the assumption that a family’s purchase of a vehicle is a function of income, this average price can be adjusted down to the Census block level based on Census Bureau data for median family income. The median household income nationally from the 2000 US Census is $41,994. Median household income for the 57 Census blocks intersecting the study area ranges from $6,925 to $200,001. Adjusting for inflation, this translates into individual values for vehicles within the study area ranging from $6,250 to $23,665 with the average value being approximately $11,400 with approximately 6,650 vehicles being in the floodplain.

1.6.4 Reach Determination

Since the H&H analysis indicates that the potential for significant flood damages exists during the low-probability event in which the levees are overtopped, structures were assigned to one of two reaches representing either the East Levee or the West Levee. Subsequently, the index location for both the East and West levees represent the point at which the respective levees would be overtopped and experience a subsequent breach. See Figure 4-3 in Appendix A for the location of the index point. During the structure identification process, structures were assigned a character designating whether the structure was located in or out of the Central Business District. Structures in the Central Business District were designated as being above ground or below ground or within the tunnel system. Table E-3 describes the reaches and stationing parameters.

Table E-3. Dallas Floodway Levee System Feasibility Study Area Reach Descriptions and Stationing

Stream Name	*Damage Reach Name*	*Beginning/ Downstream Station (000)*	*Ending/Upstream Station (000)*	*Bank*	*Index Location Station*	*Description*
Trinity	East	108280	148136	Left	134952	Behind East Levee
Trinity	West	108280	148136	Right	139920	Behind West Levee

The refined inventory enumerates 9,057 parcels with structures in 2010. These structures have a total estimated investment value of approximately $8.3 billion in structure and $5.4 billion in content. Approximately 65 percent of the structures are classified as residential, 31 percent are classified as non-residential, and the remaining are classified as unique. Unique structures, as defined in Table E-4, are those not fitting USACE depth-damage functions. These include structures such as Dallas City Hall, the American Airlines Center, Union Station, Dallas Convention Center, and Parkland Hospital. Appendix Map displays the location of the different types of structures.

Table E-4 displays the enumeration of inventoried structures at the 2010 level of development. Table E-5 displays structure and content values by reach and type at October 2013 price levels.

Table E-4. Enumeration of Inventoried Structures by Reach and Type - 2010 Level of Development

Damage Category	*East Levee*	*West Levee*	*Total*
Residential			
Single Family	466	5,312	5,778
Multi-Family	44	51	95
Mobile	0	1	1
Subtotal	**510**	**5,364**	**5,874**
Non-Residential			
Commercial	1,737	717	2,454
Industrial	78	56	134
Public	94	163	257
Subtotal	**1,909**	**936**	**2,845**
Unique			
MFR	5	0	5
Commercial	190	5	195
Industrial	1	0	1
Public	22	9	31
Tunnel	106	0	106
Subtotal	**324**	**14**	**338**
Total	**2,743**	**6,314**	**9,057**

Table E-5. Structure and Content Values of Inventoried Structures by Reach and Type
2013 Price and Development Levels Values in $1000s

Levee Category	*East*			*West*			*Grand Total*
	Structure	*Contents*	*Total*	*Structure*	*Contents*	*Total*	
Commercial	$4,848,430	$1,827,850	$6,676,280	$307,810	$207,841	$515,651	**$7,191,932**
Industrial	$148,890	$52,271	$201,161	$40,720	$24,627	$65,347	**$266,508**
MFR	$198,211	$198,211	$396,423	$77,910	$77,910	$155,820	**$552,243**
Mobile	-		$0	$9	$9	$18	**$18**
POV	$55,391	-	$55,391	$78,146	0	$78,146	**$133,537**
Public	$2,101,082	$2,553,323	$4,654,405	$186,022	$108,824	$294,846	**$4,949,251**
SFR	$40,219	$40,219	$80,438	$264,565	$264,565	$529,131	**$609,569**
Tunnel	-	$5,555	$5,555	-	-	-	**$5,555**
Total	**$7,392,223**	**$4,677,430**	**$12,069,652**	**$955,183**	**$683,775**	**$1,638,958**	**$13,708,611**

1.7 WITHOUT PROJECT STRUCTURE AND CONTENT DAMAGES

1.7.1 Methodology

1.7.1.1 Overview of Methodology

The methodology employed for this economic analysis is in accordance with current principles and guidelines and standard economic practices, as outlined in the Planning Guidance Notebook – ER 1105-2-100. Plan Formulation is computed at 2012 price levels using the federal discount rate of 4.00 percent. The period of analysis is 50 years. As mentioned earlier, these future without-project conditions reflect a base year hydrologic condition of 2015 and future hydrologic year of 2025. Finally, throughout this appendix per the Planning Guidance Notebook, flood events will be expressed in probabilistic terms rather than the classic “x-Year” event. For example, the 100-Year event will be called a 1 percent Annual Chance Event (equivalent to the HEC-FDA term Annual Exceedance Probability Event). Other equivalent probabilities can be obtained by dividing 1 by the year occurrence interval; the 500-year event is 1/500 = 0.2 percent AEP, and so forth.

A risk-based analysis (RBA) procedure has been used to evaluate without project flood damages in the study area. Guidance for conducting RBA is included in Corps Engineering Regulation 1105-2-101, Risk-Based Analysis for Evaluation of Hydrology/Hydraulics, Geotechnical Stability and Economics in Flood Damage Reduction Studies (3 January 2006).

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

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

Structure File: The basis of this analysis utilizes a structure file initially compiled by Turner Collier and Burgess (TC&B) in 2004. Their results are detailed in the “Dallas Floodway Feasibility Study, Structure File and Vehicle Updates” report, dated 2004. The initial structure file included the area protected by the Dallas Floodway Levee System and was later extended out to the 440-foot contour to ensure a more complete database. The HEC-FDA model contains updated H&H provided by the Fort Worth District Hydrology & Hydraulics Section. Details of the methodology are provided in the data collections segment of this report. The future without project hydrologic conditions utilizes 2015 as the base year and 2025 as the future hydrologic condition.

Discharge/Probability: For a flood or storm event with a given probability of occurrence, there is uncertainty regarding what the resulting discharge will be at a specific location along the stream or river. The reliability of discharge/probability estimates is directly linked to the historical record of stream gauge data available. In cases where records are small or incomplete, the associated uncertainty increases. To address this uncertainty, an analytical or graphical method is typically used to determine statistical distributions of discharge for a range of probabilities at locations throughout the floodplain. For this study, discharge/probability uncertainty has been estimated for each reach using the analytical method based on discussions between the District's H&H section and the Hydrology Committee regarding the methodology for determining the SPF. See Appendix A for further discussion regarding the development of the frequency curve.

Stage/Discharge: For a given discharge, there is uncertainty regarding what the resulting water surface elevation will be at a given location. Factors contributing to this uncertainty include bed forms, water temperatures, debris or other obstructions, unsteady flow effects, variation in hydraulic roughness with season, sediment transport, channel scour or deposition, changes in channel shape during or as a result of flood events, as well as other factors. To address this uncertainty, standard deviation estimates are developed for stages associated with a range of discharges at locations throughout the floodplain. For this study, H&H provided the standard deviation of error 0.5 foot for the 1 percent AEP stage and higher; the HEC-FDA program automatically calculated appropriately smaller stage errors for all smaller (i.e., more frequent) events based upon the 0.5 foot @ the 1 percent AEP figure.

Geo-technical Features: When there are improvements such as levees along a river or stream, there is uncertainty regarding how effective they will be in containing a given flood event. Specifically, there is uncertainty regarding what combination of discharge and stage will result in levee failure. To address this uncertainty, probable failure and non-failure points (elevations) for levees are determined at various locations along the levee's length.

Neither the East or West levee have been assigned failure curves as described above, since it was assumed they meet USACE geo-technical criteria and have been properly maintained for the overtopping analysis. For the future without project condition levee failure in these reaches refers to the situations when river stages overtop the levee and a subsequent breach occurs. The final baseline hydraulic runs showed that the East Levee could breach when the total Trinity River discharge equals or exceeds 255,000 cfs, and when it does breach, the average interior flooding elevations would vary between 415 and 420 feet. The final results also showed that the West Levee could breach when the river discharge equals or exceeds 273,000 cfs, and when it does breach, the average interior flooding elevations varied between 421 and 425 feet. For this scenario, water surface elevations for inundation of the levee protected area is determined by an interior/exterior function. This was depicted in Table E-1 for the without project condition for the East and West Levees. The levee crest elevation is elevation is set at 423.29 for both the East and West levees as the existing condition. Table E-6 depicts the levee crest elevations at the index point. The interior/exterior relationships for the levee raises in combination with the modification of the AT&SF Bridge and the interior /exterior relationships for the armoring alternatives are depicted in Section 1.9.2.2, *Initial Evaluation*, Table E-13.

Table E-6. Levee Crest Elevation at Index Points 134952 and 139920

Levee	*Levee Crest Elevation and Probability*
East	423.29 - 0.0407% future AEP event
West	424.16 - 0.0407% future AEP event

Structure Elevation: A structure's susceptibility to being inundated is a function of its location within the floodplain and its elevation. There are two sources of potential error in determining elevation. The first is the topographic ground elevation of the structure. This uncertainty is a function of the data source used to derive the elevation estimate. The other source of uncertainty is associated with estimates of first floor elevations above ground level (or foundation height). This variable is key, as a structure built on fill or with a large crawl space, for example, may sustain only minor or no damages, even though the surrounding ground is underwater. First floor elevation estimate errors also vary with the methods used to derive them, ranging from best-guess estimates from windshield surveys to professional surveys. Statistical uncertainty in elevation is typically determined by referencing the standard deviation estimates contained in Corp Engineering Manual 1110-2-1619 – Risk Based Analysis for Flood Damage Reduction Studies (1 August 1996). This publication presents standard deviation estimates for a wide range of measurement methods.

For this study, a triangulated irregular network (TIN) of the study area was created in ArcView from the 1991 two-foot contour maps provided by USACE. These same contours were used by H&H to develop the water surface elevations. The TIN dataset includes topological relationships between sample points and their neighboring triangles. Ground elevations were assigned using the TIN elevation at the parcel centroid. For parcels containing multiple structures, ground elevation corresponds to the primary structure on the parcel.

Floor corrections (foundation heights) were determined through field verification. For residential and non-residential structures, floor corrections were estimated to the nearest half-foot. Based upon the Engineering Manual cited above, the error associated with first floor elevation estimates is assumed to be normal, with a standard deviation of 0.5 feet for residential structures and 1.5 feet for non-residential structures based on the standard deviation derived from the random samples of structures for both categories. Ground elevations and first floor elevations for unique structures as well as tunnel entrance elevations were obtained by TC&B through precision field surveys conducted by the Sunland Group in March 2004.

<u>Structure Values:</u> Improvement values obtained for the DCAD served as the basis for structure values and were then adjusted using Marshall & Swift (M&S) estimating software. Adjusted values reflect depreciated replacement (DRV). The M&S Residential Estimator 7 was used to compute values for residences, townhouses, duplexes, and two apartment complexes that were residential in nature. M&S Commercial Estimator 7 was used to compute values for the remaining apartment complexes. Mobile home values were computed by determining the value of a typical mobile home using M&S multiplied by the number of mobile homes observed during field verification. Information input into M&S to derive DRV include location, square footage, exterior walls building materials, building quality and condition. Non-residential values were based on buildings from a sample of 154 parcels whose values were calculated using M&S Commercial Estimator 7. Based on the sample, an adjustment factor of 1.11 was applied to the remaining non-residential structures. Values for those structures designated as unique were also calculated using M&S Commercial Estimator 7 and compared with values from DCAD data. Uncertainties for structure values were set based on the standard deviation of the percent difference in values from DCAD and those produced for the M&S RCLD. For residential structures, this error was set at 21 percent based on a sample of 493 structures. For commercial structures this error was set at 37 percent based on the sample of 154 structures.

<u>Content Values:</u> Content values for residential structures use the generalized depth-damage curves developed by USACE Institute of Water Resources (IWR) and are based on structure value: the ratio of content-to-structure is 100 percent. The HEC-FDA program calculates this value internally making collection of residential content data unnecessary. Data from DCAD's Business Personal Property database is limited; therefore, content-to-structure value ratios (CSVR) are used to determine content values for non-residential structures. CSVRs were taken from USACE's current structure attribute file

for the study area and from the depth-damage curves used from the USACE - New Orleans District. These CSVRs are displayed in Tables E-7 and E-8.

Table E-7. Non-Residential CSVRs from USACE (Fort Worth District) Attribute File

Occupancy Code	*Description*	*CSRV*
7	Auto Dealership	6.48
13	Auto Repair	0.71
23	Bank	0.39
29	Beauty Shop	0.74
43	Book Stores	0.4
51	Car Wash	0.57
59	Church	0.11
83	Convenience Store	0.76
87	Country Club	0.46
93	Day Care Center	0.22
101	Doctor's Office	0.92
127	Fire Station	3.26
135	Food Processing	1.17
145	Funeral Home	0.54
159	Greenhouse	0.85
161	Grocery	2.82
179	Hospital	1.28
181	Hotel	0.36
203	Loading Dock	8.33
211	Machine Shop	1.07
229	Motel	0.36
233	Municipal Storage Warehouse	0.16
241	Nursing Home	0.37
249	Office Building	0.1
277	Post Office	0.24
285	Private Storage	0.16
295	Recreational Facility	0.69
305	Research Laboratory	0.96
307	Restaurant	0.39
309	Drive-In Restaurant	0.96
319	School	0.11
325	Service Station	1.56
345	Tavern	0.45
383	Veterinary Clinic	0.41
395	Warehouse	1.76
417	Barn	1
423	General Retail/Commercial	1.17
425	General Wholesale & Industrial	0.85
429	General Public Structure	0.21
431	Electrical Power Substation	0

Table E-8. Non-Residential CSVRs from USACE (New Orleans District) Depth-Damage Curves

Occupancy Code	*Description*	*CSRV*
MB_MFR	Masonry Building, Multi-Family Residence	0.37
WSF_MFR	Wood or Steel Frame Building, Multi-Family Residence	
MB_PRB	Masonry Building, Professional Businesses	0.43
MF_PRB	Metal Frame Building, Professional Businesses	
WSF_PRB	Wood or Steel Frame Building, Professional Businesses	
MB_ETR	Masonry Building, Eating & Recreation	1.14
MB_PSP	Masonry Building, Public & Semi Public	
MF_PSP	Metal Frame Building, Public & Semi Public	
MB_RPS	Masonry Building, Retail & Personal Services	1.42
MF_RPS	Metal Frame Building, Retail & Personal Services	
WSF_RPS	Wood or Steel Frame Building, Retail & Personal Services	
MB_WHC	Masonry Building, Warehouse & Contractor Services	1.68
MF_WHC	Metal Frame Building, Warehouse & Contractor Services	
WSF_WHC	Wood or Steel Frame Building, Warehouse & Contractor Services	
MB_RHU	Masonry Building, Repairs & Home Use	2.06
MF_RHU	Metal Frame Building, Repairs & Home Use	

Inundation Depth/Percent Damage: There is considerable uncertainty regarding the percentage of damage to structures and contents given a certain level of flooding. For residential structures, depth-damage functions and associated standard error estimates have been developed by IWR based upon a statistical analysis of actual flood damages that have occurred throughout the U.S. For non-residential structures, depth/damage functions are based on historical data collected by the National Flood Insurance Program of FEMA following flood disasters and on supplemental data from subsequent economic field surveys of flood plain properties in the Fort Worth District. Damage percentages for both structures and contents are based upon corresponding structure values. For structures designated as unique, TC&B sent surveys to facility managers/owners in order to develop depth/damage relationships for these structures. The survey instrument submitted to building managers was based on the approved commercial and industrial and non-residential Office of Management and Budget (OMB) flood damage surveys. One change was made to the submitted survey. Respondents were asked to estimate projected damages at increments from -2 feet to 30 feet rather than reporting information on historical flooding. Interviews and site visits were also conducted to better ascertain facilities' construction and functionality. For those structures whose managers/owners did not return a survey instrument, depth/damage functions from the New Orleans District were used since they were deemed most applicable for these structures.

The Army Corps of Engineers Hydrologic Engineering Center has developed software specifically designed for conducting risk based analysis, referred to as the HEC-FDA Program. Version 1.2.5 was used for this analysis. This program applies Monte Carlo simulation process, whereby the expected value of damages is determined explicitly through a numerical integration technique accounting for uncertainty in the basic parameters described above. For this analysis, the number of Monte Carlo simulations is set at 100 with the minimum and maximum number of intervals set at 50 and 60 respectively. Data requirements for the program include:

- Structure data, including structure I.D., category (single or multi-family residential, commercial, industrial, and public), stream location, ground and/or first floor elevation, structure value and content value. This data was developed in a Microsoft Excel spreadsheet and imported into the HEC-FDA program.
- Hydrologic and hydraulic data, including water surface profiles, frequency/discharge relationships, and stage/discharge relationships. For this study, water surface profiles were developed using the HEC-RAS program. These functions were imported into the HEC-FDA program.
- Depth/Damage functions. Functions for residential, non-residential, and unique structures were obtained from; (1) the Institute for Water Resources, (2) from FEMA's National Flood Insurance Program, (3) the New Orleans District, and (4) curves derived from surveys.
- Risk & Uncertainty Parameters, described previously, were also entered into the program.

1.8 EXISTING CONDITION EQUIVALENT ANNUAL DAMAGES

1.8.1 Existing and Future Without Project Condition

Estimates of Equivalent Annual Damages (EAD) under future without project conditions were calculated, using the risk and uncertainty model, through integration of frequency-damage data. Equivalent Annual Damages are the summation of the base year expected annual damages, in this case 2015, plus the discounted value of the most likely future year expected annual damages, for this analysis - 2025. The future expected annual damages shown here are discounted over the project life of 50 years at the Fiscal Year (FY) 2014 federal discount rate of 3.5 percent. Table E-9 shows a breakdown of where these damages are predicted to occur between the East and West Levee.

Table E-9. Expected and Equivalent Annual Damages Without-Project (Existing) Condition (October 2013 price level; $000)

Expected Annual Damages (2015)

	Comm.	*Ind.*	*MFR*	*Mobil*	*Public*	*POV*	*SFR*	*Tunnels*	*Totals*
East	$2,899	$94	$90	$0	$1,302	$24	$27	$2	$4,439
West	$130	$21	$54	$0	$97	$68	$280	$0	$650
Total	**$3,030**	**$115**	**$144**	**$0**	**$1,399**	**$91**	**$307**	**$2**	**$5,089**

Expected Annual Damages (2025)

	Comm.	*Ind.*	*MFR*	*Mobil*	*Public*	*POV*	*SFR*	*Tunnels*	*Totals*
East	$3,190	$103	$101	$0	$1,459	$26	$30	$3	$4,912
West	$144	$23	$59	$0	$106	$73	$304	$0	$708
Total	**$3,334**	**$126**	**$160**	**$0**	**$1,565**	**$100**	**$334**	**$3**	**$5,620**

Equivalent Annual Damages

	Comm.	*Ind.*	*MFR*	*Mobil*	*Public*	*POV*	*SFR*	*Tunnels*	*Totals*
East	$3,131	$101	$99	$0	$1,427	$26	$30	$3	$4,815
West	$141	$23	$58	$0	$104	$72	$299	$0	$696
Total	**$3,271**	**$124**	**$156**	**$0**	**$1,531**	**$98**	**$328**	**$3**	**$5,511**

The expected annual flood losses for the base year (2015) in the study area totaled $5,089,000 based on 2013 price levels. Expected annual damages or the future year (2025) are $5,620,000. Equivalent annual damages are $5,511,000. Approximately 62 percent of all damages are associated with commercial and industrial development, 95 percent of which is behind the East levee. Another 28 percent is associated with public structures, 93 percent of which is behind the East levee. Damages to residential structures are also identified by location with 63 percent of multi-family behind the East levee and 91 percent of single-family damages behind the West levee.

1.9 INVESTIGATION OF FLOOD RISK MANAGEMENT ALTERNATIVES

1.9.1 Critical Planning Assumptions and Policy Considerations

Critical planning assumptions, including the decisions made on policy issues, are as follows:

1. The LPP for the Dallas Floodway Extension, as authorized and currently under construction, is assumed to be in-place for hydraulic modeling purposes.
2. The City's Maintenance Deficiency Correction Period (MDCP) plan to correct O&M deficiencies serves as the without project or base condition.
3. The City's proposed modifications to the existing Dallas Floodway Levee System to meet FEMA 100-year requirements for flood insurance purposes are not part of the without project condition (Possible construction credit for such modifications will be determined on completion of the comprehensive analysis and findings of whether they are integral to the overall levee system upgrades recommended in this Feasibility Study).
4. The Dallas Floodway Levee System will be evaluated as a total project providing for comparable levels of protection to both sides of the river.
5. The economic baseline condition is based on an overtopping analysis (i.e., without project condition assumes stable levee condition for calculation of damages) as identified in the BCRA. Consideration of the potential levee failure mode resulting from interior levee erosion conditions was not addressed separately as the BCRA informs that initiation of this mode of failure requires hydraulic pressures akin to a crest overtopping. Hence, overtopping and interior erosion failure modes are expected to produce like amounts of flood damages.
6. Analysis did not address or quantify potential incidental benefits and/or other benefit categories (e.g., emergency response costs; impacts to transportation, communication & utilities; business/community impacts; public health and relief, etc.). Exclusion of these categories should not affect plan selection.
7. The plan formulation effort focuses on structural measures only.
8. Any alternative considered in the future would involve substantial borrow material from within the existing Floodway. Baseline conditions for the flood risk assessment does not include a Trinity Parkway in the Floodway. Any alternative alignment eventually selected for the Trinity Parkway, along with its habitat mitigation requirements, can and will be made compatible with the USACE's primary purposes of FRM, the BVP, and IDP during the Comprehensive Analysis.

1.9.2 Risk Reduction Alternative Formulation

The formulation and overall development of the proposed FRM NED Plan follows a phased screening and evaluation process as described below.

1.9.2.1 Preliminary Screening

Non-Structural Measures

The following describes the non-structural measures considered to reduce the risk of flooding in the study area.

Floodplain Management

Floodplain management is most effective in controlling future development of the floodplain, thereby assuring that the existing flood problems do not become worse. However, floodplain management cannot, by itself, significantly alleviate existing flooding conditions within a highly urbanized floodplain. The technique of controlled land use is particularly helpful in planning for future development, but is of limited use in highly developed areas.

Effective regulation of the floodplain is dependent on developing enforceable ordinances to ensure that floodplain uses are compatible with the flood hazard. Several means of regulation are available, including zoning ordinances, subdivision regulations, and building codes. Zoning regulations require prudent use and development of the floodplain to prevent excessive property damage, expenditure of public funds, inconvenience, and most importantly, LoL due to flooding. Subdivision regulations guide the division of large land parcels into smaller lots and requires proof of compliance with other regulations and ordinances. A subdivision ordinance with special reference to flood hazards would require installation of adequate drainage facilities, prohibit encroachment in floodway areas, require the placement of critical streets and utilities above a selected flood elevation, and require that building lots be filled or structures be elevated above a selected flood elevation.

Floodplain management is the most effective means to control future development of the floodplain, and ensure that existing flood problems do not worsen. This alternative did not require further consideration because the City of Dallas presently participates in the National Flood Insurance Program, and has adopted the Trinity River Corridor Development Certificate (CDC) process.

Flood Forecast and Warning Systems

Flood forecasting and warning systems involves the determination of imminent flooding, implementation of a plan to warn the public, and organization of assistance in the evacuation of persons and some personal property. Notification of impending flooding can be accomplished by radio, siren, individual notification, or by elaborate remote sensor devices. Some type of flood warning and emergency evacuation effort should be a part of any FRM plan. These measures normally serve to reduce the hazards to life and damage to portable personal property.

The City of Dallas currently has a flood warning system in place. In the event of flooding, Police and Fire-Rescue Dispatch issue a warning to affected residents using Reverse 911. In addition, City official will implement measures such as requesting broadcasters to disseminate Emergency Alert System (EAC) broadcasts, issue news through cable override, special news advisories to radio, television, and cable news stations. It was not necessary to evaluate this measure further since the City of Dallas currently has a flood warning system in place.

Flood Proofing

Damage to existing structures can be reduced or eliminated through various flood proofing measures. These methods protect damageable property by preventing flood waters from entering the building and/or reaching the contents inside. Flood proofing is most easily applied to new construction, and is most applicable where flooding is of short duration, low velocity, and infrequent occurrence of shallow depths.

Flood proofing is usually employed in locations where structural flood protection is not feasible or where collective action is not possible. Typically, flood proofing techniques include water-tight door and window seals, raising of structures, installation of check valves on gravity-flow water and sewer lines, incorporation of seepage controls, and sandbagging of door openings during emergency situations. Due to the relatively large number of structures and the depth of flooding, this measure was not given further consideration.

Raising Structures in Place

One method of flood proofing involves raising the structures at their existing site. This plan is most applicable where a limited number of structures are receiving a large portion of the total flood damages along a given stream reach. Since the structures are already protected by a structural levee, raising the structures to a height which would provide additional protection in the event of levee overtopping would be impractical and cost prohibitive. Based on these findings, a raise-in-place plan was determined to be infeasible for this study area.

Structure Relocation

Plans for structure relocation would involve moving the existing structures to a more non-flood-prone site. The practicality of this measure depends on the frequency of flooding, the value of the property, its importance to the community, and the need for land use areas that are more compatible with floodplain constraints. Relocation of the structures subject to catastrophic flood events within the City of Dallas to provide additional protection in the event of levee overtopping would be an impractical and cost prohibitive solution. Based on these findings, relocation was not considered any further.

Permanent Evacuation

Evacuation involves the acquisition and removal or demolition of frequently flooded structures from the floodplain. One advantage of floodplain evacuation is it generally provides high marginal benefits, because targeted structures are those being damaged at the most frequent events. Floodplain evacuation can also expand open space and enhance natural and beneficial uses and facilitate the secondary use of newly vacated land. Similar to the relocation measure, evacuation to provide additional protection during a catastrophic event can be impractical and cost prohibitive. One area was analyzed for the potential for additional localized risk reduction due to it not receiving and flood risk benefits from either the Dallas Floodway or the Dallas Floodway Extension. This area is located on Rockefeller Boulevard adjacent to Moore Park. The area has experienced significant flooding in the past from Cedar Creek. The following describes the analysis of this area.

Permanent Localized Buyouts at Rockefeller Boulevard

The Permanent evacuation of all or some of nineteen structures on Rockefeller Blvd. was evaluated for its potential as an economically viable measure at the current FY 13 Federal interest rate of 3.75 percent. Of the nineteen structures, one is in the 0.02 AEP (annual exceedance probability, commonly referred to as the 50-year event), three are in the 0.01 AEP (100-year), six are in the 0.004 AEP (250-year), and ten are in the 0.002 AEP (500-year). Estimated values and damages by event are depicted in Table E-10.

Table E-10. Number, Value, and Damage of Floodplain Properties and POVs by Event (FY 2012 Prices - $000)

	0.5 AEP		0.2 AEP		0.1 AEP		0.04 AEP		0.02 AEP		0.01 AEP		0.004 AEP		0.002 AEP	
Damage Category	*#*	*Value*	*#*	*Value*	*#*	*Value*	*#*	*Value*	*#*	*Value*	*#*	*Value*	*#*	*Value*	*#*	*Value*
Single-Family	0	$0.00	0	$0.00	0	$0.00	0	$0.00	1	$34.48	3	$96.38	6	$178.90	10	$304.44
POV	0	$0.00	0	$0.00	0	$0.00	0	$0.00	1	$6.78	3	$20.34	8	$54.24	10	$67.80
Total	**0**	**$0.00**	**0**	**$0.00**	**0**	**$0.00**	**0**	**$0.00**	**2**	**$41.26**	**6**	**$116.72**	**14**	**$233.14**	**20**	**$372.24**

Damage Category	*#*	*Damage*	*#*	*Damage*	*#*	*Damage*	*#*	*Damage*	*#*	*Damage*	*#*	*Damage*	*#*	*Damage*	*#*	*Damage*
Single-Family	0	$0.00	0	$0.00	0	$0.00	0	$0.00	1	$5.56	3	$25.61	6	$90.73	10	$138.52
POV	0	$0.00	0	$0.00	0	$0.00	0	$0.00	1	$1.95	3	$12.16	8	$47.05	10	$65.87
Total	**0**	**$0.00**	**0**	**$0.00**	**0**	**$0.00**	**0**	**$0.00**	**2**	**$7.50**	**6**	**$37.77**	**14**	**$137.78**	**20**	**$204.39**

Without project EAD for the area is approximately $1,600 a year. Preliminary estimates for first costs included structure demolition and real estate costs acquisition costs equal to the structure's estimated value. Total costs for evacuating the three structures in the 0.01 AEP are estimated at $116,600 which annualizes to $5,300. Annual benefits are $1,000 producing -$4,300 annual net benefits with a 0.2 benefit-to-cost ratio. Preliminary first costs for evacuating the six structures in the 0.004 AEP are $233,300, annualizing to $10,600. Annual benefits of $1,500 produce net benefits of -$9,100 with a benefit-to-cost ratio of 0.1. Annualized costs for the ten structures in the 0.002 AEP are $17,700 against $1,600 in annual benefits producing net benefits of -$16,100. Evacuating all sixteen structures would cost at least $622,000 which annualizes to $28,300. Annual benefits are virtually identical to 0.002 AEP evacuation producing -$26,700 in net benefits with a benefit-to-cost ratio of 0.1. The results of all four evacuation scenarios are described in Table E-11. Evacuating structures along Rockefeller Blvd. would not be economically viable and from that standpoint is not under further consideration for USACE participation.

Table E-11. Preliminary Estimates for the Permanent Evacuation of Rockefeller Blvd. (FY 2013 Prices/3.75 percent Federal Interest Rate)

	0.01 AEP BO (100-Yr)	*0.004 AEP BO (250-Yr)*	*0.002 AEP BO (500-Yr)*	*Total BO*
INVESTMENT				
Estimated First Cost	$116,600	$233,300	$388,800	$622,000
Annual Interest Rate	3.75%	3.75%	3.75%	3.75%
Project Life (years)	50	50	50	50
Construction Period (months)	12	12	12	12
Interest During Construction	$2,400	$4,700	$7,900	$12,600
Investment Cost	$119,000	$238,000	$396,600	$634,600
Interest	$4,500	$8,900	$14,900	$23,800
Amortization	$800	$1,700	$2,800	$4,500
OMRR&R ($/year)	$0	$0	$0	$0
TOTAL ANNUAL CHARGES	**$5,300**	**$10,600**	**$17,700**	**$28,300**
Without Project EAD	$1,600	$1,600	$1,600	$1,600
Residual EAD	$700	$200	$0	$0
Flood Reduction Benefits	$1,000	$1,500	$1,600	$1,600
TOTAL BENEFITS	**$1,000**	**$1,500**	**$1,600**	**$1,600**
NET BENEFITS	**$4,300**	**$9,100**	**$16,100**	**$26,700**
BENEFIT-COST RATIO	**0.2**	**0.1**	**0.1**	**0.1**

Structural Measures

Channel Widening

The Upper Trinity Reconnaissance Report dated 1990, initially demonstrated channelization as a viable solution with the examination of two channel widening alternatives with bottom widths of 200 feet and 300 feet, respectively. These channel modifications would widen the existing channel from the upstream end of the City of Dallas improvements at Houston Street to the confluence of the West and Elm Forks, a distance of approximately 32,000 linear feet (approximately 6 miles).

The costs, environmental impacts, mitigation requirements, and potential FRM benefits were evaluated and these alternatives could provide a reduction in the water surface elevations in the upstream portion of the floodway. However, the critical overtopping point of the levee is at the downstream end so channelization within the floodway would not effectively prevent critical overtopping thereby producing no meaningful reduction in damages. As a result, the channel widening measures were eliminated from further consideration since these would be ineffective as a stand-alone measure in decreasing risk of the levee overtopping.

Floodwalls

This measure includes the construction of a concrete floodwall along the levee crest for alternatives equal to two feet and above the current SPF water surface profiles. This measure was not carried forward due to the following concerns:

1. The soil conditions in the study area do not permit the use of a shallow foundation system (such as a continuous spread footing) for the flood wall, which would be no more than approximately 3 feet higher than the existing crest elevations.
2. The presence of sand lenses in the levee could destabilize the flood wall by seepage and under-seepage below the foundations.
3. Floodwall supported on a shallow foundation system would negatively impact the stability of the levee system, increasing the potential for shallow slides.
4. Supporting the floodwall on a deep foundation system is not suitable for the high-plasticity clayey soil the levee is composed of.
5. Shallow slides could result from the floodwalls which would further destabilize the slopes.
6. Floodwalls not supported on deep foundations would suffer damage due to erosion and impact of floating debris in case of a SPF condition.
7. Construction of floodwalls would restrict access for maintenance and emergency operations because of the geometric configuration of the levees (minimal crest width and bridge obstruction at many locations).

Atchison, Topeka and Santa Fe Bridge Modification

This historic railroad bridge is located at the downstream end of the Dallas Floodway Levee System and is generally referred to as the Atchison, Topeka, and Santa Fe Railroad Bridge (AT&SF). The bridge was taken out of service in the 1990s when the DART system purchased it and the right-of-way and constructed a new light rail system bridge parallel to the old bridge. At that time, the rails and cross ties were removed from the bridge deck and the remainder of the structure was left in place.

The removal of the abandoned AT&SF Bridge was identified as a FRM measure due to its significant impact to the SPF water surface profile, its location at the downstream end of the Dallas Floodway, and the fact that the bridge is no longer needed for rail traffic. Hydraulic analysis showed that the bridge causes a significant upstream rise in the SPF water surface profile due to the numerous closely spaced piers, the low-deck height, and due to the large earth embankments across the floodway.

Levee Height Modifications

This measure involves using earthen fill to raise the levee to the target water surface elevations associated with the following overtopping flow rates of 260,000 cubic feet per second (cfs), 265K, 269K, 273K, and 277K, and 289K cfs. The existing gravel access road on the crest of the levee would be removed prior to raising the levee. This is achieved by assuming an excavation of two feet from the top of the levee where the levee is to be raised in order to remove all existing impervious material. A new 8 inch crushed limestone access road would be included as part of the construction of a levee raise. The road surface would match existing conditions and tie into the existing access road on either side of the levee raise. The existing levee crown width varies; however, improvements to the levee will provide a minimum crest width of 16 feet. Quantities were developed using a 4H:1V side slope where the levees heights were modified, tying into the protected side levee crest and extending to the riverside levee slope. Following the Value Engineering workshop, quantities and costs were developed for maintaining 3H:1V side slopes throughout the levee system. The 3H:1V levee raise and access road template is shown on Figures E-2 and E-3.

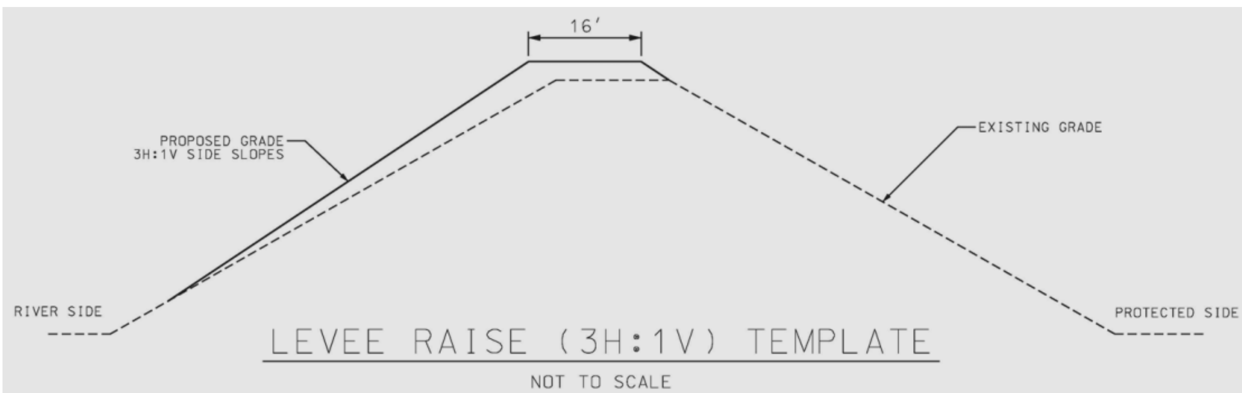

Figure E-2. 3H:1V Levee Raise Template

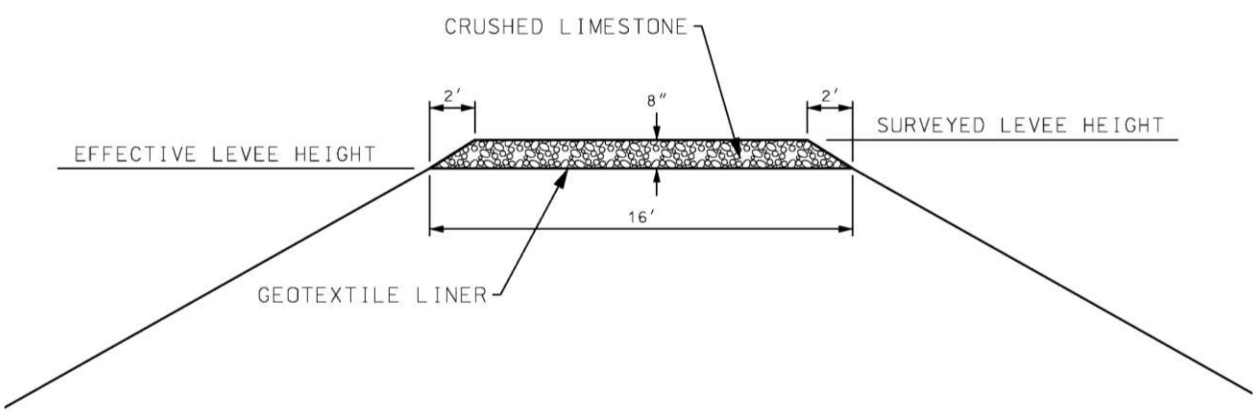

Figure E-3. New Crushed Limestone Access Road Template Armoring

This measure involves armoring the East and West Levee (including the Elm Fork and West Fork levee segments) in all areas where the existing levee height is below the water surface elevations for the designated flow rates of 255,000 cfs, 260K, 265K, 269K, 273K, 277K, 289K, and 302K cfs. The armoring will be placed using articulated concrete block (ACB). The ACBs will begin 10 feet down from the crest of the riverside slope and continue across the crest of the levee and down the entire landside slope of the levee, extending 50 feet out from the toe of the levee. The armoring would be placed on the existing surface of the levees in all identified areas. Two additional materials for armoring were considered, including turf reinforcement mats and scour protection mats. These two methods provided significant cost savings, however all materials would need to be tested to determine technical viability for their application.

Cut-Off Walls

This measure was proposed at the toe of the river side of the levee to deal with the potential for under seepage at the toe of the levee. This three foot wide cut-off wall will be composed of a soil bentonite mixture and would tie into the bedrock under the levee with a key-in depth of five (5) feet. The extent of the cut-off wall was determined through geotechnical evaluation of the borings in the Dallas Floodway project area.

1.9.2.2 Initial Evaluation

The following details the initial economic evaluation of the structural measures carried forward for detailed evaluation. These include modification of the AT&SF Bridge, both 4H:1V and 3H:1V side slope levee height modifications, armoring (with articulated concrete block – ACB), and cut-off walls.

<u>Atchison, Topeka and Santa Fe Bridge Modification</u>

The abandoned AT&SF Bridge spans the main stem of the Trinity River and is located at the downstream end of the Dallas Floodway System. The AT&SF Bridge is the divider between the Dallas Floodway and Dallas Floodway Extension Projects. The bridge is a notable risk to the levee system due to closely spaced piers with cross bracing which is expected to cause significant debris accumulation and result in increased water surface elevations upstream of the bridge during major flood events. The wood trestles on the bridge have approximately 14 foot spacing, instead of the typical 50 foot spacing on most bridge designs.

The AT&SF Bridge Modification plan is for removal of portions of the AT&SF Bridge as a potential flood risk management alternative and includes: (1) removing approximately 1,100 feet of wood trestle bridge on the left bank side of the Floodway from the new Santa Fe Trestle Trail bridge to the left bridge abutment at the East Levee, (2) removing a 660 foot concrete railroad bridge segment on the right bank side, and (3) removing two embankments on the right bank side of the Floodway.

A preliminary economic analysis for this plan using a steady flow analysis approximation for inundation depths and levee overtopping with the levees at original design grade had shown the plan was economically justified without debris impacts. However, the current unsteady flow analysis using the existing levee crest elevations for levee overtopping and breach has shown the plan is not economically justified as a stand-alone measure as noted in Table E-12. Since significant debris accumulations had been observed on the bridge following most of the higher flood events and based on discussions at the 2 November 2012 meeting between the vertical team, the PDT and the sponsor, it was determined that unsteady flow analysis for levee overtopping was justified to model the effects of debris accumulation on the performance of the bridge modification alternative. It was agreed that if a reasonable debris accumulation impact indicated the bridge modification plan to be economically justified, then the plan should be considered as a first added increment with other FRM measures. Since there is a significant degree of uncertainty for debris accumulation for extremely rare flood events, an initial analysis was performed and it was assumed that the debris accumulation would result in 50 percent blockage of the bridge structures below the bridge deck. The results of this analysis indicated that debris accumulation could cause an additional rise in the water surface just upstream of the bridge of approximately four feet for the future SPF (277,000 cfs) event and 1.5 feet for the 1 percent AEP event. At the Trinity River confluence upstream, the rise in water surface for the SPF and 1 percent AEP floods was approximately 2.2 feet and 0.3 feet, respectively for the debris impact. This analysis provided an estimate of the potential debris impacts, but actual debris accumulations are unknown and could be either higher or lower for those flooding events. This analysis is also based on the confinement of the entire flow to the Floodway without overtopping. Therefore, the estimated rise at the bridge using unsteady flow analysis would be lower than the steady flow estimate for the 277,000 cfs event since overtopping of the existing levee system would occur for this flood event. This analysis also indicates that the change in the incipient overtopping peak flow for the East Levee is approximately 225,000 cfs with the estimated debris impact compared to the 245,000 cfs threshold flow without the debris impact.

Table E-12. Economic Evaluation for AT&SF Bridge Modification (FY 2012 price level)

	No Debris	*Debris (50% Blockage)*	*1990 Flood Debris*
INVESTMENT			
Estimated First Cost	$2,221,000	$2,221,000	$2,221,000
Annual Interest Rate	4.000%	4.000%	4.000%
Project Life (years)	50	50	50
Construction Period (months)	12	12	12
Interest During Construction	$48,000	$48,000	$48,000
Investment Cost	$2,268,000	$2,268,000	$2,268,000
Interest	$91,000	$91,000	$91,000
Amortization	$15,000	$15,000	$15,000
OMRR&R ($/year)	$0	$0	$0
TOTAL ANNUAL CHARGES	**$106,000**	**$106,000**	**$106,000**
Without Project EAD	$5,015,000	$6,290,000	$5,697,000
Residual EAD	$4,984,000	$4,984,000	$4,984,000
Flood Reduction Benefits	$31,000	$1,306,000	$713,000
TOTAL BENEFITS	**$31,000**	**$1,306,000**	**$713,000**
NET BENEFITS	**($75,000)**	**$1,201,000**	**$607,000**
BENEFIT-COST RATIO	**0.29**	**12.32**	**6.73**

Following the ATR review of this analysis, it was proposed that an additional analysis be conducted based on approximating the amount of the debris on the AT&SF Bridge that accumulated during the 1990 flood of record. This analysis uses the 1990 flood event high water marks to calibrate the model to approximately match the water surface impacts of the debris during the 1990 flood event. This analysis was proposed to determine whether the modification remains economically justified with an assumption of less debris accumulation. The debris analysis was performed using the 1990 flood event peak flow of 82,300 cfs measured at the USGS Gage at the Commerce Street Bridge. The Gage peak stage reading and two other high watermarks, one upstream and one downstream of the bridge, were used to calibrate the debris impact. The floating debris technique in HEC-RAS Version 4.1.0 was used to model the debris impact. For larger flood events, it is expected the AT&SF would accumulate at least that amount of debris. The resulting approximate debris blockage of the bridge opening below the bridge deck for the 1990 flood event was 30 percent and approximately 22 percent for the 277,000 cfs flood event. The difference is due to the fact that the HEC-RAS modeling technique assumes the debris amount is floating and the blockage extends below the computed water surface for each flood event analyzed. Since the 277,000 flow water surface is much higher than the 1990 flood event, some of the debris is blocked by the bridge deck because some of the flow is higher the bridge deck. The economic analysis results are shown in Table E-12 for the 277,000 cfs flood event.

The debris analysis at 50 percent debris impact shows that the effects of modifying the bridge would provide significant economic benefits (refer to Table E-12). The 1990 Flood debris economic analysis (refer to Table E-12) shows the AT&SF Bridge modification remains economically feasible with a lower estimate of debris blockage. Therefore, all of the formulation of FRM measures includes the AT&SF Bridge Modification Plan as a first added increment.

Levee Height Modifications

Table E-14 displays the economic evaluation of the levee height modifications. Stated earlier these levee modifications were initially evaluated as incorporating 4V:1H side slopes for those areas where the levee was modified with 3V:1H side slopes being evaluated following the Value Engineering workshop. The initial analysis also evaluated these modifications with the AT&SF Bridge modifications. This was evaluated in this manner due to previous analyses that showed significant economic benefits and from a safety standpoint since the bridge can act as a debris collector during high flood events and pose a significant risk to public safety. The initial array of levee 4V:1H side slope modifications began at levels that would address flows from 260,000 cfs up to 277,000 cfs. The 289,000 cfs modification was not evaluated since earlier analyses had indicated that the lower level modifications would probably be more economically viable. As displayed in Table E-14, all showed positive net annual benefits with the modification at 269,000 cfs generating the highest net benefits at $881,000. For the 3V:1H side slopes, the 289,000 cfs was added to the array. The modification at the 277,000 cfs level produced the highest net annual benefits at $1,179,000.

Armoring

Table E-15 displays the economic evaluation of the armoring measures. Stated earlier, the array for armoring to address flows was set wider and ranged from 255,000 cfs to 302,000 cfs. A primary objective in pursuing this particular measure is the potential to prevent breeching of the levee. With this measure, the levee does not breech at armoring levels beginning at 277,000 cfs. This is illustrated by total benefits maximizing at $2,545,000. Pursuing armoring options higher than this level are pointless since there are no more benefits to be obtained. Due to the cost of this measure however, only the lower three scales in the array were economically viable with the 265,000 cfs armoring level achieving the highest net benefits of $474,000. Due to these results, there was no further consideration for armoring either as a stand-alone measure or combined with other measures.

Table E-13. Interior/Exterior Relationships for Levee Raise and Armoring Alternatives

		Without Project Stage		*260K Raise + AT&SF*		*265K Raise + AT&SF*		*269K Raise + AT&SF*		*273K Raise + AT&SF*		*277K Raise + AT&SF*	
River Discharge (cfs)	*Exterior Stage*	*East*	*West*	*East*	*West*	*East*	*West*	*East*	*West*	*East*	*West*	*East*	*West*
260,000	424.38	416.36	387.95	385.54	387.95	375.11	375.11	375.11	375.11	375.11	375.11	375.11	375.11
265,000	424.75	416.98	390.37	415.29	390.38	385.54	387.95	375.12	375.12	375.12	375.12	375.12	375.12
269,000	425.04	417.22	390.87	416.08	390.84	387.5	391.15	385.54	387.95	375.13	375.13	375.13	375.13
273,000	425.23	417.47	421.69	416.26	420.25	390	392.83	387.19	390.91	385.54	387.95	375.14	375.14
277,000	425.41	417.71	422.14	416.76	422.42	415.94	422.32	390.54	393.94	387.06	391.61	385.54	387.95
289,000	426.12	418.93	423.67	418.13	423.74	417.75	423.73	417.36	423.41	416.68	422.95	395.48	400.79
302,000	426.78	420.12	424.77	419.39	424.84	419.13	424.84	418.88	424.61	418.57	424.44	418.23	424.24

		Without Project Stage		*Armoring to 260K*		*Armoring to 265K*		*Armoring to 269K*		*Armoring to 273K*		*Armoring to 277K*	
River Discharge (cfs)	*Exterior Stage*	*East*	*West*	*East*	*West*	*East*	*West*	*East*	*West*	*East*	*West*	*East*	*West*
260,000	424.38	416.36	387.95	387.15	387.95	387.15	387.95	387.15	387.95	387.15	387.95	387.15	387.95
265,000	424.75	416.98	390.37	388.59	390.37	388.59	387.96	388.59	387.96	388.59	387.96	388.59	387.96
269,000	425.04	417.22	390.87	390.26	390.83	390.26	390.83	390.26	388.23	390.26	388.23	390.26	388.23
273,000	425.23	417.47	421.69	415.78	420.41	392.09	392.83	392.09	392.83	392.09	389.37	392.09	389.37
277,000	425.41	417.71	422.14	416.45	422.56	415.77	422.28	394.11	394.80	394.11	394.80	394.11	390.50
289,000	426.12	418.93	423.67	417.99	423.81	417.75	423.69	417.22	423.31	402.88	403.72	402.88	403.72
302,000	426.78	420.12	424.77	419.30	424.89	419.14	424.82	418.87	424.56	418.19	424.41	406.48	409.08

Table E-14. Levee Height Modifications
(FY 2012 price level)

	260K Raise + AT&SF	*265K Raise + AT&SF*	*269K Raise + AT&SF*	*273K Raise + AT&SF*	*277K Raise + AT&SF*	*289K Raise + AT&SF*
4V:1H Side Slopes						
INVESTMENT						
Estimated First Cost	$2,688,000	$2,901,000	$5,160,000	$10,390,000	$18,747,000	N/A
Annual Interest Rate	4.00%	4.00%	4.00%	4.00%	4.00%	N/A
Project Life (years)	50	50	50	50	50	N/A
Construction Period (months)	12	12	12	38	76.5	N/A
Interest During Construction	$58,000	$62,000	$111,000	$666,000	$2,528,000	N/A
Investment Cost	$2,746,000	$2,964,000	$5,271,000	$11,056,000	$21,275,000	N/A
Interest	$110,000	$119,000	$211,000	$442,000	$851,000	N/A
Amortization	$18,000	$19,000	$35,000	$72,000	$139,000	N/A
OMRR&R ($/year)	$5,000	$6,000	$8,000	$20,000	$30,000	N/A
TOTAL ANNUAL CHARGES	**$133,000**	**$143,000**	**$253,000**	**$535,000**	**$1,020,000**	N/A
Without Project EAD	$5,015,000	$5,015,000	$5,015,000	$5,015,000	$5,015,000	N/A
Residual EAD	$4,562,000	$4,174,000	$3,881,000	$3,805,000	$3,471,000	N/A
Flood Reduction Benefits	$452,000	$841,000	$1,133,000	$1,210,000	$1,544,000	N/A
TOTAL BENEFITS	**$452,000**	**$841,000**	**$1,133,000**	**$1,210,000**	**$1,544,000**	N/A
NET BENEFITS	**$319,000**	**$697,000**	**$881,000**	**$675,000**	**$523,000**	N/A
BENEFIT-COST RATIO	**3.40**	**5.88**	**4.48**	**2.26**	**1.51**	N/A
3V:1H Side Slopes						
INVESTMENT						
Estimated First Cost	$2,248,000	$2,302,000	$2,880,000	$4,221,000	$6,330,000	$11,524,000
Annual Interest Rate	4.00%	4.00%	4.00%	4.00%	4.00%	4.00%
Project Life (years)	50	50	50	50	50	50
Construction Period (months)	12	12	12	13	22	48
Interest During Construction	$48,000	$50,000	$62,000	$271,000	$854,000	$1,632,000
Investment Cost	$2,296,000	$2,352,000	$2,942,000	$4,491,000	$7,183,000	$13,156,000
Interest	$92,000	$94,000	$118,000	$180,000	$287,000	$526,000
Amortization	$15,000	$15,000	$19,000	$29,000	$47,000	$86,000
OMRR&R ($/year)	$5,000	$6,000	$8,000	$20,000	$30,000	$30,000
TOTAL ANNUAL CHARGES	**$112,000**	**$115,000**	**$144,000**	**$229,000**	**$364,000**	**$642,000**
Without Project EAD	$5,015,000	$5,015,000	$5,015,000	$5,015,000	$5,015,000	$5,015,000
Residual EAD	$4,562,000	$4,174,000	$3,881,000	$3,805,000	$3,471,000	$3,243,000
Flood Reduction Benefits	$452,000	$841,000	$1,133,000	$1,210,000	$1,544,000	$1,772,000
TOTAL BENEFITS	**$452,000**	**$841,000**	**$1,133,000**	**$1,210,000**	**$1,544,000**	**$1,772,000**
NET BENEFITS	**$340,000**	**$726,000**	**$989,000**	**$981,000**	**$1,179,000**	**$1,129,000**
BENEFIT-COST RATIO	**4.04**	**7.31**	**7.87**	**5.28**	**4.24**	**2.76**

Table E-15. Armoring (Articulated Concrete Block)
(FY 2012 price level)

	255K Armoring + AT&SF	*260K Armoring + AT&SF*	*265K Armoring + AT&SF*	*269K Armoring + AT&SF*	*273K Armoring + AT&SF*	*277K Armoring + AT&SF*	*289K Armoring + AT&SF*	*302K Armoring + AT&SF*
INVESTMENT								
Estimated First Cost	$4,317,000	$4,580,000	$7,065,000	$32,743,000	$53,634,000	$76,606,000	$166,148,000	$211,279,000
Annual Interest Rate	4.000%	4.000%	4.000%	4.000%	4.000%	4.000%	4.000%	4.000%
Project Life (years)	50	50	50	50	50	50	50	50
Construction Period (months)	15	32	52	69	69	69	69	69
Interest During Construction	$112,000	$246,000	$629,000	$3,947,000	$6,465,000	$9,234,000	$20,028,000	$25,468,000
Investment Cost	$4,429,000	$4,827,000	$7,694,000	$36,690,000	$60,100,000	$85,840,000	$186,175,000	$236,747,000
Interest	$177,000	$193,000	$308,000	$1,468,000	$2,404,000	$3,434,000	$7,447,000	$9,470,000
Amortization	$29,000	$32,000	$50,000	$240,000	$394,000	$562,000	$1,219,000	$1,551,000
OMRR&R ($/year)	$0	$0	$0	$0	$0	$0	$0	$0
TOTAL ANNUAL CHARGES	**$206,000**	**$225,000**	**$358,000**	**$1,708,000**	**$2,798,000**	**$3,996,000**	**$8,667,000**	**$11,021,000**
Without Project EAD	$5,015,000	$5,015,000	$5,015,000	$5,015,000	$5,015,000	$5,015,000	$5,015,000	$5,015,000
Residual EAD	$4,593,000	$4,362,000	$4,183,000	$3,891,000	$3,512,000	$2,469,000	$2,469,000	$2,469,000
Flood Reduction Benefits	$421,000	$653,000	$832,000	$1,123,000	$1,503,000	$2,545,000	$2,545,000	$2,545,000
TOTAL BENEFITS	**$421,000**	**$653,000**	**$832,000**	**$1,123,000**	**$1,503,000**	**$2,545,000**	**$2,545,000**	**$2,545,000**
NET BENEFITS	**$215,000**	**$428,000**	**$474,000**	**($585,000)**	**($1,295,000)**	**($1,451,000)**	**($6,121,000)**	**($8,475,000)**
BENEFIT-COST RATIO	**2.04**	**2.90**	**2.32**	**0.66**	**0.54**	**0.64**	**0.29**	**0.23**

Cut-Off Walls

This measure was proposed at the toe of the river side of the levee to deal with the potential for under seepage at the toe of the levee leading to breach. This three foot wide cut-off wall will be composed of a soil bentonite mixture and would key-into bedrock at a depth of five (5) feet. The extent of the cut-off wall was determined through geotechnical evaluation of the borings in the Dallas Floodway project area. Since this is a different probable failure mode than what was used to formulate for overtopping, this required a different baseline condition with different inflow events and breach settings. Since the seepage walls would not prevent damages from events that overtop the levees, an effort was made to separate the economic benefits associated with flood events below the top of the levee versus above the top of the levee. Therefore, two scenarios were modeled; (1) with peak flows ranging from approximately 50 percent of the levee height to the highest event overtopping the levee and, (2) with peak flows ranging from 50 percent of the levee height to the highest event not overtopping the levee. As shown in Table E-16, the no overtopping scenario produced without project EAD of $858,000 and since the cut-off wall is assumed to eliminate under seepage, the residual EAD goes to zero. For the overtopping scenario, using the assumption that the without project condition is additive between the EAD produced for addressing the overtopping PFM and the best guesstimate for without project damages that could occur due to under seepage with no overtopping, the without project EAD is $5,873,000. The benefits to be derived would then be the elimination of the portion of EAD associated with the no overtopping which would be the without project EAD associated with overtopping. In either scenario, the total benefits are $858,000. Cut-off walls are therefore not economically justified.

Table E-16. Cut-Off Walls
(FY 2012 price level)

	No Overtopping	*W/ Overtopping*
INVESTMENT		
Estimated First Cost	$36,120,000	$36,120,000
Annual Interest Rate	4.000%	4.000%
Project Life (years)	50	50
Construction Period (months)	74	74
Interest During Construction	$4,697,000	$4,697,000
Investment Cost	$40,817,000	$40,817,000
Interest	$1,633,000	$1,633,000
Amortization	$267,000	$267,000
OMRR&R ($/year)	$0	$0
TOTAL ANNUAL CHARGES	**$1,900,000**	**$1,900,000**
Without Project EAD	$858,000	$5,873,000
Residual EAD	$0	$5,015,000
Flood Reduction Benefits	$858,000	$858,000
TOTAL BENEFITS	**$858,000**	**$858,000**
NET BENEFITS	**($1,042,000)**	**($1,042,000)**
BENEFIT-COST RATIO	**0.45**	**0.45**

1.9.2.3 Final Evaluation

This round of evaluation moved forward those measures/alternatives that were competitively viable economically and further analyzed with refined costs once a cost and schedule risk analysis had been performed by the PDT. The following evaluation reflects any changes made to the modeling and costs that might ultimately impact the decision on the tentatively selected plan.

Incremental Bridge Modification Analysis

We previously noted that the bridge modification was not showing to be economically viable under the current analysis with the unsteady-state HEC-RAS model. In order to assess if the levee raise may be economically justified at some other height, an incremental analysis was done to determine whether the net benefits obtained for the levee raises were due solely to the raises themselves since all showed positive net benefits. To do this, HEC-RAS and HEC-FDA runs were done for each of the levee raises both with and without the AT&SF Bridge modification. In each of the scenarios below, the "Levee Only EAD" reflects equivalent annual damages associated with that particular levee raise without the bridge modification. The "Levee with AT&SF" EAD reflects the damages that would result from implementing both the levee raise and the bridge modification. The difference between the two is the incremental benefit of the bridge modification. Costs for the bridge modification were annualized with first costs remaining constant but the construction period varying as appropriate for each levee raise. As shown in Table E-17, two of the levee scales show positive net benefits (260K and 265K) while the other three do not.

Table E-17. Incremental Bridge Modification Analysis
(FY 2012 price level)

	260K Raise	*265K Raise*	*269K Raise*	*273K Raise*	*277K Raise*
INVESTMENT					
Estimated First Cost	$2,221,000	$2,221,000	$2,221,000	$2,221,000	$2,221,000
Annual Interest Rate	4.000%	4.000%	4.000%	4.000%	4.000%
Project Life (years)	50	50	50	50	50
Construction Period (months)	12	12	12	13	22
Interest During Construction	$48,000	$48,000	$48,000	$51,000	$82,000
Investment Cost	$2,268,000	$2,268,000	$2,268,000	$2,272,000	$2,303,000
Interest	$91,000	$91,000	$91,000	$91,000	$92,000
Amortization	$15,000	$15,000	$15,000	$15,000	$15,000
OMRR&R ($/year)	$5,000	$6,000	$8,000	$20,000	$30,000
TOTAL ANNUAL CHARGES	**$111,000**	**$111,000**	**$113,000**	**$126,000**	**$137,000**
Levee Only EAD	$4,753,000	$4,310,000	$3,961,000	$3,846,000	$3,548,000
Levee with AT&SF EAD	$4,562,000	$4,174,000	$3,881,000	$3,805,000	$3,471,000
Flood Reduction Benefits	$191,000	$136,000	$80,000	$41,000	$77,000
TOTAL BENEFITS	**$191,000**	**$136,000**	**$80,000**	**$41,000**	**$77,000**
NET BENEFITS	**$80,000**	**$25,000**	**($33,000)**	**($85,000)**	**($60,000)**
BENEFIT-COST RATIO	**1.72**	**1.23**	**0.71**	**0.33**	**0.56**

Levee Height Modifications

Table E-18 displays the economic evaluation of the levee height modifications with the AT&SF Bridge modified as well. Just as with the AT&SF Bridge modification, costs for this measure were refined due to an increase in the contingency. Differences in costs between this table and those displayed in E-14 reflect an increased level of refinement from those costs reflected in the earlier table. For the 4V:1H levee height modification the 265,000 cfs raise produced the highest net benefits at $898,000. For the 3V:1H levee height modification the 277,000 cfs raise produced the highest net benefits at $1,214,000.

Table E-18. Levee Height Modifications with AT&SF Bridge Modification (FY 2012 price level)

	260K Raise + AT&SF	*265K Raise + AT&SF*	*269K Raise + AT&SF*	*273K Raise + AT&SF*	*277K Raise + AT&SF*	*289K Raise + AT&SF*
4V:1H Side Slopes						
INVESTMENT						
Estimated First Cost	$2,811,000	$3,023,000	$4,784,000	$10,468,000	$18,771,000	N/A
Annual Interest Rate	4.000%	4.000%	4.000%	4.000%	4.000%	N/A
Project Life (years)	50	50	50	50	50	N/A
Construction Period (months)	12	12	12	38	76.5	N/A
Interest During Construction	$61,000	$65,000	$103,000	$671,000	$2,531,000	N/A
Investment Cost	$2,871,000	$3,088,000	$4,887,000	$11,139,000	$21,302,000	N/A
Interest	$115,000	$124,000	$195,000	$446,000	$852,000	N/A
Amortization	$19,000	$20,000	$32,000	$73,000	$140,000	N/A
OMRR&R ($/year)	$5,000	$6,000	$8,000	$20,000	$30,000	N/A
TOTAL ANNUAL CHARGES	**$139,000**	**$149,000**	**$235,000**	**$539,000**	**$1,022,000**	N/A
Without Project EAD	$5,015,000	$5,015,000	$5,015,000	$5,015,000	$5,015,000	N/A
Residual EAD	$4,562,000	$4,174,000	$3,881,000	$3,805,000	$3,471,000	N/A
Flood Reduction Benefits	$452,000	$841,000	$1,133,000	$1,210,000	$1,544,000	N/A
TOTAL BENEFITS	**$452,000**	**$841,000**	**$1,133,000**	**$1,210,000**	**$1,544,000**	N/A
NET BENEFITS	**$314,000**	**$692,000**	**$898,000**	**$671,000**	**$522,000**	N/A
BENEFIT-COST RATIO	**3.25**	**5.64**	**4.82**	**2.24**	**1.51**	N/A
3V:1H Side Slopes						
INVESTMENT						
Estimated First Cost	$2,360,000	$2,411,000	$2,954,000	$4,205,000	$6,211,000	$11,113,000
Annual Interest Rate	4.000%	4.000%	4.000%	4.000%	4.000%	4.000%
Project Life (years)	50	50	50	50	50	50
Construction Period (months)	12	12	12	13	22	48
Interest During Construction	$51,000	$52,000	$64,000	$97,000	$230,000	$909,000
Investment Cost	$2,411,000	$2,463,000	$3,017,000	$4,301,000	$6,441,000	$12,022,000
Interest	$96,000	$99,000	$121,000	$172,000	$258,000	$481,000
Amortization	$16,000	$16,000	$20,000	$28,000	$42,000	$79,000
OMRR&R ($/year)	$5,000	$6,000	$8,000	$20,000	$30,000	$30,000
TOTAL ANNUAL CHARGES	**$117,000**	**$120,000**	**$148,000**	**$220,000**	**$330,000**	**$590,000**
Without Project EAD	$5,015,000	$5,015,000	$5,015,000	$5,015,000	$5,015,000	$5,015,000
Residual EAD	$4,562,000	$4,174,000	$3,881,000	$3,805,000	$3,471,000	$3,243,000
Flood Reduction Benefits	$452,000	$841,000	$1,133,000	$1,210,000	$1,544,000	$1,772,000
TOTAL BENEFITS	**$452,000**	**$841,000**	**$1,133,000**	**$1,210,000**	**$1,544,000**	**$1,772,000**
NET BENEFITS	**$335,000**	**$721,000**	**$985,000**	**$989,000**	**$1,214,000**	**$1,182,000**
BENEFIT-COST RATIO	**3.86**	**7.01**	**7.66**	**5.50**	**4.68**	**3.00**

1.9.2.4 Refinement of NED Plan: 277,000 cfs Levee Raise and AT&SF Bridge modification

In the development of the NED Plan, several base assumptions were used to generate quantities and to determine scope of work. The road surface template developed assumed that the crushed gravel road surface could be considered part of the effective levee height. It was confirmed in final analysis that crushed limestone road cannot be considered part of the overall levee height and has been placed on the top of the effective levee. The increase in cost of the NED Plan was $3.3 million. Generally, each alternative would have a proportional change. The levee raises analyzed in the NED plan formulation were reanalyzed from a cost perspective to determine whether the formulation would change. The plans that are smaller than the 277,000 cfs were not considered further because net benefits for the 277,000 cfs with an additional $3.3 million in cost was still higher than the smaller plans. The overall scope and cost of the 289,000 cfs plan, based on knowledge of the 277,000 cfs scope and cost changes, is expected to increase by 60 percent. If there was a 60 percent increase in cost of the 289,000 cfs plan, the net benefits would fall below those of the 277,000 plan. The 277,000 remains the NED and no additional formulation is required to address the identified increase in quantities for the levee raises. The NED plan also includes the removal of portions of the AT&SF Bridge on the far downstream end of the Dallas Floodway Levee System. Table E-19 depicts the change in benefits due to the change in costs for the AT&SF Bridge and the 277,000 cfs levee raise. Net benefits for the AT&SF bridge modification improve to -$40,000 annually from -$75,000. Net benefits for the 277,000 levee raise with the AT&SF modifications drops for $1,214,000 annually to $1,136,000. These net benefits are still higher than the lower levee raises.

Table E-19. Refined Benefits for NED Plan (FY 2012 price level)

	ATSF Removal	*277K Raise + AT&SF*
INVESTMENT		
Estimated First Cost	$1,476,000	$7,568,000
Annual Interest Rate	4.00%	4.00%
Project Life (years)	50	50
Construction Period (months)	12	22
Interest During Construction	$32,000	$280,000
Investment Cost	$1,508,000	$7,848,000
Interest	$60,000	$314,000
Amortization	$10,000	$51,000
OMRR&R ($/year)	$0	$42,000
TOTAL ANNUAL CHARGES	**$70,000**	**$407,000**
Without Project EAD	$5,015,000	$5,015,000
Residual EAD	$4,984,000	$3,471,000
Flood Reduction Benefits	$31,000	$1,544,000
TOTAL BENEFITS	**$31,000**	**$1,544,000**
NET BENEFITS	**($40,000)**	**$1,136,000**
BENEFIT-COST RATIO	**0.44**	**3.79**

Table E-20 depicts annual costs and net benefits of the NED Plan at the current FY Federal interest rate of 3.5 percent and at 7 percent.

Table E-20. Refined Benefits for NED Plan at 3.5% and 7%
(FY 2014 price level)

	3.5 Percent	*7 Percent*
INVESTMENT		
Construction	$8,042,000	$8,042,000
PED	$901,000	$901,000
Construction Management	$800,000	$800,000
Estimated First Cost	$9,743,000	$9,743,000
Annual Interest Rate	3.5%	7.0%
Project Life (years)	50	50
Construction Period (months)	22	22
Interest During Construction	$315,000	$633,000
Investment Cost	$10,058,000	$10,376,000
Interest	$352,000	$726,000
Amortization	$77,000	$26,000
OMRR&R ($/year)	$30,000	$30,000
TOTAL ANNUAL CHARGES	**$459,000**	**$782,000**
Without Project EAD	$5,511,000	$5,456,000
Residual EAD	$3,817,000	$3,775,000
Flood Reduction Benefits	$1,695,000	$1,681,000
TOTAL BENEFITS	**$1,695,000**	**$1,681,000**
NET BENEFITS	**$1,236,000**	**$900,000**
BENEFIT-COST RATIO	**3.7**	**2.1**

1.9.3 Ancillary Damages - Emergency Costs, Damage to Infrastructure and Utilities

The District made a decision early during plan formulation that economic justification would be based strictly on the reduction in direct damages. While a discussion and quantification of the potential damages to infrastructure and utilities as well as reductions in emergency costs and cleanup can help tell a more complete story regarding project benefits, they are not required for economic justification for the recommended plan. In addition to telling a more complete story, quantification of these damages can likely result in higher project net benefits and benefit-to-cost ratios. Analyses conducted during the early stages of plan formulation indicated that economic justification would not be in jeopardy without these benefits. Additionally, additional benefits generated from these damage categories was not expected to have any impacts on the ranking of alternatives that might affect the selection of a recommended plan since they would be proportional to the direct economic benefits.

1.9.4 Annualized Probability of Failure and Annualized Loss of Life

Table E-21 depicts the annualized probability of failure and annualized loss of life for each of the flood-risk management alternatives evaluated by the Risk Management Center. These include the levee raises at 260,000, 277,000 and 302,000 cfs all in combination with the AT&SF Bridge modification; armoring at 260,000, 277,000 and 302,000 cfs all in combination also with the AT&SF Bridge modification; and the cut-off wall. As the table explains, each of the levee raises drops the annualized probability of failure from 55.2 to 73.5 percent for the East levee and from 22.3 to 73.5 percent for the West levee. The annualized loss of life drops from 52 to 76.4 percent for the East and 18.9 to 69 percent for the West levee. Armoring drops the annualized probability of failure from 55.2 to 86.7 percent for the East levee and from 22.2 to 84.8 percent for the West levee. Annualized loss of life drops from 46.9 percent to 84.2

percent for the East levee and 18.9 to 83 percent for the West levee. Cut-off walls drop the annualized probability of failure by 92.9 percent and the annualized loss of life by 93.2 percent.

Table E-21. Annualized Probability of Failure and Loss of Life for FRM Alternatives

Annualized Failure Probability	*Revised BCRA*	*260K Raise + AT&SF Bridge*	*277K Raise + AT&SF Bridge*	*302K Raise + AT&SF Bridge*
East Levee	5.42E-04	2.43E-04	1.95E-04	1.44E-04
West Levee	5.42E-04	4.22E-04	1.95E-04	1.44E-04
Annualized Life Loss				
East Levee	1.37E-01	6.56E-02	4.53E-02	3.23E-02
West Levee	4.51E-01	3.66E-01	1.84E-01	1.40E-01
% Ch. in Loss-of-Life				
Annualized Failure Probability				
East Levee	0%	-55.2%	-64.0%	-73.5%
West Levee	0%	-22.3%	-64.0%	-73.5%
Annualized Life Loss				
East Levee	0%	-52.0%	-66.8%	-76.4%
West Levee	0%	-18.9%	-59.2%	-69.0%
Annualized Failure Probability	**Revised BCRA**	**260K Armoring + AT&SF Bridge**	**277K Armoring + AT&SF Bridge**	**302K Armoring + AT&SF Bridge**
East Levee	5.42E-04	2.43E-04	2.42E-04	7.22E-05
West Levee	5.42E-04	4.22E-04	2.45E-04	8.22E-05
Annualized Life Loss				
East Levee	1.37E-01	7.27E-02	7.26E-02	2.16E-02
West Levee	4.51E-01	3.66E-01	2.29E-01	7.68E-02
% Ch. in Loss-of-Life				
Annualized Failure Probability				
East Levee	0.0%	-55.2%	-55.3%	-86.7%
West Levee	0.0%	-22.2%	-54.8%	-84.8%
Annualized Life Loss				
East Levee	0.0%	-46.9%	-47.0%	-84.2%
West Levee	0.0%	-18.9%	-49.2%	-83.0%

Annualized Failure Probability	**Revised BCRA**	**Cut-Off Walls**
East Levee	5.19E-06	3.66E-07
Annualized Life Loss		
East Levee	1.33E-03	9.12E-05
% Ch. in Loss-of-Life		
Annualized Failure Probability		
East Levee	0.0%	-92.9%
Annualized Life Loss		
East Levee	0.0%	-93.2%

1.10 RISK AND UNCERTAINTY ASSESSMENT

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

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

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

Uncertainty in the hydrology and hydraulics is addressed primarily by utilizing graphical exceedance probability functions which sets confidence limits for discharges at each discrete exceedance probability based on the equivalent record length. Uncertainty for hydrology and hydraulics is also addressed by assigning distributions to stage-damage functions. In the case of this study, the equivalent record length is set at 30 years and the error for the stage-damage functions is set at 0.5 feet. No fragility curves are assigned to the proposed levee since flooding durations are short and it would be overtopped regardless for those rare events. Instead, breaching as a result of overtopping is manifested through the use of exterior-interior relationships based on expert elicitation including extrapolation of data from the WinDam program developed for dam breach analysis. Economic uncertainties are similarly managed with normal distributions with standard errors assigned to the depth-damage functions and by defining uncertainty parameters for first floor corrections, structure and content values. Uncertainties are further handled by changing, if necessary, the number of Monte Carlo simulations and by varying the range of ordinates in the aggregated stage-damage functions. Uncertainties in the breach analysis are accounted for prior to incorporating the exterior-interior relationships into HEC-FDA.

HEC-FDA produces project performance reports to display the hydrologic and hydraulic performance of a particular plan. Table E-22 shows the project performance for the proposed levee raise. For the future without-project condition, the expected AEP for the East levee is 0.08 percent (1,250-year event). The West levee has an expected AEP of 0.06 percent (1,667-year event). Raising the levee reduces the recurrence interval to approximately an expected AEP of 0.04 percent on both the East and West levees to the 2,500-year event. Long-term performance shows that raising the East levee would have an approximately 0.4 percent chance of being exceeded in 10 years, a 1.3 percent chance of being exceeded in 30 years, and 2.1 percent chance of being exceeded in 50 years. The West levee would have virtually the same long-term performance with only a slightly higher chance of being exceeded over 50 years. The project performance report also shows that raising the East levee would have a 100 percent chance of containing the 10-year, 25-year, and 50-year events, a 97 percent chance of containing the 100-year event, 96 percent for the 250-year event, and an 87 percent for the 500-year event. The West levee also shows virtually the same project performance.

Table E-22. Risk Performance of Proposed Levee

Without Project

		Long-Term Risk (years)			Assurance by Event					
Damage Reach	**Expected AEP**	**10**	**30**	**50**	**10%**	**4%**	**2%**	**1%**	**0.40%**	**0.20%**
East	0.1%	0.8%	2.3%	3.8%	100.0%	100.0%	99.9%	99.0%	92.1%	78.8%
West	0.1%	0.6%	1.8%	3.0%	100.0%	100.0%	99.94%	99.3%	93.8%	82.3%

With Project

		Long-Term Risk (years)			Assurance by Event					
Damage Reach	**Expected AEP**	**10**	**30**	**50**	**10%**	**4%**	**2%**	**1%**	**0.40%**	**0.20%**
East	0.04%	0.4%	1.3%	2.1%	100.0%	100.0%	100.0%	99.6%	95.8%	87.1%
West	0.04%	0.4%	1.3%	2.2%	100.0%	100.0%	99.97%	99.6%	95.8%	86.9%

Percent Change		Long-Term Risk (years)			Assurance by Event					
Damage Reach	**Expected AEP**	**10**	**30**	**50**	**10%**	**4%**	**2%**	**1%**	**0.40%**	**0.20%**
East	-50.0%	-44.9%	-44.6%	-44.5%	0.0%	0.0%	0.1%	0.5%	4.1%	10.6%
West	-33.3%	-29.0%	-28.3%	-28.0%	0.0%	0.0%	0.03%	0.3%	2.1%	5.6%

1.11 SECTION 902 OF THE WATER RESOURCES DEVELOPMENT ACT (WRDA) OF 1986

Section 902 of the WRDA of 1986, as amended, legislates a maximum total project cost. Projects to which this limitation applies and for which increases in costs exceed the limitations established by Section 902, as amended, will require further authorization by Congress raising the maximum cost established for the project. No funds may be obligated or expended nor any credit afforded that would result in the maximum cost being exceeded, unless the House and Senate committees on Appropriations have been notified that Section 106 of the Energy and Water Development Appropriations Act of 1997 will be utilized. The maximum project cost allowed by Section 902 includes the authorized cost (adjusted for inflation), the current cost of any studies, modifications, and actions authorized by the WRDA of 1986 or any later law, and 20 percent of the authorized cost (without adjustment for inflation).

The following table outlines the pertinent figures for calculating the Section 902 limit. The authorized project cost in the original WRDA 2007 authorization is $459 million; all of which was authorized for construction only. This figure inflated to current dollars is $521.170 million. The current cost estimate for the project is $560.838 million and $673.066 million inflated through construction. The authorized cost of the project inflated through construction is $625.460 million. Twenty percent of the original authorized cost of the project is $91.8 million. This added to the authorized cost inflated through construction provides a maximum cost limited by Section 902 of $717.260 million. The project is therefore under the Section 902 limit by $44.194 million.

Table E-22. Section 902, WRDA 1986 Limit

Total Authorized Cost:	**$459,000**
Authorized Cost for Construction	$459,000
Authorized Cost for Real Estate	$0
Date of Authorized Price Level	10/1/2007
First Year of Expenditure	10/1/2015
Authorized cost at current price levels	$521,170
Current Cost Estimate (At Current price level)	$560,838
Current Cost Estimate (At Current price level inflated through Construction)	$673,066
Ratio between Current Project Estimate and Current Fully Funded Estimate	1.2001
Authorized cost, inflated through construction	$625,460
Cost of modifications required by law	$0
20 percent of authorized cost	$91,800
Maximum cost limited by section 902	$717,260
Over (Under)	($44,194)