Mississippi River Valley Division
Regional Planning and Environmental Division South

Amite River and Tributaries - East of the Mississippi River, Louisiana

Appendix F - Economic and Social Consideration
November 2019

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1.1 INTRODUCTION

1.1.1 General

This appendix presents an economic evaluation of the flood risk management alternatives for the Amite River and Tributaries (ART) Study East of the Mississippi River, Louisiana. It was prepared in accordance with Engineering Regulation (ER) 1105-2-100, Planning Guidance Notebook, and ER 1105-2-101, Planning Guidance, Risk Analysis for Flood Damage Reduction Studies. The National Economic Development Procedures Manual for Flood Risk Management and Coastal Storm Risk Management, prepared by the Water Resources Support Center, Institute for Water Resources, was also used as a reference, along with the User's Manual for the Hydrologic Engineering Center Flood Damage Analysis Model (HEC-FDA).

This appendix consists of a description of the methodology used to determine National Economic Development (NED) damages and benefits under existing conditions and the project's costs. The damages and costs were calculated using Fiscal Year (FY) 2019 price levels. Costs were annualized using the FY 2020 Federal discount rate of 2.75 percent and a period of analysis of 50 years with the year 2026 as the base year. The expected annual damage and benefit estimates were compared to the annual construction costs and the associated Operations, Maintenance, Relocations, Rehabilitation, and Repair (OMRR&R) costs for each of the project alternatives.

1.1.2 NED Benefit Categories Considered

The NED procedure manuals for coastal and urban areas recognize four primary categories of benefits for flood risk management measures: inundation reduction, intensification, location, and employment benefits. The majority of the benefits attributable to a project alternative generally result from the reduction of actual or potential damages caused by inundation. Inundation reduction includes the reduction of physical damages to structures, contents, and vehicles and indirect losses to the national economy.

Physical Flood Damage Reduction. Physical flood damage reduction benefits include the decrease in potential damages to residential and commercial structures, their contents, and the privately owned vehicles associated with these structures.

Emergency Cost Reduction Benefits. Emergency costs are those costs incurred by a community during and immediately following a major storm. The cost of debris removal from inundated residential and non-residential structures was the only emergency cost reduction benefit considered for this analysis.

1.2 DESCRIPTION OF THE STUDY AREA

1.2.1 Geographic Location

The ART study area includes the Amite River Basin in addition to an influence area directly south of the basin, which extends to the Mississippi River. The area includes portions of four Mississippi counties: Amite, Lincoln, Franklin, and Wilkinson in the upper portion of the basin; and portions of eight Louisiana parishes: East Feliciana, St. Helena, East Baton Rouge, Livingston, Iberville, St. James, St. John the Baptist, and Ascension in the mid- to lower-basin. An inventory of residential and non-residential structures was developed for the portions of these counties and parishes within the HEC-RAS modeled area. Figure F:1-1 shows the structure inventory and the boundaries of the counties/parishes along with the study area boundary.

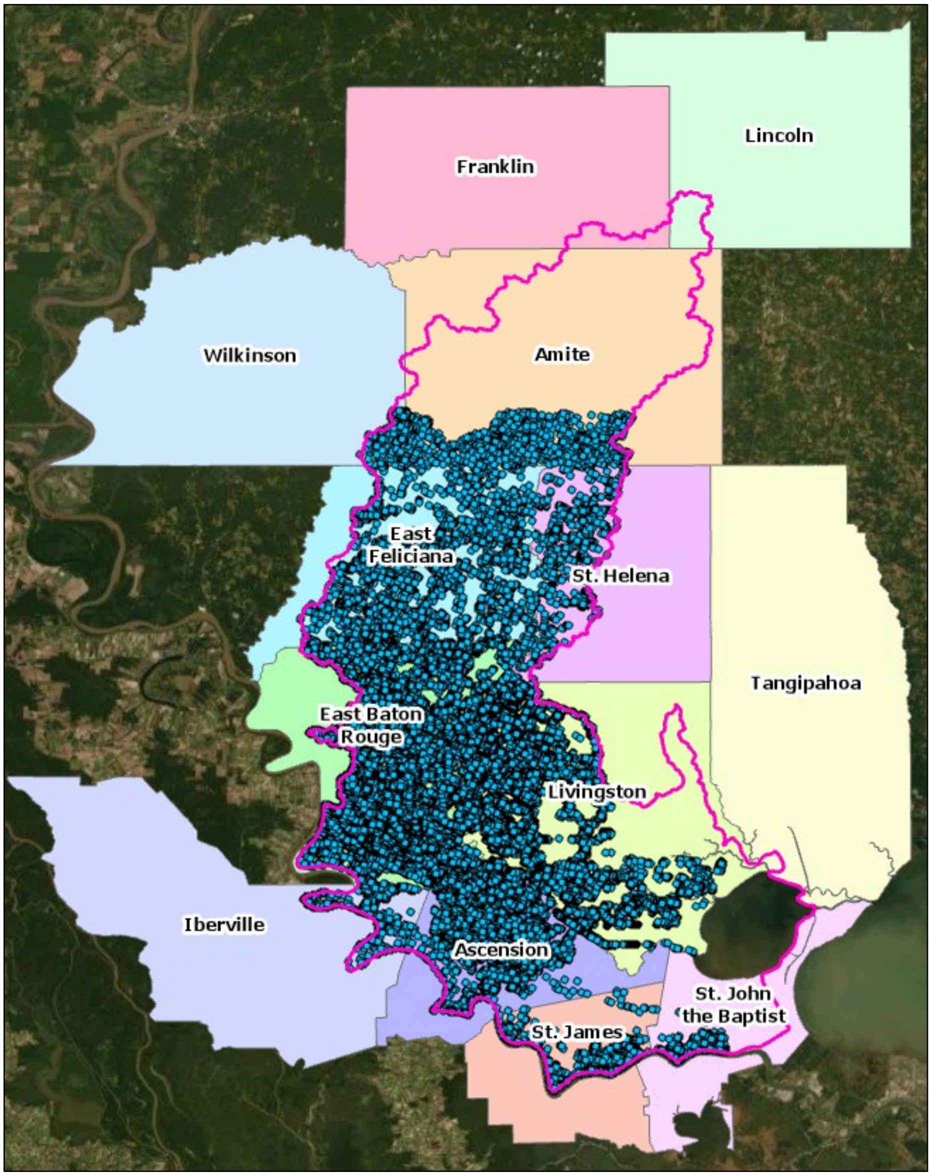

Figure F:1-1. Parish/County Boundaries, Structure Inventory, and Study Area Boundary

The portion of the study area included in the hydraulic model was divided into 106 reaches with each of the structure points functioning as a station. These settings were used to calculate flood damages using version 1.4.2 of the HEC-FDA certified model. Figure F:1-2 shows the study area reach boundaries for the ART study area.

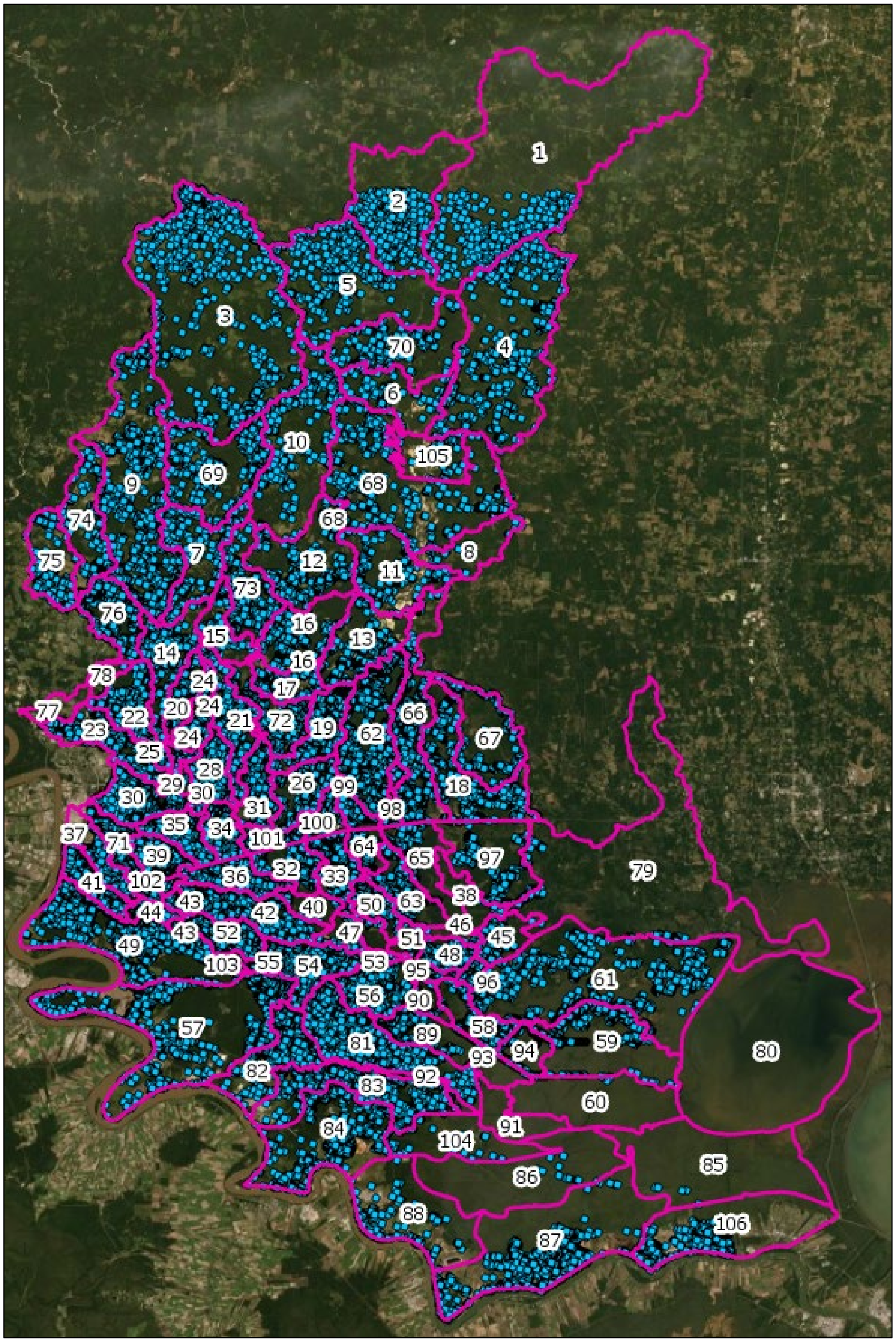

Figure F:1-2. Study Area Reaches with Structure Inventory

1.2.2 Land Use

The total number of acres of developed, agricultural, and undeveloped land in the study area is shown in Table F:1-1. As shown in the table, undeveloped land makes up the majority of the study area with 13 percent of the total acres categorized as developed land.

Table F:1-1. Land Use in the Study Area

Land Class Name	Acres	Percentage of Total
Developed Land	945,085	13%
Agricultural Land	986,813	14%
Undeveloped Land	5,097,445	73%
Total	7,029,343	100%

Source: USGS National Land Cover Database 2015

1.3 SOCIOECONOMIC SETTING

1.3.1 Population, Number of Households, and Employment

Tables F:1-2, F:1-3, and F:1-4 display the population, number of households, and the employment (number of jobs) for each of the parishes and counties for the years 2000, 2010, and 2017 as well as projections for the years 2025 and 2045. The 2000 and 2010 population, number of households and employment is based on estimates from the 2010 U.S. Census and the projections were developed by Moody's Analytics (ECCA) Forecast, which has projections to the year 2045.

Table F:1-2 Historical and Projected Population by Parish/County

Parish/County	2000	2010	2017	2025	2045
Ascension	76,627	107,215	122,948	136,988	161,973
East Baton Rouge	412,852	440,171	446,268	441,495	415,720
East Feliciana	21,360	20,267	19,412	18,140	15,910
Iberville	33,320	33,387	33,027	31,166	27,428
Livingston	91,814	128,026	138,228	150,306	166,260
St. Helena	10,525	11,203	10,363	9,681	8,592
St. James	21,201	22,006	21,790	22,599	23,727
St. John the Baptist	43,248	45,621	44,078	45,713	47,995
Amite	13,599	13,131	12,447	11,992	11,680
Franklin	8,448	8,118	7,765	7,517	7,476
Lincoln	33,166	34,869	34,347	35,400	36,479
Wilkinson	10,312	9,878	8,804	8,335	7,823
Total	776,472	873,893	899,477	919,332	931,063

Sources: 2000, 2010, 2017 from U.S. Census Bureau; 2025, 2045 from Moody's Analytics (ECCA) Forecast

Table F:1-1. Existing Condition and Projected Households by Parish/County

Parish/County	2000	2010	2017	2025	2045
Ascension	26,995	38,050	44,890	51,815	66,244
East Baton Rouge	156,740	172,440	179,910	184,008	186,082
East Feliciana	6,694	6,996	6,922	6,752	6,411
Iberville	10,697	11,075	11,229	11,137	10,643
Livingston	32,997	46,297	52,184	57,891	69,149
St. Helena	3,890	4,323	4,116	3,995	3,810
St. James	7,002	7,691	7,945	8,561	9,727
St. John the Baptist	14,381	15,875	16,005	17,249	19,602
Amite	5,261	5,349	5,213	5,149	5,252
Franklin	3,205	3,214	3,118	3,138	3,272
Lincoln	12,563	13,313	13,682	14,272	15,446
Wilkinson	3,584	3,452	3,236	3,097	3,065
Total	284,008	328,074	348,450	367,063	398,703

Sources: 2000, 2010 from U.S. Census Bureau; 2017, 2025, 2045 from Moody’s Analytics (ECCA) Forecast

Table F:1-2. Existing Condition and Projected Employment by Parish/County

Parish/County	2000	2010	2017	2025	2045
Ascension	36,431	49,414	59,670	65,803	82,614
East Baton Rouge	197,789	205,112	227,301	222,833	222,810
East Feliciana	7,811	7,427	7,866	7,321	6,820
Iberville	11,745	12,622	13,661	12,892	12,054
Livingston	42,326	56,675	66,010	70,000	82,219
St. Helena	3,830	4,097	4,171	3,868	3,649
St. James	8,102	8,949	8,940	9,257	10,448
St. John the Baptist	18,702	19,252	18,794	19,479	21,968
Amite	5,274	4,385	4,206	4,023	4,082
Franklin	3,234	2,866	2,721	2,650	2,747
Lincoln	13,981	12,940	13,614	13,749	14,784
Wilkinson	3,239	2,968	2,610	2,404	2,343
Total	352,463	386,704	429,564	434,280	466,538

Sources: 2000, 2010 from U.S. Bureau of Labor Statistics; 2017, 2025, 2045 from Moody’s Analytics (ECCA) Forecast

1.3.2 Income

Table F:1-5 shows the per capita personal income levels for the twelve parishes and counties for the years 2000, 2010, 2017, and 2025, with projections provided by Moody’s Analytics Forecast.

Table F:1-5. Per Capita Income ($) by Parish/County

Parish/County	2000	2010	2017	2025
Ascension	24,052	39,416	47,628	60,180
East Baton Rouge	27,228	39,651	48,120	60,048
East Feliciana	20,049	33,122	39,908	53,331
Iberville	18,681	32,342	38,960	50,288
Livingston	21,521	32,621	39,883	51,341
St. Helena	16,821	34,136	41,273	55,046
St. James	18,722	38,421	45,219	60,576
St. John the Baptist	20,002	33,894	41,505	57,423
Amite	17,923	25,620	32,225	41,711
Franklin	15,844	27,175	33,133	42,441
Lincoln	20,257	30,468	36,895	44,607
Wilkinson	14,667	24,322	28,745	37,916

Sources: 2000, 2010 from U.S. Census Bureau; 2017, 2025 from Moody's Analytics (ECCA) Forecast

1.3.3 Compliance with Policy Guidance Letter (PGL) 25 and Executive Order 11988

Given continued growth in employment and income, it is expected that development will continue to occur in the study area with or without the storm surge risk reduction system, and will not conflict with PGL 25 and EO 11988, which state that the primary objective of a flood risk reduction project is to protect existing development, rather than to make undeveloped land available for more valuable uses. However, the overall growth rate is anticipated to be the same with or without the project in place. Thus, the project would not induce development, but would rather reduce the risk of the population being displaced after a major storm event.

1.4 RECENT FLOOD HISTORY

1.4.1 Flood Events

The study area has experienced riverine flooding from excessive rainfall events in addition to incurring flood damages associated with hurricanes and tropical storms. Since 1851, the paths of 51 tropical events have crossed the study area. The paths and intensities of these storms are shown in Figure F:1-3.

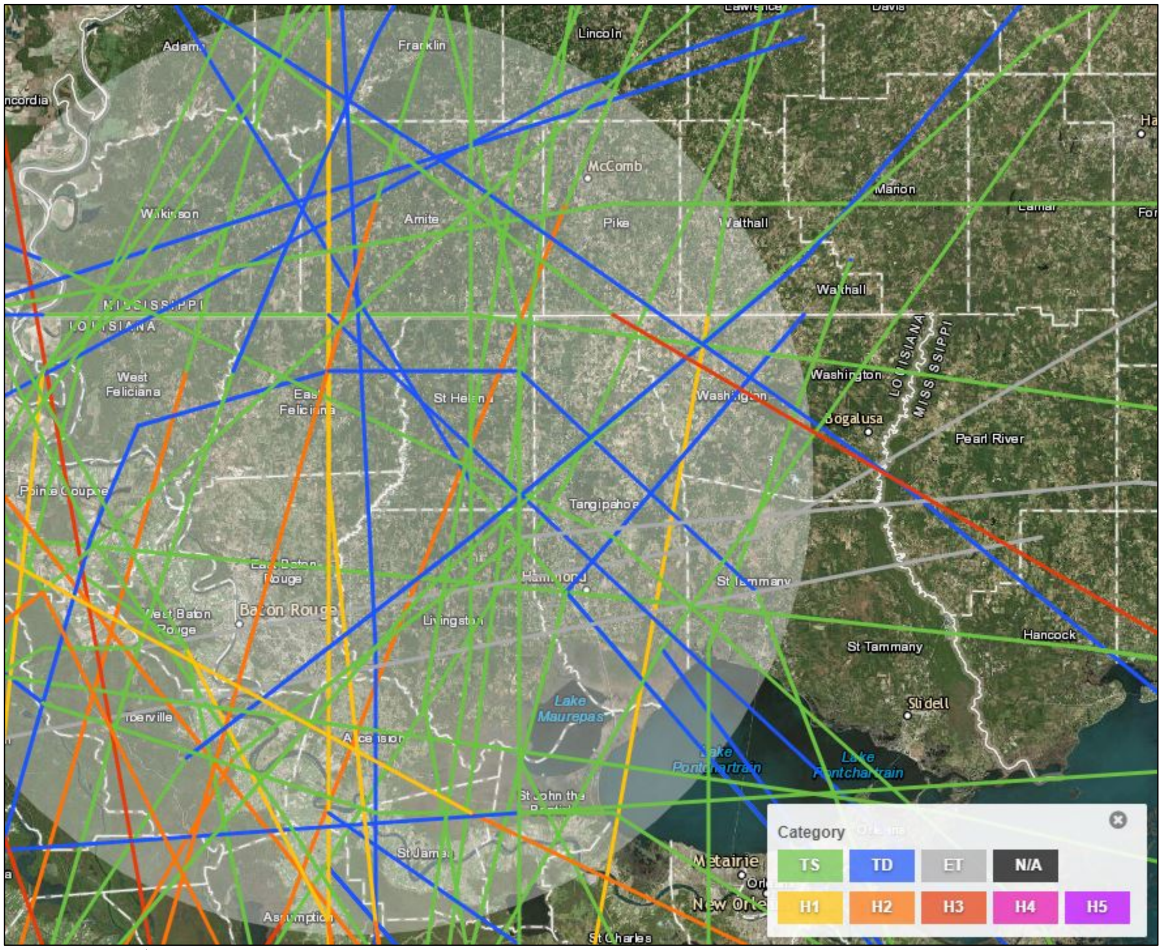

Figure F:1-3. Hurricane and Tropical Storm Paths Since 1851

1.4.2 FEMA Flood Claims

The most recent event to affect the study area was the 2016 Louisiana Floods. This event brought catastrophic flooding damage to Baton Rouge and the surrounding areas with both localized flooding and riverine flooding from the Amite and Comite Rivers and their tributaries. The FEMA flood claims for the most recent events to impact the area are shown in Table F:1-6.

Table F:1-7 shows the FEMA flood claims paid between January 1978 and September 2018 for all counties and parishes in the study area. The table includes the number of claims, number of paid losses, and the total amount paid in the dollar value at the time of the payment. The table excludes losses that were not covered by flood insurance.

Table F:1-6. Top Tropical Storms by Amount Paid by FEMA

Event	Month & Year	Number of Paid Claims	Total Amount Paid (millions)
2016 Louisiana Floods	August 2016	26,909	$2,455.7
Tropical Storm Lee	September 2011	9,900	$462.2
Hurricane Ike	September 2008	46,684	$2,700.1
Hurricane Gustav	September 2008	4,545	$112.6
Hurricane Rita	September 2005	9,354	$466.2
Hurricane Andrew	August 1992	5,587	$169.1

Source: Federal Emergency Management Agency (FEMA)

Note 1: Total amount paid is at price level at time of the event.
Note 2: Claims and amount paid are for entire event, which may include areas outside of the study area.

Table F:1-7. FEMA Flood Claims by Parish/County (January 1978-September 2018)

Parish/County	Total Number of Claims	Number of Paid Claims	Total Payments (millions)
Ascension	6,606	5,658	$336.8
East Baton Rouge	19,926	17,139	$1,170.6
East Feliciana	83	72	$2.8
Iberville	540	453	$7.8
Livingston	14,394	12,684	$813.9
St. Helena	51	38	$2.3
St. James	249	204	$6.2
St. John the Baptist	4,942	3,996	$264.2
Amite	4	4	$0.0
Franklin	3	1	$0.0
Lincoln	23	16	$0.1
Wilkinson	1,883	1,603	$21.0
Total	48,704	41,868	$2,625.8

Source: Federal Emergency Management Agency (FEMA)

Section 2

Economic and Engineering Inputs to the HED-FDA Model

2.1 HEC-FDA MODEL

2.1.1 Model Overview

The Hydrologic Engineering Center Flood Damage Analysis (HEC-FDA) Version 1.4.2 Corps-certified model was used to calculate the damages and benefits for the Amite River and Tributaries FRM evaluation. The economic and engineering inputs necessary for the model to calculate damages for the project base year (2026) include the existing condition structure inventory, contents-to-structure value ratios, vehicle inventory, foundation heights, ground elevations, depth-damage relationships, and without-project and with-project stage-probability relationships.

The uncertainty surrounding each of the economic and engineering variables was also entered into the model. Either a normal probability distribution (with a mean value and a standard deviation) or a triangular probability distribution (with a most likely maximum, and minimum value) was entered into the model to quantify the uncertainty associated with the key economic variables. A normal probability distribution was entered into the model to quantify the uncertainty surrounding the first floor elevations. While normal distributions were preferred to represent the uncertainty in the economic variables, triangular distributions were utilized in select variables where not enough observations were known to fully develop a normal distribution. Instead of modeling without uncertainty, the economics team decided to use a triangular distribution to represent known variations in the data. The number of years that stages were recorded at a given gauge was entered for each study area reach to quantify the hydrologic uncertainty or error surrounding the stage-probability relationships.

2.2 ECONOMIC INPUTS TO THE HEC-FDA MODEL

2.2.1 Structure Inventory

A structure inventory of residential and non-residential structures within East Baton Rouge Parish was created from parcel data. After the parcels were converted to centroid points, the following modifications were made:

- Structures located within the parish, but outside of the study area boundary, were removed from the structure inventory database;
- Ground elevations were assigned based on LiDAR data used in the hydraulic model, and foundation heights were assigned based on Google Earth Street View and sampling techniques;
- Parcel resource types were assigned a corresponding occupancy from the 2019 RSMeans Square Foot Catalog;

- Total depreciated structure values were calculated based on the 2019 RSMeans Square Foot Catalog;
- Depth-damage functions were assigned to structure categories and structure occupancies;
- Stations (smaller geographic areas within a reach having consistent water surface profiles) and study area reaches (larger geographic area, containing stations, used to report damage results) were assigned to individual structures using GIS tools.

A structure inventory of residential and non-residential structures for the remainder of the study outside of East Baton Rouge Parish was obtained through the second version of the National Structure Inventory (NSI). After collection, the following modifications were made:

- Ground elevations were assigned based on the LiDAR data used in the hydraulic model, and foundation heights were assigned based on Google Earth Street View and sampling techniques;
- NSI occupancy types were assigned a corresponding occupancy from the 2019 RSMeans Square Foot Catalog;
- Total depreciated structure values were calculated based on the 2019 RSMeans Square Foot Catalog;
- Depth-damage functions were assigned to structure categories and structure occupancies;
- Stations (smaller geographic areas within a reach having consistent water surface profiles) and study area reaches (larger geographic area, containing stations, used to report damage results) were assigned to individual structures using GIS tools.

Table F:2-1 shows the total number of residential, mobile homes, commercial, industrial, and vehicles associated with residential units by study area reach.

Table F:2-1. Number of Structures in the Existing Condition by Category

Reach Name	Residential	Commercial	Industrial	Total Structures
1	317	1	1	319
2	356	4	1	361
3	2,241	127	25	2,393
4	731	17	6	754
5	373	6	4	383
6	153	8	0	161
7	634	13	12	659
8	34	0	0	34
9	2,295	94	35	2,424
10	573	16	10	599
11	387	5	30	422
12	731	5	5	741
13	916	26	19	961
14	2,025	86	47	2,158
15	383	4	6	393
16	957	9	13	979
17	743	14	3	760
18	1,886	157	47	2,090
19	4,186	126	55	4,367
20	958	8	4	970
21	4,157	62	8	4,227
22	4,770	181	64	5,015
23	4,941	288	193	5,422
24	1,624	18	8	1,650
25	657	13	16	686
26	4,580	296	79	4,955
27	1,045	18	1	1,064
28	3,986	160	29	4,175
29	195	6	9	210
30	12,900	1,026	248	14,174
31	3,359	41	18	3,418
32	1,947	154	92	2,193

Table F:2-1. Number of Structures in the Existing Condition by Category

Reach Name	Residential	Commercial	Industrial	Total Structures
33	2,756	121	50	2,927
34	7,243	488	240	7,971
35	6,354	1,200	451	8,005
36	7,527	804	217	8,548
37	7,234	762	151	8,147
38	58	3	2	63
39	6,506	1,057	182	7,745
40	485	14	7	506
41	7,953	1,025	75	9,053
42	10,110	1,164	547	11,821
43	1,086	127	61	1,274
44	2,478	194	54	2,726
45	364	2	0	366
46	73	3	0	76
47	418	2	11	431
48	643	21	9	673
49	13,977	1,642	323	15,942
50	1,082	25	4	1,111
51	511	15	14	540
52	4,526	607	215	5,348
53	276	6	6	288
54	5,524	347	151	6,022
55	528	69	20	617
56	3,911	104	39	4,054
57	4,336	290	150	4,776
58	1,149	42	16	1,207
59	1,864	8	3	1,875
60	32	0	0	32
61	1,777	27	19	1,823
62	4,859	112	62	5,033
63	2,476	39	22	2,537

Table F:2-1. Number of Structures in the Existing Condition by Category

Reach Name	Residential	Commercial	Industrial	Total Structures
64	1,572	18	12	1,602
65	1,080	30	15	1,125
66	3,258	268	68	3,594
67	476	8	6	490
68	610	14	10	634
69	740	69	17	826
70	210	1	1	212
71	9,081	1,311	218	10,610
72	2,690	93	30	2,813
73	948	10	12	970
74	359	23	5	387
75	432	10	2	444
76	2,447	94	25	2,566
77	29	1	0	30
78	40	0	0	40
79	242	2	1	245
81	9,155	493	217	9,865
82	5,389	264	165	5,818
83	4,863	454	132	5,449
84	3,075	331	143	3,549
85	0	0	0	0
86	16	0	0	16
87	3,964	273	80	4,317
88	319	35	19	373
89	1,203	41	29	1,273
90	178	10	0	188
92	525	32	8	565
93	20	2	1	23
94	575	24	6	605
95	574	17	2	593
96	205	3	0	208
97	811	37	17	865

Table F:2-1. Number of Structures in the Existing Condition by Category

Reach Name	Residential	Commercial	Industrial	Total Structures
98	1,221	55	13	1,289
99	1,064	97	38	1,199
100	2,248	268	74	2,590
101	3,056	395	106	3,557
102	1,238	108	11	1,357
103	532	23	17	572
104	39	11	6	56
105	94	0	0	94
106	2,255	189	83	2,527
Total	239,989	18,423	5,778	264,190

Structure Values. The 2019 RSMeans Square Foot Costs Data catalog (RSMeans catalog) was used to assign a depreciated replacement cost to the residential and non-residential structures in the study area reaches. Residential replacement costs per square foot were provided for four exterior walls types (wood siding on wood frame, brick veneer on wood frame, stucco on wood frame, and solid masonry) and three sizes (1-story, 2-story, and split-level) for homes constructed with average quality materials. An average replacement cost per square foot for the four exterior wall types was calculated for each size. Based on windshield surveys, it was determined that the majority of the structures in the study area were in average condition, with an approximate age of 20 years. The associated depreciation proportion was used to calculate a most-likely depreciated square foot cost. An additional regional adjustment factor (85 percent of the national square foot costs) for the Baton Rouge area was then applied to the depreciated cost per square foot. The square footage for each of the individual residential structures was multiplied by the most-likely depreciated cost per square for the average construction class to obtain a total depreciated cost. Finally, the Marshall and Swift Valuation Service was used to calculate a depreciated replacement cost per square foot for the manufactured or mobile homes in the study area.

Non-residential replacement costs per square foot were provided in the RSMeans catalog for six exterior wall types, which were specific to each occupancy type. An average replacement cost per square foot was calculated for each of the six exterior wall types in each non-residential occupancy. The RSMeans catalog depreciation schedule for non-residential structures provides depreciation percentages for three building materials: frame, masonry on wood, and masonry on masonry or steel. Based on windshield surveys, it was determined that the majority of the structures in the study area were built with masonry on wood, with an observed age of 20 years. The associated depreciation proportion was used to calculate a most-likely depreciated square foot cost. An additional regional adjustment factor (85 percent of the national square foot costs) for the Baton Rouge area was then applied to the depreciated cost per square foot. The square footage for each of the individual structures was multiplied by the most-likely depreciated cost per square foot for each non-residential occupancy to obtain a total depreciated cost.

Table F:2-2 shows the average depreciated replacement cost for residential and non-residential structure categories.

Table F:2-2. Residential and Non-Residential Structure Inventory (FY19, $1,000s)

Category	Occupancy Type	Number	Average Depreciated Replacement Value
Residential	1-Story Slab	115,320	$192.5
	1-Story Pier	60,859	$190.8
	2-Story Slab	31,552	$212.4
	2-Story Pier	16,241	$219.2
	Mobile Home	16,017	$26.9
	Total Residential	**239,989**	
Non-Residential	Eating and Recreation	2,076	$1,275.4
	Professional	5,128	$827.7
	Public and Semi-Public	1,901	$1,133.8
	Repair and Home Use	2,112	$731.1
	Retail and Personal Services	4,487	$845.6
	Warehouse	5,647	$729.4
	Multi-Family Occupancy	2,463	$920.3
	Total Non-Residential	**23,814**	
Autos	Vehicles	238,161	$10.1

Structure Value Uncertainty. A triangular probability distribution based on the depreciated replacement costs was used to represent the uncertainty surrounding the residential structure values in each occupancy category. The most-likely depreciated value for residential structures was based a 20 percent depreciation rate (consistent with an estimated age of a 20-year old structure in average condition), the minimum value was based on a 45 percent depreciation rate (consistent with an estimated age of a 30-year old structure in poor condition), and the maximum value was based on a 7 percent depreciation rate (consistent with an estimated age of a 10-year old structure in good condition). These values were then converted to a percentage of the most-likely value with the most-likely value equal to 100 percent of the average value for each occupancy category. The triangular probability distributions were entered into the HEC-FDA model to represent the uncertainty surrounding the structure values in each residential occupancy category.

A triangular probability distribution based on the depreciated replacement costs was used to represent the uncertainty surrounding the non-residential structure values in each occupancy category. The most-likely depreciated value for non-residential structures was based a 25 percent depreciation rate (consistent with an observed age of a 20-year old masonry on wood structure), the minimum value was based on a 40 percent depreciation rate (consistent with an observed age of a 30-year old frame structure), and the maximum value was based on an 8 percent depreciation rate (consistent with an observed age of a 10-year old masonry on masonry or steel structure). These values were then converted to a percentage of the most-likely value with the most-likely value equal to 100 percent of the average value for each occupancy category. The triangular probability distributions were entered into the HEC-FDA model to represent the uncertainty surrounding the structure values in each non-residential occupancy category.

Table F:2-3 shows the minimum and maximum percentages of the most-likely structure values assigned to the various structure categories.

Table F:2-3. Structure Value Uncertainty Parameters

Category	Occupancy Type	Structure Value Error	
		Lower (%)	Upper (%)
Residential	1-Story Slab	69	116
	1-Story Pier	69	116
	2-Story Slab	69	116
	2-Story Pier	69	116
	Mobile Home	48	147
Non-Residential	Eating and Recreation	80	123
	Professional	80	123
	Public and Semi-Public	80	123
	Repair and Home Use	80	123
	Retail and Personal Services	80	123
	Warehouse	80	123
	Multi-Family Occupancy	80	123

2.2.2 Residential and Non-Residential Content-to-Structure Value Ratios

The content-to-structure value ratios (CSVRs) applied to the residential and non-residential structure occupancies were taken from an extensive survey of owners in coastal Louisiana for three large CSRM evaluations. These interviews included a sampling from residential and non-residential content categories from each of the three evaluation areas.

Since only a limited number of property owners participated in the field surveys and the participants were not randomly selected, statistical bootstrapping was performed to address the potential sampling error in estimating the mean and standard deviation of the CSVR values. Statistical bootstrapping uses re-sampling with replacement to improve the estimate of a population statistic when the sample size is insufficient for straightforward statistical inference. The bootstrapping method has the effect of increasing the sample size and accounts for distortions caused by a specific sample that may not be fully representative of the population.

2.2.3 Content-to-Structure Value Ratio Uncertainty

For each of the residential and non-residential occupancies, a mean CSVR and a standard deviation was calculated and entered into the HEC-FDA model. A normal probability density function was used to describe the uncertainty surrounding the CSVR for each content category. The expected CSVR percentage values and standard deviations for each of the residential and non-residential occupancies are shown in Table F:2-4.

Table F:2-4. Content-to-Structure Value Ratios (CSVRs) and Standard Deviations (SDs) by Occupancy

Category	Occupancy Type	CSVR (%)	SD (%)
Residential	1-Story Slab	69	37
	1-Story Pier	69	37
	Two-Story Slab	67	35
	Two-Story Pier	67	35
	Mobile Home	114	79
Non-Residential	Eating and Recreation	170	293
	Professional	54	54
	Public and Semi-Public	55	80
	Repair and Home Use	236	295
	Retail and Personal Services	119	105
	Warehouse	207	325
	Multi-Family Occupancy	28	17

2.2.4 Vehicle Inventory and Values

Based on 2017 Census estimates for the state of Louisiana, there are an average of 1.67 vehicles associated with each household (owner occupied housing or rental unit). According to the Southeast Louisiana Evacuation Behavioral Report published in 2006 following Hurricanes Katrina and Rita, approximately 70 percent of privately owned vehicles are used for evacuation during storm events. The remaining 30 percent of the privately owned vehicles remain parked at the residences and are subject to flood damages. According to the Edmunds Used Vehicle Report, the average value of a used car was $20,250 as of the first quarter 2019. Because only those vehicles not used for evacuation can be included in the damage calculations, an adjusted average vehicle value of $10,150 ($20,250 x 1.67 x 0.30) was assigned to each individual residential automobile structure record in the HEC-FDA model. If an individual structure contained more than one housing unit, then the adjusted vehicle value was assigned to each housing unit in a residential or multi-family structure category. Only vehicles associated with residential structures were included in the analysis. Finally, every apartment building was assumed to contain 25 units so every apartment building has $253,750 as the average value for vehicles.

2.2.5 Vehicle Value Uncertainty

The uncertainty surrounding the values assigned to the vehicles in the inventory was determined using a triangular probability distribution function. The average value of a used car, $20,250, was used as the most-likely value. The average value of a new vehicle, $36,500, before taxes, license, and shipping charges was used as the maximum value, while the average 10-year depreciation value of a vehicle, $3,000, was used as the minimum value. The percentages were developed for the most-likely, minimum, and the maximum values with the most-likely equal to 100 percent, and the minimum and the maximum values as percentages of the most-likely value (minimum=15 percent, most-likely=100 percent, maximum=180 percent). These percentages were entered into the HEC-FDA model as a triangular probability distribution to represent the uncertainty surrounding the vehicle value.

2.2.6 First Floor Elevations

Topographical data based on Light Detection and Ranging (LiDAR) data using the North American Vertical Datum of 1988 (NAVD 88) were used to assign ground elevations to structures and vehicles in the study area. The assignment of ground elevations and the placement of structures were based on a digital elevation model (DEM) with a 2-foot by 2-foot grid resolution developed by the United States Geological Survey (USGS), which was resampled at a 40-foot by 40-foot resolution. This ground elevation raster was obtained from the HEC-RAS hydraulic model to avoid continuity errors between the engineering and economic inputs. The ground elevation was added to the height of the foundation of the structure above the ground in order to obtain the first floor elevation of each structure in the study area. Vehicles were assigned to the ground elevation of the adjacent residential structures.

Sampling of Foundation Heights Above Ground. The foundation heights of the residential and non-residential structures above the ground were determined using statistical random sampling procedures. Sampling was necessary due to varying types of structure foundations (slab on grade and pier/pile) and the large variation in the heights of these foundations above the ground elevation. Statistical formulas were used to account for the estimated variation, acceptable error, and level of confidence and to determine a statistically significant number of structures to be surveyed. A focused Agency Technical Review (ATR) was conducted in on this process in April of 2017 to confirm the adequacy of the sampling techniques used to develop the results.

The East Baton Rouge portion of the study area was divided into 58 neighborhoods, which were used to stratify the sample and ensure the entire area was sampled from. A total of 347 residential and non-residential structures were randomly selected for the sample in East Baton Rouge Parish. If a selected structure had been demolished or razed, then an adjacent structure was surveyed in its place. The survey team used Google Earth to collect the required information including the height of the foundation above ground (measured from the bottom of the front door to adjacent ground), the foundation type (slab or pier), and the number of stories (1-story, and 2 or more stories). This information was used to develop the average height above ground of slab on grade and pier/pile foundation structures in each neighborhood, the proportion of slab on grade foundations and pier/pile foundations, and the proportion of 1-story and 2-story structures in each neighborhood.

The mean foundation height and proportions of sampled residential 1-story and 2-story pile foundation structures and residential 1-story and 2-story slab foundation structures were applied to all the unsampled residential structures in each East Baton Rouge neighborhood. The mean foundation height and proportions of the sampled commercial 1-story and 2-story pile foundation structures and commercial 1-story and 2-story slab foundation structures were randomly applied to the unsampled commercial structures in each neighborhood. Since the commercial depth-damage relationships are only provided for commercial 1-story structures, all the commercial structures were treated as 1-story structures.

The remainder of the study area was stratified by the occupancy and foundation types provided in the National Structure Inventory. A total of 357 residential and non-residential structures were randomly selected for the sample outside of East Baton Rouge Parish. If a selected structure had been demolished or razed, then an adjacent structure was surveyed in its place. The survey team used Google Earth to collect the required information including the height of the foundation above ground (measured from the bottom of the front door to adjacent ground) and the foundation type (slab or pier). This information was used to develop the average height above ground of slab on grade and pier/pile foundation structures and the proportion of slab on grade foundations and pier/pile foundations.

The mean foundation height and proportions of sampled residential 1-story and 2-story pile foundation structures and residential 1-story and 2-story slab foundation structures were applied to all the unsampled residential structures outside East Baton Rouge Parish. The mean foundation height and proportions of the sampled commercial 1-story and 2-story pile foundation structures and commercial 1-story and 2-story slab foundation structures were randomly applied to the unsampled commercial structures. Since the commercial depth-damage relationships are only provided for commercial 1-story structures, all the commercial structures were treated as 1-story structures.

2.2.7 Uncertainty Surrounding Elevations

There are two sources of uncertainty surrounding the first floor elevations: the use of the LiDAR data for the ground elevations, and the methodology used to determine the structure foundation heights above ground elevation. The error surrounding the LiDAR data was determined to be plus or minus 0.5895 feet at the 95 percent level of confidence. This uncertainty was normally distributed with a mean of zero and a standard deviation of 0.3 feet.

The uncertainty surrounding the foundation heights for the residential and commercial structures was estimated by calculating the standard deviations surrounding the sampled mean values for the combined inventory. An overall weighted average standard deviation for the four structure groups was computed for each structure category. The standard deviation was calculated to be 0.75 feet for residential pier foundation structures and 0.25 feet for slab foundation structures. The standard deviation for non-residential structures was calculated to be 0.64 feet.

The standard deviations for the ground elevations and foundation heights were combined, which resulted in a 0.81 feet standard deviation for residential pier foundation structures and 0.439 for slab foundation structures. For non-residential structures, the combined standard deviation was calculated to be 0.71 feet. Table F:2-5 displays the calculations used to combine the uncertainty surrounding the ground elevations with uncertainty surrounding the foundation height to derive the uncertainty surrounding the first floor elevations of residential and non-residential structures. Table F:2-6 displays the average foundation heights and standard deviations by occupancy type.

Table F:2-5. First Floor Stage Uncertainty Standard Deviation (SD) Calculation

Ground - LiDAR

(conversion cm to inches to feet)

+/- 18 cm @ 95% confidence		18cm
	x	0.393
z = (x - u)/ std. dev.		7.074in
	÷	12
1.96 = (0.5895 - 0)/ std.dev. 0.3007 = std.dev.		0.5895ft

Foundation Height

(shown in feet)

Residential		Commercial	Industrial
Pier	Slab	All	All
0.75	0.25	0.64	0.64

Combined First Floor

(shown in feet)

Residential		Commercial	Industrial	
Pier	Slab	All	All	
0.30	0.30	0.30	0.30	ground std. dev.
0.09	0.09	0.09	0.09	ground std. dev. Squared
0.75	0.25	0.64	0.64	1st floor std. dev.
0.56	0.06	0.41	0.41	1st floor std. dev. squared
0.65	0.15	0.50	0.50	Sum of Squared
0.81	**0.39**	**0.71**	**0.71**	**Square Root of Sum of Squared = Combined Std. Dev.**

Note 1: Mobile Homes are assigned the same uncertainty as Residential Pier.

Note 2: Autos do not have foundations, so only ground uncertainty is used.

Table F:2-6. Average Foundation Heights and Standard Deviations (SD) by Occupancy Type (feet)

Category	Occupancy Type	Average Foundation Height	Standard Deviations		
			Ground Stage SD	Foundation Height SD	First Floor SD
Residential	1-Story Slab	0.58	0.30	0.25	0.39
	1-Story Pier	1.97	0.30	0.75	0.81
	2-Story Slab	0.63	0.30	0.25	0.39
	2-Story Pier	2.00	0.30	0.75	0.81
	Mobile Home	3.15	0.30	0.75	0.81
Non-Residential	Eating and Recreation	0.65	0.30	0.64	0.71
	Professional	0.63	0.30	0.64	0.71
	Public and Semi-Public	0.65	0.30	0.64	0.71
	Repair and Home Use	0.64	0.30	0.64	0.71
	Retail and Personal Services	0.64	0.30	0.64	0.71
	Warehouse	0.64	0.30	0.64	0.71
	Multi-Family Occupancy	0.62	0.30	0.64	0.71
Autos	Vehicles	0.00	0.30	0.00	0.30

2.2.8 Debris Removal Costs

Debris removal costs are typically discussed in the “Other Benefit Categories” section of the Economic Appendix. However, since debris removal costs were included as part of the HEC-FDA structure records for the individual residential and non-residential structures in the Amite study area, these costs are being treated as an economic input. The HEC-FDA model does not report debris removal costs separately from the total expected annual without-project and with-project damages.

Following Hurricanes Katrina and Rita, interviews were conducted with experts in the fields of debris collection, processing and disposal to estimate the cost of debris removal following a storm event. Information obtained from these interviews was used to assign debris removal costs for each residential and non-residential structure in the structure inventory. The experts provided a minimum, most likely, and maximum estimate for the cleanup costs associated with the 2 feet, 5 feet, and 12 feet depths of flooding. A prototypical structure size in square feet was used for the residential occupancy categories and for the non-residential occupancy categories. The experts were asked to estimate the percentage of the total cleanup caused by floodwater and to exclude any cleanup that was required by high winds.

In order to account for the cost/damage surrounding debris cleanup, values for debris removal were incorporated into the structure inventory for each record according to its occupancy type. These values were then assigned a corresponding depth-damage function with uncertainty in the HEC-FDA model. For all structure occupancy types, 100 percent damage was reached at 12 feet of flooding. All values and depth-damage functions were selected according to the freshwater flooding data specified in a report titled "Development of Depth-Emergency Cost and Infrastructure Damage Relationships for Selected South Louisiana Parishes." The debris clean-up values provided in the report were expressed in 2010 price levels for the New Orleans area. These values were converted to 2019 price levels using the indexes provided by Gordian's 40th edition of "Square Foot Costs with RSMeans Data." The debris removal costs were included as the "other" category on the HEC-FDA structure records for the individual residential and non-residential structures and used to calculate the expected annual without-project and with-project debris removal and cleanup costs.

2.2.9 Debris Removal Costs Uncertainty

The uncertainty surrounding debris percentage values at 2-feet, 5-feet and 12-feet depths of flooding were based on range of values provided by the four experts in the fields of debris collection, processing, and disposal. The questionnaires used in the interview process were designed to elicit information from the experts regarding the cost of each stage of the debris cleanup process by structure occupancy type. The range of responses from the experts were used to calculate a mean value and standard deviation value for the cleanup costs percentages provided at 2-feet, 5-feet, and 12-feet depths of flooding. The mean values and the standard deviation values were entered into the HEC-FDA model as a normal probability distribution to represent the uncertainty surrounding the costs of debris removal for residential and non-residential structures. The depth-damage relationships containing the damage percentages at the various depths of flooding and the corresponding standard deviations representing the uncertainty are shown with in the depth–damage tables.

2.2.10 Depth-Damage Relationships

The depth-damage relationships, developed by a panel of building and construction experts for the Lower Atchafalaya and Morganza to the Gulf, Louisiana feasibility studies, were used in the economic analysis. These relationships were deemed appropriate because the two study areas are geographically close and have similar structure categories and occupancies. Because the ART study area is mainly impacted by riverine and rainfall flooding, the long-duration freshwater (2 to 3 days) depth-damage curves were selected.

Depth-damage relationships indicate the percentage of the total structure and content value that would be damaged at various depths of flooding. For residential structures, damage percentages were provided at each 1-foot increment from 2 feet below the first floor elevation to 16 feet above the first floor elevation for the structural components and the content components. Damage percentages were determined for each 0.5- foot increment from 0.5-foot below first floor elevation to 2 feet above first floor, and for each 1-foot increment from 2 feet to 15 feet above first floor elevation for non-residential structures. Vehicle damage relationships were provided from 0.5-foot above the ground to 3 feet above the ground (which corresponds to a total loss of the vehicle's value).

2.2.11 Uncertainty Surrounding Depth-Damage Relationships

A triangular probability density function was used to determine the uncertainty surrounding the damage percentage associated with each depth of flooding for all occupancy types. A minimum, maximum, and most-likely damage estimate was provided by a panel of experts for each depth of flooding. The specific range of values regarding probability distributions for the depth-damage curves can be found in the final report dated May 1997 entitled *Depth-Damage Relationships for Structures, Contents, and Vehicles and Content-to-Structure Value Ratios (CSVRs) in Support of the Lower Atchafalaya Reevaluation and Morganza to the Gulf, Louisiana Feasibility Studies.* The specific range of values regarding probability distributions for the debris depth-damage curves can be found in the final report dated March 2012 entitled *Development of Depth-Emergency Cost and Infrastructure Damage Relationships for Selected South Louisiana Parishes.*

Tables F:2-6 through F:2-10 show the damage relationships for structures, contents, vehicles, and debris removal. The tables contain the damage percentages at each depth of flooding along with the uncertainty surrounding the damage percentages.

Table F:2-6. Depth-Damage Relationships for Structures, Contents, Vehicles, and Debris Removal

Residential 1-Story Pier 1STY-PIER			
Depth in Structure	**Structure Percent Damage**	**Structure Lower Percent**	**Structure Upper Percent**
-1.1	0	0	0
-1	1.6	0	3.6
-0.5	2.7	0.9	4
0	19.8	3.5	41.9
0.5	47.1	14.8	51.2
1	53.8	44	64.5
1.5	56.1	46.6	65.2
2	58.5	47.3	65.2
3	63.7	52.1	72.2
4	71.2	61.8	75.8
5	75.6	65.1	92.5
6	78.8	67.7	98.2
7	79.3	70.6	98.2
8	83.3	74.7	102.3
9	87.1	74.7	107.9
10	87.4	74.7	107.9
11	87.8	74.7	108.2
12	87.9	74.7	108.2
13	88.2	74.7	109.2
14	88.3	74.7	109.2
15	88.5	74.7	109.2
Depth in Structure	**Content Percent Damage**	**Content Lower Percent**	**Content Upper Percent**
-1	0	0	0
-0.5	0	0	0
0	35	27.5	38.6
0.5	46.8	39.9	51.2

Residential 1-Story Slab 1STY-SLAB			
Depth in Structure	**Structure Percent Damage**	**Structure Lower Percent**	**Structure Upper Percent**
-1.1	0	0	0
-1	0	0	0
-0.5	1	0	6
0	9.8	2.8	41.2
0.5	31.1	14.1	45.5
1	36.7	26.6	45.5
1.5	40.4	28.5	45.5
2	43.1	30	54.6
3	48.2	36	57
4	60.3	52.1	75.9
5	64.7	52.7	75.9
6	67.1	53.6	80.3
7	67.5	56.6	80.3
8	71.9	62.9	89.1
9	78.2	67.2	92.8
10	78.9	67.2	96.2
11	79	67.2	96.2
12	79	67.2	96.2
13	79.5	67.2	96.2
14	79.5	67.2	96.2
15	79.5	67.2	96.2
Depth in Structure	**Content Percent Damage**	**Content Lower Percent**	**Content Upper Percent**
-1	0	0	0
-0.5	0	0	0
0	35	27.5	38.6
0.5	46.8	39.9	51.2

Residential 2-Story Pier 2STY-PIER			
Depth in Structure	**Structure Percent Damage**	**Structure Lower Percent**	**Structure Upper Percent**
-1.1	0	0	0
-1	1.5	0	3.4
-0.5	2.4	0.4	5.6
0	8.7	0.4	30.5
0.5	22.6	10.8	34.3
1	27.5	19.2	34.3
1.5	29.2	21.5	34.6
2	32.9	27.6	43.7
3	34.7	28.6	43.7
4	41.7	31	55.2
5	44.2	35.3	55.9
6	45.2	37.2	58.8
7	45.8	38	58.8
8	47.8	38	61.2
9	60.9	48.3	75.7
10	62.9	53.1	76.9
11	64.3	55.9	80.7
12	65.8	57.1	80.8
13	68.3	57.6	85.6
14	69.6	58.6	91.9
15	70.4	60.7	91.9
Depth in Structure	**Content Percent Damage**	**Content Lower Percent**	**Content Upper Percent**
-1.1	0	0	0
-1	0.1	0	0.2
-0.5	0.7	0	1.5
0	21.3	19.6	22.1

Residential 2-Story Slab 2STY-SLAB			
Depth in Structure	**Structure Percent Damage**	**Structure Lower Percent**	**Structure Upper Percent**
-1.1	0	0	0
-1	0	0	0
-0.5	0	0	0
0	5.6	0	34
0.5	18.5	5.8	38.3
1	24.4	14.1	40.5
1.5	25.2	15.3	40.8
2	28.4	20.8	48.3
3	30.7	22.4	48.3
4	38.6	27.8	65.2
5	40.8	32.2	65.2
6	41.4	33.2	67.3
7	41.7	33.2	67.3
8	44.5	34.3	73
9	54.2	44.8	74.1
10	56.1	49.4	75.2
11	57.1	50.5	75.2
12	58.8	52.9	75.2
13	60.7	55.1	75.2
14	60.7	55.1	75.2
15	60.8	55.1	75.2
Depth in Structure	**Content Percent Damage**	**Content Lower Percent**	**Content Upper Percent**
-1.1	0	0	0
-1	0.1	0	0.2
-0.5	0.7	0	1.5
0	21.3	19.6	22.1

1	48.4	45.2	51.9		1	48.4	45.2	51.9		0.5	24.8	22.9	25.8		0.5	24.8	22.9	25.8
1.5	50.3	48	54.9		1.5	50.3	48	54.9		1	30.7	29.7	36.1		1	30.7	29.7	36.1
2	56.7	53	59.1		2	56.7	53	59.1		1.5	34.6	33.5	35.6		1.5	34.6	33.5	35.6
3	67.5	65.6	69.5		3	67.5	65.6	69.5		2	37.7	36.5	38.8		2	37.7	36.5	38.8
4	76.3	74.1	80.6		4	76.3	74.1	80.6		3	45.6	44.2	46.9		3	45.6	44.2	46.9
5	80.9	78.5	85.4		5	80.9	78.5	85.4		4	50.5	49	53.9		4	50.5	49	53.9
6	88.1	85.5	92.9		6	88.1	85.5	92.9		5	55.7	54	59.5		5	55.7	54	59.5
7	88.4	85.7	93.2		7	88.4	85.7	93.2		6	60.6	58.7	64.7		6	60.6	58.7	64.7
8	89.1	86.4	93.9		8	89.1	86.4	93.9		7	61.6	59.7	65.7		7	61.6	59.7	65.7
9	89.1	86.5	94		9	89.1	86.5	94		8	62.3	60.4	66.4		8	62.3	60.4	66.4
10	89.1	86.5	94		10	89.1	86.5	94		9	68.1	66	72.7		9	68.1	66	72.7
11	89.1	86.5	94		11	89.1	86.5	94		10	68.1	66	72.7		10	68.1	66	72.7
12	89.1	86.5	94		12	89.1	86.5	94		11	72	69.7	76.7		11	72	69.7	76.7
13	89.1	86.5	94		13	89.1	86.5	94		12	74	71.7	78.9		12	74	71.7	78.9
14	89.1	86.5	94		14	89.1	86.5	94		13	75.8	73.4	80.8		13	75.8	73.4	80.8
15	89.1	86.5	94		15	89.1	86.5	94		14	77	74.6	82.1		14	77	74.6	82.1
										15	77.2	74.8	82.3		15	77.2	74.8	82.3
Depth in Structure	**Debris Percent Damage**	**Debris Standard Deviation**			**Depth in Structure**	**Debris Percent Damage**	**Debris Standard Deviatio n**			**Depth in Structure**	**Debris Percent Damage**	**Debris Standard Deviatio n**			**Depth in Structure**	**Debris Percent Damage**	**Debris Standard Deviatio n**	
0	0	0			0	0	0			0	0	0			0	0	0	
2	85	15			2	87	14			2	84	14			2	87	14	
5	92	14			5	94	15			5	91	14			5	94	15	
12	100	15			12	100	15			12	100	15			12	100	15	

Table F:2-7. Depth-Damage Relationships for Structures, Contents, Vehicles, and Debris Removal

Residential Mobile Home MOBILE

Depth in Structure	Structure Percent Damage	Structure Lower Percent	Structure Upper Percent
-1.1	0	0	0
-1	7.3	0	10.8
-0.5	11.2	0	18.9
0	32.2	9.6	54.7
0.5	48.5	39.8	61.6
1	54	49.6	62.2
1.5	56.1	52.8	62.8
2	58.9	55.8	69.7
3	60.3	59.1	71.2
4	64.3	60.7	75.4
5	67.5	61.4	82.2
6	68	61.4	82.2
7	69	61.4	84
8	80	73	95.1
9	81.7	73	95.1
10	82.8	73	95.1
11	82.8	73	95.1
12	82.8	73	95.1
13	82.8	73	95.1
14	82.8	73	95.1
Depth in Structure	**Content Percent Damage**	**Content Lower Percent**	**Content Upper Percent**
-1	0	0	0
-0.5	0	0	0
0	0.1	0	0.1
0.5	15	14.5	15.4
1	30.1	29.1	30.9
1.5	45.6	44.2	46.9
2	58.8	57	62.8
3	69.2	67.1	73.9
4	78.3	75.9	83.6

Commercial Multi-Family Occupancy MULTI

Depth in Structure	Structure Percent Damage	Structure Lower Percent	Structure Upper Percent
-1	0	0	0
-0.5	0	0	0
0	0	0	0
0.5	27.1	7.3	38.3
1	31.6	19.7	45.1
1.5	34	27.2	49.2
2	36.3	28.1	50.7
3	37.8	28.9	51.1
4	44.9	41.2	52.2
5	47.1	46.6	56.9
6	49.3	51.4	56.9
7	51.7	52.4	69.2
8	58.6	60.5	75.4
9	61	65.2	75.4
10	63.5	65.2	75.4
11	63.6	65.2	75.4
12	65.3	65.3	75.4
13	65.3	65.3	75.4
14	65.4	65.3	75.4
15	65.6	65.3	75.4
Depth in Structure	**Content Percent Damage**	**Content Lower Percent**	**Content Upper Percent**
-1	0	0	0
-0.5	0	0	0
0	0	0	0
0.5	10	3.7	13.2
1	30	21.2	32.3
1.5	30	26.5	32.7
2	30	28	34.2
3	30	28.7	35.1
4	60	58.1	61.7

Commercial Professional PROF

Depth in Structure	Structure Percent Damage	Structure Lower Percent	Structure Upper Percent
-1	0	0	0
-0.5	0.5	0	1.5
0	0.5	0	1.5
0.5	13.1	3.8	20
1	16.7	11.9	21.2
1.5	19.3	13.9	29.8
2	21.1	14.4	31.4
3	23.4	16.5	33
4	27.5	20.7	36.4
5	28	21.1	37.3
6	30	21.1	47
7	31.6	21.1	52.5
8	39.2	26.8	58.5
9	46.1	32.1	65.1
10	46.8	39.6	65.1
11	51	39.7	65.6
12	53.6	41.3	66.7
13	54	41.6	66.7
14	55.3	42.9	67.8
15	55.4	42.9	67.8
Depth in Structure	**Content Percent Damage**	**Content Lower Percent**	**Content Upper Percent**
-1	0	0	0
-0.5	0	0	0
0	0	0	0
0.5	10.5	9.5	12.7
1	14.6	13.2	17.5
1.5	19.2	17.3	23
2	23.2	20.9	27.8
3	67.6	61	81.2
4	86.9	78.3	100

Commercial Public and Semi-Public PUBLIC

Depth in Structure	Structure Percent Damage	Structure Lower Percent	Structure Upper Percent
-1	0	0	0
-0.5	0.5	0	1.5
0	0.5	0	1.5
0.5	13.1	3.8	20
1	16.7	11.9	21.2
1.5	19.3	13.9	29.8
2	21.1	14.4	31.4
3	23.4	16.5	33
4	27.5	20.7	36.4
5	28	21.1	37.3
6	30	21.1	47
7	31.6	21.1	52.5
8	39.2	26.8	58.5
9	46.1	32.1	65.1
10	46.8	39.6	65.1
11	51	39.7	65.6
12	53.6	41.3	66.7
13	54	41.6	66.7
14	55.3	42.9	67.8
15	55.4	42.9	67.8
Depth in Structure	**Content Percent Damage**	**Content Lower Percent**	**Content Upper Percent**
-1	0	0	0
-0.5	0	0	0
0	0	0	0
0.5	0.9	0.8	1.1
1	1.7	1.5	2
1.5	1.7	1.5	2
2	1.7	1.5	2
3	90	90	100
4	100	90	100

5	82.4	79.8	87.9	5	80	77.3	82.1	5	86.9	78.3	100	5	100	90	100
6	84.3	81.7	89.9	6	80	77.3	82.1	6	99	89.1	100	6	100	90	100
7	84.4	81.7	90	7	80	77.3	82.1	7	99	89.2	100	7	100	90	100
8	84.4	81.7	90	8	100	96.7	100	8	99	89.2	100	8	100	90	100
9	84.4	81.7	90	9	100	96.7	100	9	99	89.2	100	9	100	90	100
10	84.4	81.7	90	10	100	96.7	100	10	99	89.2	100	10	100	90	100
11	84.4	81.7	90	11	100	96.7	100	11	99	89.2	100	11	100	90	100
12	84.4	81.7	90	12	100	96.8	100	12	99	89.2	100	12	100	90	100
13	84.4	81.7	90	13	100	96.8	100	13	99	89.2	100	13	100	90	100
14	84.4	81.7	90	14	100	96.8	100	14	99	89.2	100	14	100	90	100
15	84.4	81.7	90	15	100	96.8	100	15	99	89.2	100	15	100	90	100
Depth in Structure	**Debris Percent Damage**	**Debris Standard Deviation**		**Depth in Structure**	**Debris Percent Damage**	**Debris Standard Deviation**		**Depth in Structure**	**Debris Percent Damage**	**Debris Standard Deviation**		**Depth in Structure**	**Debris Percent Damage**	**Debris Standard Deviation**	
0	0	0		0	0	0		0	0	0		0	0	0	
2	85	15		2	81	8		2	96	23		2	96	23	
5	92	15		5	89	8		5	98	23		5	98	23	
12	100	15		12	100	9		12	100	23		12	100	23	

Table F:2-8. Depth-Damage Relationships for Structures, Contents, Vehicles, and Debris Removal

Commercial Repair and Home Use REPAIR				Commercial Retail and Personal Services RETAIL				Commercial Eating and Recreation EAT				Autos Vehicles AUTO			
Depth in Structure	**Structure Percent Damage**	**Structure Lower Percent**	**Structure Upper Percent**	**Depth in Structure**	**Structure Percent Damage**	**Structure Lower Percent**	**Structure Upper Percent**	**Depth in Structure**	**Structure Percent Damage**	**Structure Lower Percent**	**Structure Upper Percent**	**Depth in Structure**	**Structure Percent Damage**	**Structure Lower Percent**	**Structure Upper Percent**
-1	0	0	0	-1	0	0	0	-1	0	0	0	0	0	0	0
-0.5	0	0	0	-0.5	0.5	0	1.5	-0.5	0.5	0	1.5	0.5	0	0	0
0	3.9	2.4	22.8	0	0.5	0	1.5	0	0.5	0	1.5	1	6	4	8
0.5	15.2	4.8	24.7	0.5	13.1	3.8	20	0.5	13.1	3.8	20	1.5	15	13	17
1	17.3	10.4	25.6	1	16.7	11.9	21.2	1	16.7	11.9	21.2	2	19	18	21
1.5	19	13.2	25.6	1.5	19.3	13.9	29.8	1.5	19.3	13.9	29.8	3	100	100	100
2	22.1	16	35.6	2	21.1	14.4	31.4	2	21.1	14.4	31.4				
3	24.4	18	36	3	23.4	16.5	33	3	23.4	16.5	33				
4	31.2	21.1	52.7	4	27.5	20.7	36.4	4	27.5	20.7	36.4				
5	31.9	21.7	52.7	5	28	21.1	37.3	5	28	21.1	37.3				
6	32.2	21.7	53.2	6	30	21.1	47	6	30	21.1	47				
7	32.8	21.7	53.2	7	31.6	21.1	52.5	7	31.6	21.1	52.5				
8	42.5	32.5	62.1	8	39.2	26.8	58.5	8	39.2	26.8	58.5				
9	44.6	34.2	62.1	9	46.1	32.1	65.1	9	46.1	32.1	65.1				
10	45.8	36.1	62.1	10	46.8	39.6	65.1	10	46.8	39.6	65.1				
11	46.6	36.1	62.1	11	51	39.7	65.6	11	51	39.7	65.6				
12	46.9	36.1	62.5	12	53.6	41.3	66.7	12	53.6	41.3	66.7				
13	46.9	36.1	62.5	13	54	41.6	66.7	13	54	41.6	66.7				
14	47.3	36.1	65.2	14	55.3	42.9	67.8	14	55.3	42.9	67.8				
15	47.3	36.1	66.2	15	55.4	42.9	67.8	15	55.4	42.9	67.8				
Depth in Structure	**Content Percent Damage**	**Content Lower Percent**	**Content Upper Percent**	**Depth in Structure**	**Content Percent Damage**	**Content Lower Percent**	**Content Upper Percent**	**Depth in Structure**	**Content Percent Damage**	**Content Lower Percent**	**Content Upper Percent**				
-1	0	0	0	-1	0	0	0	-1	0	0	0				
-0.5	0	0	0	-0.5	0	0	0	-0.5	0	0	0				
0	0	0	0	0	0	0	0	0	0	0	0				
0.5	17	15.3	19.6	0.5	49.8	44.7	62.2	0.5	15.9	14.3	18.3				
1	23.7	21.4	27.3	1	65.8	59.2	82.3	1	56.8	51.1	65.1				
1.5	32.9	29.7	37.8	1.5	65.8	59.2	82.3	1.5	72.9	65.5	83.7				

2	33.7	30.3	38.7		2	74.2	66.8	92.8		2	95.9	86.3	100					
3	63.9	57.5	73.4		3	79.9	72.2	95.6		3	97.7	87.9	100					
4	66	59.4	75.9		4	85.5	76.9	95.6		4	100	89.9	100					
5	68	61.2	78.2		5	91.1	82	95.6		5	100	90.1	100					
6	73	65.8	84		6	91.1	82	95.6		6	100	90.1	100					
7	76.4	68.7	87.8		7	91.1	82	95.6		7	100	90.1	100					
8	76.4	68.7	87.8		8	91.1	82	95.6		8	100	90.1	100					
9	76.4	68.7	87.8		9	92.7	83.5	95.6		9	100	90.1	100					
10	76.4	68.7	87.8		10	92.7	83.5	95.6		10	100	90.1	100					
11	76.4	68.7	87.8		11	92.7	83.5	95.6		11	100	90.1	100					
12	76.4	68.7	87.8		12	92.7	83.5	95.6		12	100	90.1	100					
13	76.4	68.7	87.8		13	92.7	83.5	95.6		13	100	90.1	100					
14	76.4	68.7	87.8		14	92.7	89.8	95.6		14	100	90.1	100					
15	76.4	68.7	87.8		15	92.7	89.8	95.6		15	100	90.1	100					
Depth in Structure	**Debris Percent Damage**	**Debris Standard Deviation**			**Depth in Structure**	**Debris Percent Damage**	**Debris Standard Deviation**			**Depth in Structure**	**Debris Percent Damage**	**Debris Standard Deviation**						
0	0	0			0	0	0			0	0	0						
2	96	23			2	96	23			2	96	23						
5	98	23			5	98	23			5	98	23						
12	100	23			12	100	23			12	100	23						

Table F:2-9. Depth-Damage Relationships for Structures, Contents, Vehicles, and Debris Removal

Commercial Professional PROFFP				Commercial Public and Semi-Public PUBLICFP				Commercial Repair and Home Use REPAIRFP				Commercial Retail and Personal Services RETAILFP			
Depth in Structure	Structure Percent Damage	Structure Lower Percent	Structure Upper Percent	Depth in Structure	Structure Percent Damage	Structure Lower Percent	Structure Upper Percent	Depth in Structure	Structure Percent Damage	Structure Lower Percent	Structure Upper Percent	Depth in Structure	Structure Percent Damage	Structure Lower Percent	Structure Upper Percent
-1	0	0	0	-1	0	0	0	-1	0	0	0	-1	0	0	0
-0.5	0	0	0	-0.5	0	0	0	-0.5	0	0	0	-0.5	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.5	0	0	0	0.5	0	0	0	0.5	0	0	0	0.5	0	0	0
1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0
1.5	0	0	0	1.5	0	0	0	1.5	0	0	0	1.5	0	0	0
2	0	0	0	2	0	0	0	2	0	0	0	2	0	0	0
3	0	0	0	3	0	0	0	3	0	0	0	3	0	0	0
4	27.5	20.7	36.4	4	27.5	20.7	36.4	4	31.2	21.1	52.7	4	27.5	20.7	36.4
5	28	21.1	37.3	5	28	21.1	37.3	5	31.9	21.7	52.7	5	28	21.1	37.3
6	30	21.1	47	6	30	21.1	47	6	32.2	21.7	53.2	6	30	21.1	47
7	31.6	21.1	52.5	7	31.6	21.1	52.5	7	32.8	21.7	53.2	7	31.6	21.1	52.5
8	39.2	26.8	58.5	8	39.2	26.8	58.5	8	42.5	32.5	62.1	8	39.2	26.8	58.5
9	46.1	32.1	65.1	9	46.1	32.1	65.1	9	44.6	34.2	62.1	9	46.1	32.1	65.1
10	46.8	39.6	65.1	10	46.8	39.6	65.1	10	45.8	36.1	62.1	10	46.8	39.6	65.1
11	51	39.7	65.6	11	51	39.7	65.6	11	46.6	36.1	62.1	11	51	39.7	65.6
12	53.6	41.3	66.7	12	53.6	41.3	66.7	12	46.9	36.1	62.5	12	53.6	41.3	66.7
13	54	41.6	66.7	13	54	41.6	66.7	13	46.9	36.1	62.5	13	54	41.6	66.7
14	55.3	42.9	67.8	14	55.3	42.9	67.8	14	47.3	36.1	65.2	14	55.3	42.9	67.8
15	55.4	42.9	67.8	15	55.4	42.9	67.8	15	47.3	36.1	66.2	15	55.4	42.9	67.8
Depth in Structure	Content Percent Damage	Content Lower Percent	Content Upper Percent	Depth in Structure	Content Percent Damage	Content Lower Percent	Content Upper Percent	Depth in Structure	Content Percent Damage	Content Lower Percent	Content Upper Percent	Depth in Structure	Content Percent Damage	Content Lower Percent	Content Upper Percent
-1	0	0	0	-1	0	0	0	-1	0	0	0	-1	0	0	0
-0.5	0	0	0	-0.5	0	0	0	-0.5	0	0	0	-0.5	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.5	0	0	0	0.5	0	0	0	0.5	0	0	0	0.5	0	0	0
1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0
1.5	0	0	0	1.5	0	0	0	1.5	0	0	0	1.5	0	0	0
2	0	0	0	2	0	0	0	2	0	0	0	2	0	0	0
3	0	0	0	3	0	0	0	3	0	0	0	3	0	0	0
4	86.9	78.3	100	4	100	90	100	4	66	59.4	75.9	4	85.5	76.9	95.6

5	86.9	78.3	100	5	100	90	100	5	68	61.2	78.2	5	91.1	82	95.6
6	99	89.1	100	6	100	90	100	6	73	65.8	84	6	91.1	82	95.6
7	99	89.2	100	7	100	90	100	7	76.4	68.7	87.8	7	91.1	82	95.6
8	99	89.2	100	8	100	90	100	8	76.4	68.7	87.8	8	91.1	82	95.6
9	99	89.2	100	9	100	90	100	9	76.4	68.7	87.8	9	92.7	83.5	95.6
10	99	89.2	100	10	100	90	100	10	76.4	68.7	87.8	10	92.7	83.5	95.6
11	99	89.2	100	11	100	90	100	11	76.4	68.7	87.8	11	92.7	83.5	95.6
12	99	89.2	100	12	100	90	100	12	76.4	68.7	87.8	12	92.7	83.5	95.6
13	99	89.2	100	13	100	90	100	13	76.4	68.7	87.8	13	92.7	83.5	95.6
14	99	89.2	100	14	100	90	100	14	76.4	68.7	87.8	14	92.7	89.8	95.6
15	99	89.2	100	15	100	90	100	15	76.4	68.7	87.8	15	92.7	89.8	95.6
Depth in Structure	**Debris Percent Damage**	**Debris Standard Deviation**		**Depth in Structure**	**Debris Percent Damage**	**Debris Standard Deviation**		**Depth in Structure**	**Debris Percent Damage**	**Debris Standard Deviation**		**Depth in Structure**	**Debris Percent Damage**	**Debris Standard Deviation**	
0	0	0		0	0	0		0	0	0		0	0	0	
2	96	23		2	96	23		2	96	23		2	96	23	
5	98	23		5	98	23		5	98	23		5	98	23	
12	100	23		12	100	23		12	100	23		12	100	23	

Table F:2-10. Depth-Damage Relationships for Structures, Contents, Vehicles, and Debris Removal

Commercial Eating and Recreation EATFP			
Depth in Structure	**Structure Percent Damage**	**Structure Lower Percent**	**Structure Upper Percent**
-1	0	0	0
-0.5	0	0	0
0	0	0	0
0.5	0	0	0
1	0	0	0
1.5	0	0	0
2	0	0	0
3	0	0	0
4	27.5	20.7	36.4
5	28	21.1	37.3
6	30	21.1	47
7	31.6	21.1	52.5
8	39.2	26.8	58.5
9	46.1	32.1	65.1
10	46.8	39.6	65.1
11	51	39.7	65.6
12	53.6	41.3	66.7
13	54	41.6	66.7
14	55.3	42.9	67.8
15	55.4	42.9	67.8
Depth in Structure	**Content Percent Damage**	**Content Lower Percent**	**Content Upper Percent**
-1	0	0	0
-0.5	0	0	0
0	0	0	0
0.5	0	0	0
1	0	0	0
1.5	0	0	0
2	0	0	0
3	0	0	0
4	100	89.9	100

Commercial Multi-Family Occupancy MULTIFP			
Depth in Structure	**Structure Percent Damage**	**Structure Lower Percent**	**Structure Upper Percent**
-1	0	0	0
-0.5	0	0	0
0	0	0	0
0.5	0	0	0
1	0	0	0
1.5	0	0	0
2	0	0	0
3	0	0	0
4	44.9	41.2	52.2
5	47.1	46.6	56.9
6	49.3	51.4	56.9
7	51.7	52.4	69.2
8	58.6	60.5	75.4
9	61	65.2	75.4
10	63.5	65.2	75.4
11	63.6	65.2	75.4
12	65.3	65.3	75.4
13	65.3	65.3	75.4
14	65.4	65.3	75.4
15	65.6	65.3	75.4
Depth in Structure	**Content Percent Damage**	**Content Lower Percent**	**Content Upper Percent**
-1	0	0	0
-0.5	0	0	0
0	0	0	0
0.5	0	0	0
1	0	0	0
1.5	0	0	0
2	0	0	0
3	0	0	0
4	60	58.1	61.7

Industrial Warehouse WAREFP			
Depth in Structure	**Structure Percent Damage**	**Structure Lower Percent**	**Structure Upper Percent**
-1	0	0	0
-0.5	0	0	0
0	0	0	0
0.5	0	0	0
1	0	0	0
1.5	0	0	0
2	0	0	0
3	0	0	0
4	31.2	21.1	52.7
5	31.9	21.7	52.7
6	32.2	21.7	53.2
7	32.8	21.7	53.2
8	42.5	32.5	62.1
9	44.6	34.2	62.1
10	45.8	36.1	62.1
11	46.6	36.1	62.1
12	46.9	36.1	62.5
13	46.9	36.1	62.5
14	47.3	36.1	65.2
15	47.3	36.1	66.2
Depth in Structure	**Content Percent Damage**	**Content Lower Percent**	**Content Upper Percent**
-1	0	0	0
-0.5	0	0	0
0	0	0	0
0.5	0	0	0
1	0	0	0
1.5	0	0	0
2	0	0	0
3	0	0	0
4	34.1	30.6	39.2

5	100	90.1	100		5	80	77.3	82.1		5	41.6	37.4	47.7
6	100	90.1	100		6	80	77.3	82.1		6	49	44.1	56.3
7	100	90.1	100		7	80	77.3	82.1		7	56.5	50.9	64.9
8	100	90.1	100		8	100	96.7	100		8	63.9	57.6	73.5
9	100	90.1	100		9	100	96.7	100		9	71.4	64.2	82
10	100	90.1	100		10	100	96.7	100		10	75.2	67.6	86.3
11	100	90.1	100		11	100	96.7	100		11	75.2	67.6	86.3
12	100	90.1	100		12	100	96.8	100		12	75.2	67.6	86.3
13	100	90.1	100		13	100	96.8	100		13	75.2	67.6	86.3
14	100	90.1	100		14	100	96.8	100		14	75.2	67.6	86.3
15	100	90.1	100		15	100	96.8	100		15	75.2	67.6	86.3
Depth in Structure	**Debris Percent Damage**	**Debris Standard Deviation**			**Depth in Structure**	**Debris Percent Damage**	**Debris Standard Deviation**			**Depth in Structure**	**Debris Percent Damage**	**Debris Standard Deviation**	
0	0	0			0	0	0			0	0	0	
2	96	23			2	81	8			2	85	19	
5	98	23			5	89	8			5	89	19	
12	100	23			12	100	9			12	100	19	

2.3 ENGINEERING INPUTS TO THE HEC-FDA MODEL

2.3.1 Stage-Probability Relationships

Stage-probability relationships were provided for the base year (2026) without-project and with-project conditions. Water surface profiles were provided for eight annual exceedance probability (AEP) events: 0.50 (2-year), 0.20 (5-year), 0.10 (10-year), 0.04 (25-year), 0.02 (50-year), 0.01 (100-year), 0.005 (200-year), and 0.002 percent (500-year). The water surface profiles were based on a combination of rainfall and surge from the lower portion of the basin. Relative sea level rise was added to the areas impacted by surge.

2.3.2 Uncertainty Surrounding the Stage-Probability Relationships

A 50-year equivalent record length was used to quantify the uncertainty surrounding the stage-probability relationships for each study area reach. Based on this equivalent record length, the HEC-FDA model calculated the confidence limits surrounding the stage-probability functions.

Section 3

National Economic Development (NED) Flood Damage and Benefit Calculations

3.1 HEC-FDA MODEL CALCULATIONS

The HEC-FDA model was utilized to evaluate flood damages using risk-based analysis. Damages were reported at the index location for each of the 106 study area reaches for which a structure inventory had been created. A range of possible values, with a maximum and a minimum value for each economic variable (first floor elevation, structure and content values, and depth-damage relationships), was entered into the HEC-FDA model to calculate the uncertainty or error surrounding the elevation-damage, or stage-damage, relationships. The model also used the number of years that stages were recorded at a given gage to determine the hydrologic uncertainty surrounding the stage-probability relationships.

The possible occurrences of each variable were derived through the use of Monte Carlo simulation, which used randomly selected numbers to simulate the values of the selected variables from within the established ranges and distributions. For each variable, a sampling technique was used to select from within the range of possible values. With each sample, or iteration, a different value was selected. The number of iterations performed affects the simulation execution time and the quality and accuracy of the results. This process was conducted simultaneously for each economic and hydrologic variable. The resulting mean value and probability distributions formed a comprehensive picture of all possible outcomes.

3.1.1 Stage-Damage Relationships with Uncertainty

The HEC-FDA model used the economic and engineering inputs to generate a stage-damage relationship for each structure category in each study area reach under base year (2026) conditions. The possible occurrences of each economic variable were derived through the use of Monte Carlo simulation. A total of 1,000 iterations were executed in the model for the stage-damage relationships. The sum of all sampled values was divided by the number of samples to yield the expected value for a specific simulation. A mean and standard deviation was automatically calculated for the damages at each stage.

3.1.2 Stage-Probability Relationships with Uncertainty

The HEC-FDA model used an equivalent record length (50 years) for each study area reach to generate a stage-probability relationship with uncertainty for the without-project condition under base year (2026) conditions through the use of graphical analysis. The model used the eight stage-probability events together with the equivalent record length to define the full range of the stage-probability functions by interpolating between the data points. Confidence bands surrounding the stages for each of the probability events were also provided.

3.1.3 Without-Project Expected Annual Damages

The model used Monte Carlo simulation to sample from the stage-probability curve with uncertainty. For each of the iterations within the simulation, stages were simultaneously selected for the entire range of probability events. The sum of all damage values divided by the number of iterations run by the model yielded the expected value, or mean damage value, with confidence bands for each probability event. The probability-damage relationships are integrated by weighing the damages corresponding to each magnitude of flooding (stage) by the percentage chance of exceedance (probability). From these weighted damages, the model determined the expected annual damages (EAD) with confidence bands (uncertainty). For the without-project alternative, the EAD were totaled for each study area reach to obtain the total without-project EAD under base year (2026) conditions.

Table F:3-1 shows the number and type of structures that are damaged by each annual exceedance probability event for the year 2026 under without-project conditions. Table F:3-2 shows the without-project damages for the structure categories for each of the annual exceedance probability event for the year 2026.

Table F:3-1. Structures Damaged by Probability Event and Category in Existing Without-Project Conditions

Annual Exceedance Probability (AEP)	Residential	Commercial	Industrial	Total
Base year 2026				
0.50 (2 yr)	0	0	0	0
0.20 (5 yr)	0	0	0	0
0.10 (10 yr)	2,493	162	83	2,738
0.04 (25 yr)	4,293	256	131	4,680
0.02 (50 yr)	6,774	410	260	7,444
0.01 (100 yr)	10,359	738	393	11,490
0.005 (200 yr)	17,104	1,264	588	18,956
0.002 (500 yr)	34,191	2,433	1,105	37,729

Table F:3-2. Damages by Probability Event and Category in Existing Without-Project Conditions (FY19, $1,000s)

Annual Exceedance Probability (AEP)	Residential	Commercial	Industrial	Total
Base year 2026				
0.50 (2 yr)	$0	$0	$0	$0
0.20 (5 yr)	$0	$0	$0	$0
0.10 (10 yr)	$245,830	$25,411	$14,096	$285,337
0.04 (25 yr)	$441,573	$58,221	$24,360	$524,155
0.02 (50 yr)	$708,702	$104,615	$44,315	$857,632
0.01 (100 yr)	$1,110,101	$342,148	$88,510	$1,540,759
0.005 (200 yr)	$1,929,066	$980,480	$176,111	$3,085,658
0.002 (500 yr)	$4,310,859	$1,927,512	$405,559	$6,643,930

3.1.4 Expected Annual Damages and Benefits for the Project Alternatives

The HEC-FDA model was used to calculate the 2026 expected annual damages for the final array of plans. The final array included the following project plans: without project (no action); Darlington Reduced Wet Dam; Darlington Dry Dam; Sandy Creek Dam; Lilley, Darlington, and Bluff Creek Dams; nonstructural measures for the 25-year floodplain (0.04 AEP); and nonstructural measures for the 50-year floodplain (0.02 AEP). Due to time constraints, hydraulic modeling for Darlington Dam was only completed for the dry alternative. The damages and benefits were then applied to the reduced wet alternative. For more information about this decision and corresponding risk, please see the Appendix G: Hydrologic and Hydraulic Models. Tables F:3-3 through F:3-5 show the base year expected annual damages and benefits, damages by category, and damage reduction for the final array.

Table F:3-3. Expected Annual Damages and Benefits 2026 (FY19, $1,000s)		
Plan	**Expected Annual Damages**	**Expected Annual Benefits**
Without Project	$173,983	$0
Darlington Dam	$108,917	$65,066
Sandy Creek Dam	$160,334	$13,649
Lilley, Darlington, and Bluff Creek Dams	$167,852	$6,131
0.04 AEP Nonstructural	$120,436	$53,547
0.02 AEPr Nonstructural	$110,441	$63,542

Table F:3-4. Structure Categories and Project Alternatives Expected Annual Damages 2026 (FY19, $1,000s)					
Plan	**Vehicles**	**Commercial**	**Industrial**	**Residential**	**Total**
Without Project	$7,542	$43,325	$14,391	$108,725	$173,983
Darlington Dam	$4,693	$23,752	$9,393	$71,080	$108,917
Sandy Creek Dam	$7,058	$39,529	$13,923	$99,825	$160,334
Lilley, Darlington, and Bluff Creek Dams	$7,286	$42,308	$14,662	$103,596	$167,852
0.04 AEP Nonstructural	$7,584	$36,526	$11,408	$64,918	$120,436
0.02 AEP Nonstructural	$7,536	$33,553	$10,433	$58,919	$110,441

Table F:3-5. Expected Annual Damages 2026 (FY19, $1,000s)			
Plan Name	**Total Without Project Damages**	**Total With Project Damages**	**Damage Reduced**
Darlington Dam	$173,983	$108,917	$65,066
Sandy Creek Dam	$173,983	$160,334	$13,649
Lilley, Darlington, and Bluff Creek Dams	$173,983	$167,852	$6,131
0.04 AEP Nonstructural	$173,983	$120,436	$53,547
0.02 AEP Nonstructural	$173,983	$110,441	$63,542

Section 4
Project Costs of the TSP

4.1 CONSTRUCTION SCHEDULE

Construction of the Darlington Dam alternative is expected to take 4 years, while the other dam alternatives are expected to take 2 years to build. Construction would continue through the year 2026, which was established as the base year for analysis.

4.2 STRUCTURAL COSTS

Structural cost estimates for the final array were developed by the New Orleans District Cost Engineering Branch and were commensurate with a level 4 cost estimate. An abbreviated cost risk analysis was completed to determine the contingencies used for all structural measures. The structural costs include acquisitions associated with the real estate plan in conjunction with the Darlington Dam alternative. Details of the acquisitions can be found in the Real Estate Appendix.

4.3 NONSTRUCTURAL COSTS – ACQUISITION, ELEVATION & FLOODPROOFING

Based on the economic analysis of the focused array, the NED plan is the Darlington Dry Dam. Nonstructural measures will be used to reduce the residual risk associated with the TSP. The residential and nonresidential structures, damaged under the with project conditions in year 2026 that incurred flood damages by the stage associated with the 0.04 AEP event, were considered eligible for elevation, and floodproofing based upon criteria described in Section 4.4.

Nonstructural cost estimates for the final array were developed through a joint effort between the New Orleans District Economics and Cost Engineering Branches. A 34.5 percent contingency was applied to all nonstructural cost estimates to represent the uncertainty regarding the cost and schedule risk of these measures. The contingency amount was computed during a detailed cost risk analysis performed for the Southwest Coastal Louisiana Feasibility Study and was applied to this study after reviewing the associated risks and concluding they were similar for both studies.

4.3.1 Residential Structures

The estimate of the cost to elevate all residential structures was computed once model execution was completed. Elevation costs were based on the difference in the number of feet between the original first floor elevation and the target elevation (the future condition 100-year stage, including sea level rise) for each structure in the HEC-FDA module. The number of feet that each structure was raised was rounded to the closest 1-foot increment, with the exception that structures less than 1 foot below the target elevation were rounded-up to 1 foot. Elevation costs by structure were summed to yield an estimate of total structure elevation costs.

The cost per square foot for raising a structure was based on data obtained during interviews in 2008 with representatives of three major metropolitan New Orleans area firms that specialize in the structure elevation. Composite costs were derived for residential structures by type: slab and pier foundation, 1- story and 2- story configuration, and for mobile homes. These composite unit costs also vary by the number of feet that structures may be elevated. Table F:4-1 displays the costs for each of the five residential categories analyzed and by the number of feet elevated.

The cost per square foot to raise an individual structure to the target height was multiplied by the footprint square footage of each structure to compute the costs to elevate the structure. The footprint square footage for each structure was determined by applying the average square footage estimated for each residential structure. Added to the elevation cost was the cost of performing an architectural survey, which is associated with cultural resources concerns. The total costs for all elevated structures were annualized over the 50-year period of analysis of the project using the FY 2020 Federal discount rate of 2.75 percent. The square foot costs for elevation was price indexed to FY19 price levels using RSMeans cost catalog

4.3.2 Non-residential Structures

The floodproofing measures were applied to all non-residential structures. Separate cost estimates were developed to floodproof non-residential structures based on their relative square footage. Table F:4-2 shows a summary of square footage costs for floodproofing. These costs were developed for the Draft Nonstructural Alternatives Feasibility Study, Donaldsonville, LA to the Gulf evaluation (September 14, 2012) by contacting local contractors and were adopted for this study due to the similarity in the structure types between the two study areas. Added to the floodproofing cost was the cost of performing an architectural survey, which is associated with cultural resources concerns. Again, final cost estimates are expressed in FY 2019 prices.

Table F:4-1. Nonstructural Elevation Costs for Residential Structures (FY19, $/Sq ft)

Height (ft)	1-Story Pier	1-Story Slab	2-Story Pier	2-Story Slab	Mobile
1	105	118	116	130	58
2	105	118	116	130	58
3	109	121	120	133	58
4	109	125	120	143	71
5	109	125	120	143	71
6	112	128	122	144	71
7	112	128	122	144	71
8	114	132	125	149	71
9	114	132	125	149	71
10	114	132	125	149	71
11	114	132	125	149	71
12	114	132	125	149	71
>=13	116	136	128	157	71

Table F:4-2. Nonstructural Floodproofing Costs for Non-residential Structures FY19)

Square Footage	**Cost**
<=20,000	153,006
30,000	361,536
40,000	361,536
50,000	361,536
60,000	361,536
70,000	361,536
80,000	361,536
90,000	361,536
100,000	361,536
>= *110,000*	893,720

4.4 NONSTRUCTURAL COSTS – ACQUISITION & RELOCATION ASSISTANCE

As previously described, the default criteria for applying nonstructural mitigation measures is elevating residential structures and floodproofing nonresidential structures. The two exceptions to this criteria are based on engineering limitations with elevation height and structures being located in FEMA regulated floodways.

Following detailed design, it may also become necessary to acquire structures for permanent evacuation of the FEMA regulatory floodway. Such determination would be based on risk and performance. Additionally, if a structure would require elevating greater than 13 feet to meet the future year 0.01 AEP BFE, the structure would not be eligible for elevation. The 13 feet height is based on guidance provided in the FEMA publication P-550. During further refinement, should the Life Safety Risk Analysis indicate the need for acquisitions for permanent evacuation of the FEMA regulatory floodway or any other areas of critical concern, then eminent domain would be retained as a method of accomplishing acquisitions required of the NFS, consistent with USACE Planning Bulletins 2016-01 and 2019-03. Relocation Assistance for occupants of acquired structures would therefore apply to owner-occupants as well as tenants of the residential/non-structural structure who would be eligible to receive relocation benefits including advisory services and moving expenses, in accordance with 49 CFR Part 24.

Outside of the acquisitions required as part of the Darlington Dam measure, acquisitions have not been included in the economic analysis of the nonstructural measures of the TSP. Should acquisitions will be required in the FEMA regulated floodway, costs have been presented in the following two sections for acquisition and relocations. The final report will fully incorporate any acquisitions and relocation costs and benefits associated with the recommended plan.

4.4.1 Acquisition

The estimate of the cost of acquiring structures was computed once model execution was completed. Acquisition costs are based on the cost of acquiring the parcel of land, the structure(s) built on the land, an architectural survey, and miscellaneous costs associated with the acquisition process. The depreciated replacement value of the structure (excluding any contents) was used to represent the cost of the structure, which was previously described as being sourced from RSMeans Square Foot Cost data. The cost of acquiring the parcel was provided by the New Orleans Real Estate Branch, and is based on a square foot estimate for residential and non-residential structures. The square foot estimate was applied to the size of the parcel of land and not the size of the structure and varies based on if the structure is located within the floodway or floodplain. Added to the acquisition cost was the cost of performing an architectural survey, which is associated with cultural resources concerns. Finally, a cost of $47,000 for residential structures and $141,000 for non-residential structures was added to represent the cost of demolition, deed changes, legal fees, and regarding the surface. These miscellaneous costs associated with acquisition were sourced from the 2010 USACE Cedar Rapids, Iowa Feasibility Report. The prices derived from the 2010 report were price indexed to 2019 price levels. Acquisition costs by structure were summed to yield an estimate of total structure acquisition cost.

4.4.2 Relocation Assistance

The estimate of the cost of relocation assistance to owners of property that will be acquired was computed after model execution was completed. Relocation costs are based on the cost of relocating the occupant that has been removed from the acquired parcel. Costs associated with Uniform Relocation Assistance and Real Property Acquisition Act of 1970 (URA) include assisting the occupant with moving costs and incidentals for residential structures and moving costs, searching expenses, and re-establishing costs for non-residential structures. The URA costs amount to $38,000 per residential structure and $50,000 per non-residential structure. Relocation costs by structure were summed to yield an estimate of total structure relocation cost.

The total acquisition and relocation costs were added together and applied on a per structure basis to determine the full cost of acquisition and relocation assistance.

4.5 ANNUAL PROJECT COSTS

The initial construction costs (first costs) were used to determine the interest during construction and gross investment cost at the end of the installation period (2026). The FY 2020 Federal interest rate of 2.75 percent was used to discount the costs to the base year and then amortize the costs over the 50-year period of analysis.

The annual OMRR&R costs for the Darlington Dry Dam and Reduced Wet Dam from the 1997 Darlington Reservoir Re-evaluation Study were indexed to present value for use in this analysis. The Darlington Dry Dam cost was utilized as a parametric cost for the smaller dry dam alternatives.

Section 5
Results of the Economic Analysis

5.1 NET BENEFIT ANALYSIS

5.1.1 Calculation of Net Benefits

The expected annual benefits were compared to the annual costs to develop a benefit-to-cost ratio for the alternatives. The net benefits for the alternatives were calculated by subtracting the annual costs from the base year expected annual benefits. The net benefits were used to determine the economic justification of the project alternatives and identify the National Economic Development (NED) plan. This analysis found the Darlington Dry Dam alternative to be the NED plan, which is also the structural component of the Tentatively Selected Plan (TSP). Tables F:5-1 through F:5-6 show the net benefits for the project plans in the final array. First Costs may vary by up to $1,000 due to rounding.

Table F:5-1. Darlington Reduced Wet Dam Total Expected Annual Net Benefits (FY19, $1,000s, 2.75% Discount Rate)

Item	Expected Annual Without Project Damages	Expected Annual With Project Damages	Expected Annual Benefits and Costs
Damage Category			
Structure, Contents, Vehicles, and Debris Removal	$173,983	$108,917	$65,066
Total Benefits			$65,066
First Costs			$1,788,531
Interest During Construction			$100,590
Annual Operation & Maintenance Costs			$658
Total Annual Costs			$70,633
B/C Ratio			0.92
Expected Annual Net Benefits			-$5,567

Table F:5-2. Darlington Dry Dam Total Expected Annual Net Benefits (FY19, $1,000s, 2.75% Discount Rate)			
Item	**Expected Annual Without Project Damages**	**Expected Annual With Project Damages**	**Expected Annual Benefits and Costs**
Damage Category			
Structure, Contents, Vehicles, and Debris Removal	$173,983	$108,917	$65,066
Total Benefits			$65,066
First Costs			$1,278,523
Interest During Construction			$71,907
Annual Operation & Maintenance Costs			$439
Total Annual Costs			$50,461
B/C Ratio			1.29
Expected Annual Net Benefits			$14,605

Table F:5-3. Sandy Creek Dry Dam Total Expected Annual Net Benefits (FY19, $1,000s, 2.75% Discount Rate)

Item	Expected Annual Without Project Damages	Expected Annual With Project Damages	Expected Annual Benefits and Costs
Damage Category			
Structure, Contents, Vehicles, and Debris Removal	$173,983	$160,334	$13,649
Total Benefits			$13,649
First Costs			$270,977
Interest During Construction			$7,477
Annual Operation & Maintenance Costs			$220
Total Annual Costs			$10,534
B/C Ratio			1.3
Expected Annual Net Benefits			$3,115

Table F:5-4. Lilley, Darlington, and Bluff Creek Dry Dams *Total Expected Annual Net Benefits* *(FY19, $1,000s, 2.75% Discount Rate)*			
Item	**Expected Annual Without Project Damages**	**Expected Annual With Project Damages**	**Expected Annual Benefits and Costs**
Damage Category			
Structure, Contents, Vehicles, and Debris Removal	$173,983	$167,852	$6,131
Total Benefits			$6,131
First Costs			$349,980
Interest During Construction			$9,658
Annual Operation & Maintenance Costs			$659
Total Annual Costs			$13,980
B/C Ratio			0.44
Expected Annual Net Benefits			-$7,849

Table F:5-5. 0.04 AEP Nonstructural *Total Expected Annual Net Benefits* *(FY19, $1,000s, 2.75% Discount Rate)*			
Item	**Expected Annual Without Project Damages**	**Expected Annual With Project Damages**	**Expected Annual Benefits and Costs**
Damage Category			
Structure, Contents, Vehicles, and Debris Removal	$173,983	$120,436	$53,547
Total Benefits			$53,547
First Costs			$1,335,282
Interest During Construction			$4,536
Annual Operation & Maintenance Costs			$0
Total Annual Costs			$49,628
B/C Ratio			1.08
Expected Annual Net Benefits			$3,919

Table F:5-6. 0.02 AEP Nonstructural

Total Expected Annual Net Benefits (FY19, $1,000s, 2.75% Discount Rate)

Item	Expected Annual Without Project Damages	Expected Annual With Project Damages	Expected Annual Benefits and Costs
Damage Category			
Structure, Contents, Vehicles, and Debris Removal	$173,983	$110,441	$63,542
Total Benefits			$63,542
First Costs			$2,160,836
Interest During Construction			$7,340
Annual Operation & Maintenance Costs			$0
Total Annual Costs			$80,311
B/C Ratio			0.79
Expected Annual Net Benefits			-$16,769

5.2 RISK ANALYSIS

5.2.1 Benefit Exceedance Probability Relationship

The HEC-FDA model incorporates the uncertainty surrounding the economic and engineering inputs to generate results that can be used to assess the performance of proposed plans. The HEC-FDA model was used to calculate expected annual without-project and with-project damages and the damages reduced for each of the project alternatives. Table F:5-7 shows the expected annual benefits and the benefits at the 75, 50, and 25 percentiles for the final array. These percentiles reflect the percentage chance that the benefits will be greater than or equal to the indicated values. The benefit exceedance probability relationship for each of the project alternatives can be compared to the point estimate of the average annual costs for each of the project alternatives. The table indicates the percent chance that the expected annual benefits will exceed the annual costs, therefore the benefit cost ratio is greater than one and the net benefits are positive.

Table F:5-7. Probability Expected Annual Damages Exceed Annual Costs (FY19, $1,000s, 2.75% Discount Rate)

Plan Name	Expected Annual Damages Reduced	Probability Damage Reduced Exceeds Indicated Values			Annual Costs	Probability Benefits Exceed Costs
		75%	50%	25%		
Darlington Reduced Wet Dam	$65,066	$27,812	$46,086	$78,825	$50,461	Between 25 and 50 percent
Darlington Dry Dam	$65,066	$27,812	$46,086	$78,825	$50,461	Between 25 and 50 percent
Sandy Creek Dam	$13,649	$6,935	$10,299	$14,094	$10,534	Between 25 and 50 percent
Lilley, Darlington, and Bluff Creek Dams	$6,131	$5,055	$5,786	$4,512	$13,980	Less than 25 percent
0.04 AEP Nonstructural	$53,547	$38,589	$50,185	$66,366	$49,628	Between 50 and 75 percent
0.02 AEP Nonstructural	$63,542	$43,071	$58,403	$79,461	$80,311	Less than 25 percent

5.2.2 Residual Risk

The flood risk that remains in the floodplain after the proposed alternative is implemented is known as the residual flood risk. Nonstructural measures can be used to reduce the residual risk associated with construction of the structural component of the Tentatively Selected Plan (TSP). The residential and non-residential structures damaged under with project conditions in 2026 that incurred flood damages by the stage associated with the 0.4 (25-year) AEP event were considered eligible for acquisition, elevation, and floodproofing. Residential structures would be either acquired by the Federal government or elevated to the stage associated with the future year with project 0.01 (100-year) AEP event (not to exceed 13 feet). Non-residential structures would be either acquired by the Federal government or floodproofed to three feet above ground elevation. A preliminary analysis found a total of 3,252 residential structures were eligible for acquisition or elevation and an additional 314 non-residential structures were eligible for acquisition or floodproofing. Table F:5-8 shows the expected annual net benefits for the TSP of Darlington Dry Dam with elevation and floodproofing in the 25-year floodplain (0.04 AEP) to address residual risk.

As previously stated in Section 4.4, acquisitions will be mandatory and used conditionally for structures in the FEMA regulated floodway or structures being elevating greater than 13 feet to meet the future year 0.01 AEP BFE. Benefits associated with such acquisitions and relocation assistance have not yet been developed. As hydraulic and economic modeling is refined, the benefits of acquisitions and relocation assistance will be developed and included in the analysis for the recommended plan.

Table F:5-8. Darlington Dry Dam with 0.04 AEP Elevations and Floodproofing Total Expected Annual Net Benefits (FY19, $1,000's, 2.75% Discount Rate)

Item	Expected Annual Benefits and Costs
Damage Category	
Structure, Contents, Vehicles, and Debris Removal	$109,065
Total Benefits	$109,065
Structural First Costs	$1,278,524
Nonstructural First Costs*	$1,024,198
Total First Costs	$2,302,722
Interest During Construction	$75,386
Annual Operation & Maintenance Costs	$439
Total Annual Costs	$88,527
B/C Ratio	1.23
Expected Annual Net Benefits	$20,539

*Note: Acquisitions and related relocation assistance were not included at this stage of the analysis, so related costs are not included in the Nonstructural First Costs item.