Arcadia Section 205
Feasibility Study
Economic Appendix

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1. BACKGROUND INFORMATION

1.1. Introduction

This appendix presents an economic evaluation of the flood risk management alternatives for the Arcadia, Wisconsin Section 205 Feasibility Study. The evaluation area is defined by the 0.2 percent annual exceedance probability event floodplain in the City of Arcadia, which is fully within Trempealeau County. 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).

The economic appendix consists of a description of the methodology used to determine National Economic Development (NED) damages and benefits under existing conditions. The project costs were provided by Engineering Division. All damages and costs are at 2019 price levels and were annualized using the fiscal year (FY) 2020 Federal discount rate of 2.75 percent and a period of analysis of 50 years with the year 2025 as the base year. The expected annual damage and benefit estimates were compared to the annual construction costs and the associated OMRR&R costs for each of the project alternatives.

1.2. NED Benefit Categories Considered

The NED procedure manuals 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.

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.

2. DESCRIPTION OF THE STUDY AREA

2.1. Geographic Location

The City of Arcadia, located in Trempealeau County, in western Wisconsin, has an area of approximately 2.9 square miles. Principle modes of transport include the Canadian National Railway rail line, highway 93 running North/South, and highway 95 running East/West.

To assist with the economic benefit analysis for without-project and with-project alternative plans, and to better identify potential project areas that could be economically justified, the study area was divided into two basins: Trempealeau and Turton Creek. Within the Trempealeau basin, separate reaches were created to individually analyze alternative results for structures on the northwest side of the river and southeast side of the river. These settings were used to calculate flood damages using version 1.4.2 of the HEC-FDA certified model. Figure 1 shows the structure inventory and the eight economic reach boundaries of the study area.

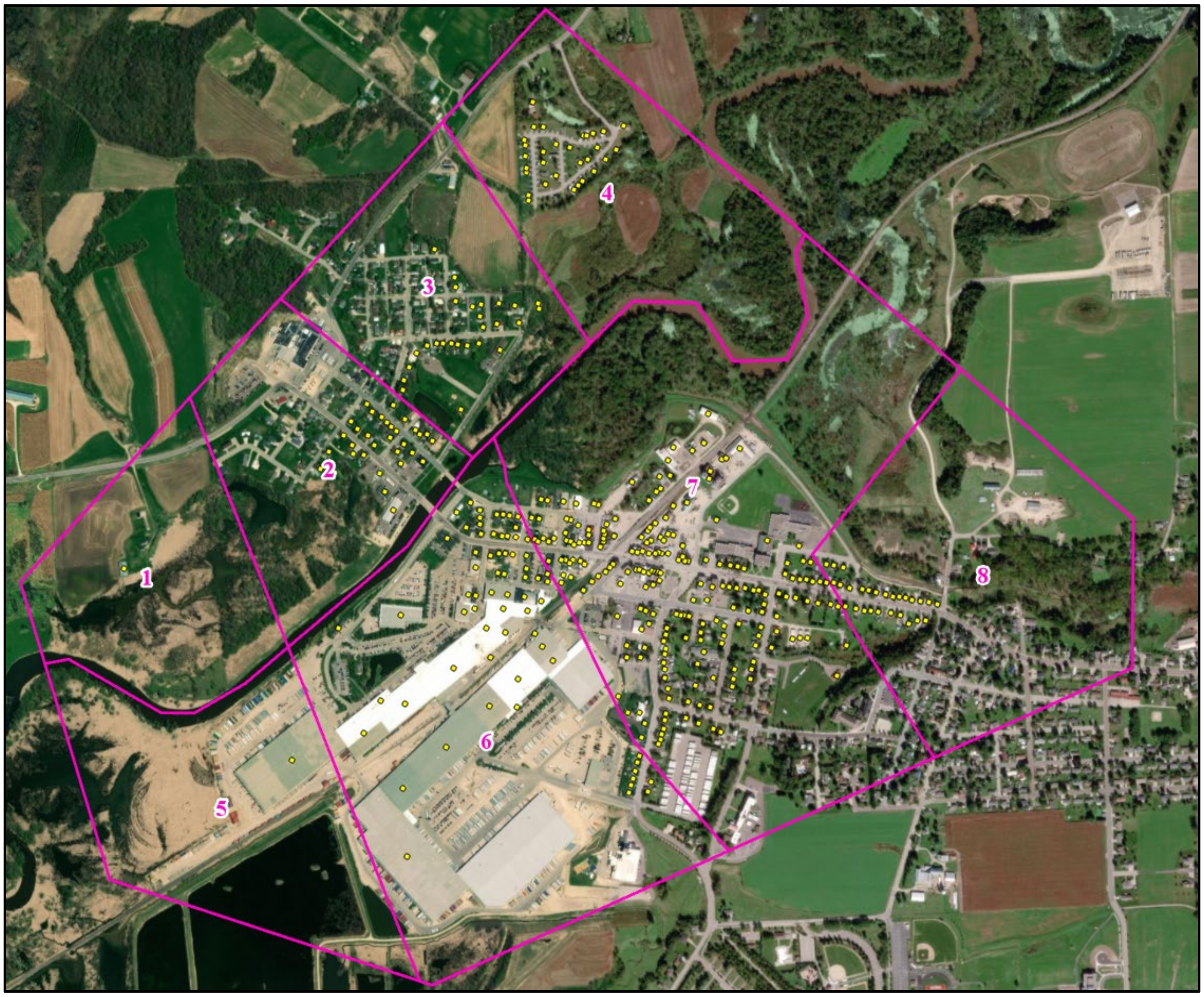

Figure 1. Structure Inventory with Economic Reach Boundaries

The without-project future conditions in Arcadia are identified as: (1) continued flooding impacts from future inundation events, and (2) the possibility of an increase in damages resulting from both progressive degradation of the existing levee and persistent sedimentation of the waterway channels. It is expected that current interior drainage issues will persist, due to the uncertain ability of the current drainage system to effectively reduce ponding from severe precipitation events. Substantial amounts of additional residential and commercial development within the floodplain appears unlikely, since zoning regulations require compliance with flood insurance and management policies, and business activity has gradually become more concentrated above the floodplain along the highway 93 corridor. However, expanding local industries and a growing population indicate that the business, civic, and community activity will remain within the floodplain.

2.2. Land Use

Arcadia is the largest city in a predominantly rural and agricultural county. Most of the community's downtown and older structures were built close to the Trempealeau River and Turton Creek, and lay within the floodplain. Notable structures within the floodplain include the fire station, public school, Post Office, Library, Ashley Furniture Industries, numerous local business establishments, and community residences.

Recent and newly built structures in the growing community can be expected to be built above the floodplain elevation, or to take advantage of present-day flood control regulations and not be a source of major future damages. Structures tend to be economical in construction, but built to last a long time, and it is expected that most structures within the floodplain will continue to be maintained and used into the foreseeable future.

A levee was constructed several decades ago for the south bank of Turton Creek and the south bank of the Trempealeau River. The levee is not presently in compliance with Corps safety guidance, and contains numerous utilities built within the levee, and residences and outbuildings encroach upon the landward levee slopes.

2.3. Socioeconomic Setting

2.3.1. Population, Employment, and Income

The City of Arcadia is located within Trempealeau County, Wisconsin. The population in the study area has shown a steady increase, which is expected to continue. Table 1 displays the population trend contextualizing population data on a statewide and also on a nationwide basis. The trends are analyzed from the year 1990 to the year 2020. The table indicates a population growth from all three levels. State and national levels have a higher growth rate, which can be explained by migration patterns. As seen in Table 2, the race of the population in this study area is predominantly white.

Table 1. Historic and Estimated Population (thousands)

Area	1990	2000	2010	2020
Trempealeau	25	27	29	30
Wisconsin	4,904	5,374	5,690	5,850
United States	248,709	281,421	307,745	328,461

Source: U.S. Census Bureau; Moody's Analytics (ECCA) Forecast

Table 2. Race of Population (%)

Area	White Alone	African American Alone	Asian Alone
Trempealeau	96.10	0.60	0.70
Wisconsin	87.10	6.00	3.00
United States	76.50	13.40	5.90

Source: U.S. Census Bureau

Table 3 displays the higher education levels in Trempealeau County in context with the state and national levels. The table compares the percent of the population over the age of 25 in that area that holds a bachelor’s degree or higher.

Table 3. Adult Population with Bachelor Degree or Higher (%)

Area	2014-2018
Trempealeau	19.4
Wisconsin	29.5
United States	31.5

Source: U.S. Census Bureau

As seen above, Trempealeau County has a lower percentage of adults holding four-year degrees or higher than both the state and national levels. This could be due to the prevalence of trade and factory work, which does not require such degrees. Ashley Furniture is the city's largest employer, and serves as an economic driver for Arcadia and surrounding communities by directly employing over 4,000 workers at its Arcadia corporate headquarters and manufacturing plants. Another large private employer within the city is the Pilgrim's Pride processing plant. Note on Tables 4 and 5 below, the lower rate of adults with bachelor's degrees or higher does not translate to a higher unemployment rate or significantly lower income per capita when compared to the state and national levels.

Table 4. Unemployment Rate (%)

Area	1990	2000	2010	2020
Trempealeau	6.41	4.10	7.55	3.66
Wisconsin	5.25	3.98	9.39	4.16
United States	5.60	4.00	9.60	3.70

Source: U.S. Bureau of Labor Statistics

Table 5. Income Per Capita ($)

Area	1990	2000	2010	2020
Trempealeau	15,156	24,659	35,919	50,540
Wisconsin	15,944	26,096	35,493	52,861
United States	14,387	22,346	26,558	40,154

Source: U.S. Census Bureau; Moody's Analytics (ECCA) Forecast

2.3.2. Compliance with Policy Guidance Letter 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 a risk reduction system, and will not conflict with Policy Guidance Letter 25 and EO 11988, which state that the primary objective of a flood risk reduction project is to lower risk to 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. The City of Arcadia is committed to enforcing development in compliance with FEMA floodplain regulations and will continue to do so with or without the project in place. Thus, the project will not induce development, but would rather reduce the risk of the population being displaced after a major storm event.

3. RECENT FLOOD HISTORY

The study area remains subject to periodic flood damages resulting from inundation of low-lying areas adjacent to the Trempealeau River, Turton Creek, and Meyers Valley waterways. The waterway confluence of the Trempealeau River and Turton Creek is proximate to Arcadia's downtown business district, school, and Fire station, and severe flood conditions in one water way can generate backwater flooding for locations in the adjacent waterway. Coincident flooding of the Trempealeau River and Turton Creek poses a higher flood risk. Arcadia has a history of damage caused by flood events. A severe event in 2010 washed out roads, downed power lines, damaged infrastructure, and flooded basements. A recent event, 2017, affected the study area when Turton Creek overtopped its levee and washed out a portion of Oak Street. This event brought severe flooding damage to downtown Arcadia.

Fluvial flooding in the river basins may occur as a result of high precipitation storm events, the impacts of which can be exacerbated by melt water from thawing snow and ice accumulation, and inopportune water releases from an upstream reservoir in Independence, WI. Development throughout the watershed has increased the potential of water runoff and headwater flows to contribute to the flood hazard. Agriculture practices throughout the upstream watershed have been attributed to sedimentation buildup in the study area, which may adversely impact channel capacity by lowering the hydraulic gradient.

Some areas that were not previously known to be subject to flooding were exposed as being at risk of damage from the recent flood in 2010. Future without-project conditions would likely result in a continuation of historic flood damage patterns, with some potential for additional risk of damage resulting from severe weather conditions, altered land use practices upstream of the study area, and risk of degradation and failure in the existing levee.

4. ECONOMIC AND ENGINEERING INPUTS TO THE HEC-FDA MODEL

4.1. HEC-FDA Model

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 Arcadia study area. The economic and engineering inputs necessary for the model to calculate damages for the project base year (2025) 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. Uncertainty values were generated based on an equivalent hydraulic record lengths of 87 years for the Trempealeau River and 38 years for Turton Creek. The flood damage analysis quantified without-project exepcted annual damages (EAD) and the with-project EAD for all alternatives. Residual interior drainage issues relating to floodwall/levee structures were not considered to be sufficient to warrant separate reach assignments and damage calculations for the feasibility level analysis. A comprehensive interior drainage analysis may be conducted in later stages of an optimization level analysis.

4.2. Economic Inputs to the HEC-FDA Model

Structure Inventory. The structural inventory survey was conducted in 2017, with depreciated replacement values estimated using a price level of January 2019. A database of residential and nonresidential structures in the study area was compiled to assist in calculating flood damages.

The structure inventory data was generated by a survey of the structures located within or near the 0.002 annual exceedance probability event floodplain, mostly obtained through Geographic Information Systems (GIS) mapping data for each vulnerable structure. To be classified as falling within the floodplain limits, only a portion of the polygon representing the structure had to fall within the geometry of the floodplain extents. The inventory categorized structures by type, main floor elevation, elevation of beginning flood damages, and identified the depreciated structure replacement value. Mapping elevations were expressed in feet, and were based on horizontal datum NAD 1983 and vertical datum NAVD 1988. Table 6 outlines the data obtained for the structure inventory.

Table 6. Surveyed Structure Inventory Characteristics

Data Collected During Survey
Structure ID
Damage Reach
Map Location
Structure Type/Damage Category
Usage Code Lookup
Size (Sq. Ft.)
Stories
Basement
Garages
Exterior
Build Quality
Condition
Reverence Elevation
First Floor Height
Low Opening
Depreciated Replacement Structure Value

The data collected was used to categorize the structure population into groups with common physical features. Data pertaining to structure usage, condition, size and number of stories assisted in the structure value analysis. For each building, data was also gathered pertaining to its damage potential including ground and main floor elevations, lowest opening, likely construction material, depreciation condition, and the presence of basements and garages. The final structure inventory identified over 450 structures within the floodplain as having the potential to benefit from flood risk management measures.

A small number of structures were screened out of the inventory, due to the determination that they were either built or substantially improved in non-compliance with U.S. legal Code: 33 U.S.

Code § 2318 - Flood plain management. Table 7 shows the total number of residential, commercial, industrial and vehicles associated with residential units by study area reach.

Table 7. Number of Structures by HEC-FDA Reach and Category

Structure Category	Reach Name								
	1	2	3	4	5	6	7	8	Total
Residential	0	40	61	29	0	29	103	27	289
Industrial	0	0	0	0	0	0	3	0	3
Apartment	0	0	1	0	0	0	9	0	10
Public	0	0	0	0	0	1	5	0	6
Commercial	1	7	4	2	0	8	97	0	119
Vehicles	0	40	62	29	0	29	112	27	299
Ashley Furniture Structures	0	0	0	0	1	30	0	0	31
Ashley Furniture Vehicles	0	0	0	0	0	5	0	0	5
Ashley Furniture Equipment	0	0	0	0	0	5	0	0	5
Total	1	87	128	60	1	107	329	54	767

Structure Values. The structural depreciated replacement values were calculated for all structures using square foot costs. Baseline costs were taken from the 2017 book *Square Foot Costs with RSMeans Data*, an industry standard valuation reference. The square foot costs for residential finished living spaces and basements, plus unit costs for garages, used both economy quality and average quality baselines. Index calculations enabled residential values to be calculated for structures of varying scales. Non-residential and apartment structure valuation lookup tables were simplified by assigning typical square foot costs to a structure category, and then multiplying the baseline category cost by the structure's measured square footage. Depreciation tables from *RSMeans* were used for residential and non-residential structures. Characteristics gathered during the structure survey were used to determine which *RSMeans* depreciation category the structure belonged in. Once the structures were categorized individually, the corresponding depreciation value was applied. Reference values were initially set to the January 2017 price level. Calculated depreciated values were then adjusted for location using *RSMeans* location factors. Since the initial development, inventory values have been indexed to the January 2019 price level using a more recent version of the same *RSMeans* book.

Some inventory data was provided directly to USACE by corresponding property owners. As appropriate and with verification, these values were manually adjusted to better quantify the square foot measurements, contents and vehicles, and the resulting calculated depreciation values. Table 8 shows the average depreciated replacement value by occupancy type. Tables 9 and 10 show the cumulative structure and content values by occupancy type and study area reach.

Table 8. Structure Inventory Depreciated Valuation by Occupancy Type

Category	Occupancy	Occupancy Description	Number of Structures	Average Depreciated Replacement Value (Thousands, 2019 Price Level)
Residential	RS-MH	Mobile Home	27	$76.32
	RS-OS-NB	One Story without Basement	18	$132.57
	RS-OS-WB	One Story with Basement	54	$147.83
	RS-SL-NB	Split Level without Basement	1	$197.29
	RS-TS-WB	Two Story with Basement	189	$182.91
		Total Residential	**289**	**$163.31**
Apartment	APT-E	Apartment	10	$778.20
Commercial	CLOTH-E	Clothing Store	3	$471.47
	CONV-E	Convenience Store	5	$295.80
	ELEC-E	Electronics Store	4	$895.12
	FFR-E	Fast Food Restaurant	1	$912.75
	FURN-E	Furniture Store	3	$416.49
	GROC-E	Grocery Store	3	$341.31
	MED-E	Medical Office	1	$2,007.30
	OFF-E	Engineered Office Building	13	$547.18
	OFF-P	Pre-Engineered Office Building	1	$74.89
	REST-E	Restaurant	18	$397.25
	SERV-E	Service Station	6	$519.57
Industrial	LT-E	Engineered Light Industrial	1	$514.69
	LT-P	Pre-Engineered Light Industrial	3	$523.07
	WH-E	Engineered Warehouse	10	$186.64
	WH-P	Pre-Engineered Warehouse	43	$114.99
Public	PS-E	Protective Services	1	$682.86
	REC-E	Engineered Recreation Facility	3	$711.37
	REC-P	Pre-Engineered Recreation Facility	1	$87.61
	RF-E	Religious Facility	3	$973.23
	SCH-E	Engineered School	4	$3,081.20
	SCH-P	Pre-Engineered School	1	$404.61

		Total Non-Residential	**138**	**$466.33**
Ashley	A-LT-E	Light Industrial Manufacturing	24	$7,601.07
	A-OFF-E	Office	2	$3,294.79
	A-REST-E	Restaurant	1	$462.23
	A-WH-E	Engineered Warehouse	3	$278.29
	A-WH-P	Pre-Engineered Warehouse	1	$292.49
Ashley Equipment	RKD	Ashley Furniture Contents	5	$10,578.36
Ashley Autos	PIV	Ashley Furniture Vehicle	5	$1,070.68
		Total Ashley Furniture	**41**	**$6,069.51**
Vehicles	AUTO	Vehicles	299	$12.10

Table 9. Total Structure Inventory Value by Category Type and Study Area Reach

Structure Category	Reach Name								
	1	2	3	4	5	6	7	8	Total
Residential	$0	$47,396	$74,292	$16,876	$0	$33,098	$120,833	$37,886	$330,382
Industrial	$0	$0	$0	$0	$0	$0	$10,985	$0	$10,985
Apartment	$0	$0	$16,587	$0	$0	$0	$37,887	$0	$54,474
Public	$0	$0	$0	$0	$0	$4,780	$89,106	$0	$93,886
Commercial	$1,344	$26,398	$9,264	$756	$0	$21,061	$232,311	$0	$291,134
Vehicles	$0	$2,945	$5,669	$2,135	$0	$2,135	$10,455	$1,988	$25,327
Ashley Furniture Structures	$0	$0	$0	$0	$218,398	$1,115,836	$0	$0	$1,334,233
Ashley Furniture Vehicles	$0	$0	$0	$0	$0	$37,474	$0	$0	$37,474
Ashley Furniture Equipment	$0	$0	$0	$0	$0	$370,243	$0	$0	$370,243
Total	$1,344	$76,740	$105,812	$19,767	$218,398	$1,584,626	$501,576	$39,874	$2,548,137

Table 10. Total Content Value by Category Type and Study Area Reach

Structure Category	Reach Name								
	1	2	3	4	5	6	7	8	Total
Residential	$0	$47,396	$74,292	$2,452	$0	$33,098	$120,833	$37,886	$315,958
Industrial	$0	$0	$0	$0	$0	$0	$5,185	$0	$5,185
Apartment	$0	$0	$1,642	$0	$0	$0	$3,751	$0	$5,393
Public	$0	$0	$0	$0	$0	$3,322	$5,815	$0	$9,137
Commercial	$629	$12,468	$800	$354	$0	$7,953	$83,212	$0	$105,416
Vehicles	$0	$0	$0	$0	$0	$0	$0	$0	$0
Ashley Furniture Structures	$0	$0	$0	$0	$83,428	$416,612	$0	$0	$500,040
Ashley Furniture Vehicles	$0	$0	$0	$0	$0	$0	$0	$0	$0
Ashley Furniture Equipment	$0	$0	$0	$0	$0	$370,243	$0	$0	$370,243
Total	$629	$59,864	$76,734	$2,806	$83,428	$831,228	$218,795	$37,886	$1,311,371

Structure Value Uncertainty. The analysis recognizes that estimates of depreciated structure value based on survey inventories contain inherent uncertainty. First floor standard deviations of 0.6 feet or 0.1 feet were selected based on occupancy type, methodology, and recommendations in the USACE Engineering Manual, EM 1110-2-1619. The IWR residential depth-damage functions assume a structural value following a normal distribution with a coefficient of variation of 10%. Residential vehicle values followed a normal distribution with a 30% coefficient of variation.

Within the EE2013 non-residential and apartment depth-damage functions, a coefficient of variation of 22.05% was applied to most structure values on a normal distribution, and a 20.12% coefficient of variation was applied for apartment structures. Table 11 shows the uncertainty assigned to the depreciated structure values by occupancy type.

Table 11. Structure Uncertainty Parameters by Structure Category

Category	Occupancy	Occupancy Description	Structure Value Error (Standard Deviation Percent)
Residential	RS-MH	Mobile Home	10
	RS-OS-NB	One Story without Basement	10
	RS-OS-WB	One Story with Basement	10
	RS-SL-NB	Split Level without Basement	10

	RS-TS-WB	Two Story with Basement	10
Apartment	APT-E	Apartment	20.12
Commercial	CLOTH-E	Clothing Store	22.05
	CONV-E	Convenience Store	22.05
	ELEC-E	Electronics Store	22.05
	FFR-E	Fast Food Restaurant	22.05
	FURN-E	Furniture Store	22.05
	GROC-E	Grocery Store	22.05
	MED-E	Medical Office	22.05
	OFF-E	Engineered Office Building	22.05
	OFF-P	Pre-Engineered Office Building	22.05
	REST-E	Restaurant	22.05
	SERV-E	Service Station	22.05
Industrial	LT-E	Engineered Light Industrial	22.05
	LT-P	Pre-Engineered Light Industrial	22.05
	WH-E	Engineered Warehouse	22.05
	WH-P	Pre-Engineered Warehouse	22.05
Public	PS-E	Protective Services	22.05
	REC-E	Engineered Recreation Facility	22.05
	REC-P	Pre-Engineered Recreation Facility	22.05
	RF-E	Religious Facility	22.05
	SCH-E	Engineered School	22.05
	SCH-P	Pre-Engineered School	22.05
Ashley	A-LT-E	Light Industrial Manufacturing	22.05
	A-OFF-E	Office	22.05
	A-REST-E	Restaurant	22.05
	A-WH-E	Engineered Warehouse	22.05
	A-WH-P	Pre-Engineered Warehouse	22.05
Ashley Equipment	RKD	Ashley Furniture Contents	0
Ashley Autos	PIV	Ashley Furniture Vehicle	30
Automotives	AUTO	Vehicles	30

Content-to-Structure Value Ratios and Uncertainty. Residential and non-residential structure occupancies were assigned content-to-structure value ratios (CSVRs). For residential occupancies, EM 1110-2-1619 suggests that in lieu of better site-specific information, CSVRs based on large samples of Flood Insurance Administration (FIA) claims records can be used (Table 6-4 presented in EM 1110-2-1619). Most of the residential damage functions present content damage as 100% of structure value, and the CSVR was estimated to have a 10% coefficient of variation for residential functions. Slight adjustments were made for the mobile home damage function, developed through USACE North Atlantic Division, and containing a 25% coefficient of variation for the CSVR.

Non-residential structures were assigned CSVRs and assigned triangular distributions that differed according to damage category and occupancy type. Minimum and maximum error margins were assigned as percentage increments, and were individually adjusted for the relevant category and occupancy type. The CSVR percentage values and corresponding uncertainties for each of the residential and non-residential occupancies are shown in Table 12. Some industrial structures participated in surveys, which allowed for structure-specific CSVRs and corresponding uncertainties to be developed. All other non-residential CSVRs and corresponding uncertainties were developed for the Fargo-Moorhead Metro Feasibility study, during which they were assessed and deemed appropriate through the Agency Technical Review process.

Table 12. Content-to-Structure Value Ratio (CSVR) Percentage and Uncertainty Standard Deviation (SD) Percentage by Occupancy

Category	Occupancy	Occupancy Description	CSVR (%)	CSVR Error		
				Normal Distribution	Triangular Distribution	
				Standard Deviation (%)	Minimum Error (%)	Maximum Error (%)
Residential	RS-MH	Mobile Home	0	25	0	0
	RS-OS-NB	One Story without Basement	100	0	0	0
	RS-OS-WB	One Story with Basement	100	0	0	0
	RS-SL-NB	Split Level without Basement	100	0	0	0
	RS-TS-WB	Two Story with Basement	100	0	0	0
Apartment	APT-E	Apartment	9.9	0	7.5	13.5
Commercial	CLOTH-E	Clothing Store	45	0	36.5	52.5
	CONV-E	Convenience Store	34	0	25	40
	ELEC-E	Electronics Store	65	0	57.2	73.2
	FFR-E	Fast Food Restaurant	27.2	0	21	32.5
	FURN-E	Furniture Store	36.5	0	31	42.6
	GROC-E	Grocery Store	70	0	61.5	78.5
	MED-E	Medical Office	60.4	0	53.2	66.2

	OFF-E	Engineered Office Building	18.1	0	14	24
	OFF-P	Pre-Engineered Office Building	20.8	0	15	26.2
	REST-E	Restaurant	22.9	0	16.5	28.5
	SERV-E	Service Station	66	0	55.5	73.8
Industrial	LT-E	Engineered Light Industrial	38.2	0	31.5	44
	LT-P	Pre-Engineered Light Industrial	47.2	0	38.9	55
	WH-E	Engineered Warehouse	37.4	0	31	43.5
	WH-P	Pre-Engineered Warehouse	46.8	0	36.2	53.5
Public	PS-E	Protective Services	69.5	0	60	75
	REC-E	Engineered Recreation Facility	24.6	0	20	31
	REC-P	Pre-Engineered Recreation Facility	29.8	0	21.9	35
	RF-E	Religious Facility	6.9	0	5	10.5
	SCH-E	Engineered School	6.5	0	5	9
	SCH-P	Pre-Engineered School	7.3	0	5	10.5
Ashley	A-LT-E	Light Industrial Manufacturing	38.2	0	31.5	44
	A-OFF-E	Office	18.1	0	14	24
	A-REST-E	Restaurant	22.9	0	16.5	28.5
	A-WH-E	Engineered Warehouse	37.4	0	31	43.5
	A-WH-P	Pre-Engineered Warehouse	46.8	0	36.2	53.5
Ashley Equipment	RKD	Ashley Furniture Contents	100	0	0	0
Ashley Autos	PIV	Ashley Furniture Vehicle	0	0	0	0
Automotives	AUTO	Vehicles	0	0	0	0

Vehicle Inventory and Values. Since the IWR residential depth-damage functions do not estimate other-to-structure damages, structure associated vehicle estimates were assigned their own entries in the inventory. The most recently published Department of Transportation (DOT) data was used to determine the average number of vehicles per residence in the study area floodplain. Flood damages associated with vehicles were computed in accordance with USACE guidance found in EGM 09-04, "Generic Depth-Damage Relationships for Vehicles", 22 June 2009. For each structure assumed to have associated motor vehicles, an additional 'structure' was added to the inventory to represent those vehicles. Residential vehicle values followed a normal distribution with a 30% coefficient of variation. To facilitate this component of the analysis, the following simplifying assumptions were made during the estimation of the number and value of vehicles likely to be present in the study area during flood events:

1. The number of vehicles associated with each housing unit in the study area was taken from the most recent DOT Bureau of Transport Statistics data.
2. The average depreciated value of a vehicle in the study area was based on the Edmunds Q3 2016 used vehicle market report.

3. In the absence of more detailed data, sedans are assumed to be the predominant vehicle type in the study area; hence the sedan depth-damage function in Table 4 of EGM 09-04 has been assigned to all vehicles in the inventory.
4. The total number of housing units in any residential structure was estimated by assuming that each structure covered by EGM 04-01 depth-damage functions contains a single unit, and that the number of units in an apartment building or other multi-family residence can be derived by dividing the building's total square footage by 1,200 (1,000 square feet for the assumed average apartment size plus an additional 200 square feet to account for hallways and other common areas).
5. The probability that vehicle owners would move their vehicles to higher ground before a flood was assumed to be 73%. In the absence of definitive information regarding local warning times in advance of flood events, this figure is derived from an average of the percentages given in Table 5 of EGM 09-04. This evacuation percentage is optimistic considering the flash flooding experienced in the study area, resulting in a conservative estimate of damages in such an event.
6. The damage reference elevations for all vehicles in the inventory were assumed to be equal to the ground elevation of the associated structure, unless more detailed information was available.
7. It was assumed that vehicles would remain outside of non-residential structures during a flood event, with exceptions for private companies that stated otherwise.

Since the initial creation, all vehicle values have been indexed to a 2019 price level.

First Floor Elevations and Uncertainty. First floor elevations are a combination of the ground elevation at the structure and the foundation height above ground. Topographical data based on Light Detection and Ranging (LiDAR) data using NAVD 88 vertical datum 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). 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, which was gathered during the structure survey, 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. First floor standard deviations of 0.6 feet or 0.1 feet were selected based on occupancy type, methodology, and recommendations in the USACE Engineering Manual, EM 1110-2-1619. Table 13 displays the average foundation heights and standard deviations by occupancy type.

Table 13. Average Foundation Height and First Floor Stage Uncertainty Standard Deviation (SD) by Structure Category

Category	Occupancy	Occupancy Description	Average Foundation Height	SD First Floor (feet)
Residential	RS-MH	Mobile Home	1.93	0.6
	RS-OS-NB	One Story without Basement	1.25	0.6
	RS-OS-WB	One Story with Basement	2.50	0.6
	RS-SL-NB	Split Level without Basement	2.00	0.6
	RS-TS-WB	Two Story with Basement	2.54	0.6
Apartment	APT-E	Apartment	1.34	0.1
Commercial	CLOTH-E	Clothing Store	0.89	0.1
	CONV-E	Convenience Store	0.27	0.1
	ELEC-E	Electronics Store	1.00	0.1
	FFR-E	Fast Food Restaurant	0.67	0.1
	FURN-E	Furniture Store	0.22	0.1
	GROC-E	Grocery Store	0.67	0.1
	MED-E	Medical Office	2.00	0.1
	OFF-E	Engineered Office Building	0.51	0.1
	OFF-P	Pre-Engineered Office Building	0.00	0.1
	REST-E	Restaurant	0.19	0.1
	SERV-E	Service Station	0.00	0.1
Industrial	LT-E	Engineered Light Industrial	1.33	0.1
	LT-P	Pre-Engineered Light Industrial	0.67	0.1
	WH-E	Engineered Warehouse	0.13	0.1
	WH-P	Pre-Engineered Warehouse	0.36	0.1
Public	PS-E	Protective Services	0.00	0.1
	REC-E	Engineered Recreation Facility	0.89	0.1
	REC-P	Pre-Engineered Recreation Facility	0.00	0.1
	RF-E	Religious Facility	4.00	0.1
	SCH-E	Engineered School	1.83	0.1
	SCH-P	Pre-Engineered School	4.00	0.1
Ashley	A-LT-E	Light Industrial Manufacturing	2.25	0.1
	A-OFF-E	Office	-1.12	0.1

	A-REST-E	Restaurant	0.51	0.1
	A-WH-E	Engineered Warehouse	2.03	0.1
	A-WH-P	Pre-Engineered Warehouse	2.46	0.1
Ashley Equipment	RKD	Ashley Furniture Contents	0.00	0.1
Ashley Autos	PIV	Ashley Furniture Vehicle	0.00	1
Vehicles	AUTO	Automotive	0.00	1

Depth-Damage Relationships. Depth-percent damage functions for structures, contents and automobiles were applied to calculate floodwater damage. The primary source of damage functions were generic depth-damage functions.

Tables 17-33 show the damage relationships for structure, contents, and vehicles. The tables contain the damage percentages at each depth of flooding along with the uncertainty surrounding the damage percentages. The tables can be found at the end of this appendix in Attachment 1.

The damage functions for most residential structures were developed by USACE and the Institute for Water Resources (IWR), following an expert opinion elicitation exercise carried out by FEMA and USACE/IWR. These functions include depth-damage estimates for structures and content. For further information on IWR residential damage functions, see Economic Guidance Memorandum (EGM) 04-01, Generic Depth-Damage Relationships for Residential Structures with Basements.

Some industrial structures participated in surveys, which allowed for structure-specific damage functions and corresponding uncertainties to be developed. All other non-residential damage functions and corresponding uncertainties were developed in 2009, and later revised in 2013, based on an Expert Opinion Elicitation (EE2013). These standard non-residential damage functions were developed in collaboration with numerous entities, including FEMA, USACE, URS Corporation, and various local, state, and federal officials.

The IWR generic functions are certified for residential structures, and the EE2013 damage functions are appropriate for the non-residential structures and apartments due to the closeness of the function designs and the Arcadia structure types and contents.

Indirect Sewer Backup Flooding. A regular characteristic of flooding in the Arcadia area is the potential for basement damage caused by backup of sanitary sewer lines. Homes not directly contacted by flood waters can incur basement damage via sewer lines originating from homes that are directly flooded. This phenomenon allows areas with a seemingly adequate level of topographic relief to incur indirect basement flood damage due to direct flooding of lower homes within the same sanitary sewer basin. A sanitary sewer basin is a subarea of the city in which all structures within the basin are connected to the same localized sewer system and whose drainage and flows to the sewage treatment plant are controlled by the same pump station. The lowest opening elevation of a structure is the lowest elevation at which flood water may enter a structure and cause damages to begin accruing.

While flooding due to indirect sewer backup from the sanitary sewer system is significant, it was determined that this flooding is a local drainage issue and therefore outside the scope of this study. As such, the lowest entry points recorded for the HEC-FDA inventory were used as a begin damage point without any adjustments.

4.3. Engineering Inputs to the HEC-FDA Model

For the Arcadia HEC-FDA model, an equivalent hydraulic record length of 87 years was assumed for the Trempealeau River and 38 years for Turton Creek. Water Surface Profiles (WSP) were generated with steady state hydraulic modeling of discharge flows. The Log Pearson type III analytical approach was applied to Trempealeau River frequency-discharge relationships for the representation of uncertainty in event frequencies, while Graphical frequency-discharge relationships were applied to the Turton Creek basin. The frequency-discharge functions were then converted into the discharge-stage relationships (rating curves) using normal distributions of uncertainty. The discharge-stage functions were then related to depth-damage functions to derive the stage-damage relationships. All of the depth-damage function uncertainty distributions, for all occupancy types, followed either normal or triangular uncertainty distributions.

Stage-probability relationships were provided for the base year without-project and with-project conditions. Water surface profiles were provided for eight annual exceedance probability events: 0.5, 0.2, 0.1, 0.05, 0.02, 0.01, 0.005, and 0.002.

5. NATIONAL ECONOMIC DEVELOPMENT (NED) FLOOD DAMAGE AND BENEFIT CALCULATIONS

HEC-FDA Model Calculations. The HEC-FDA model version 1.4.2 was utilized to evaluate flood damages using risk-based analysis. Damages were reported for each of the 8 study area reaches. 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 an equivalent record length for each stream 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.

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 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.

Stage-Probability Relationships with Uncertainty. The HEC-FDA model used an equivalent record length of 87 years for each study area reach assigned to the Trempealeau River (Reaches 1-7) to generate a stage-probability relationship with uncertainty for the without-project and with-project conditions through the use of analytical analysis with Log Pearson III Statistics. The model used an equivalent record length of 38 years for the study are reach assigned to Turton Creek (Reach 8) to generate a stage-probability relationship with uncertainty for the without-project and with-project 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.

Without-Project Expected Annual Damages. The model used Monte Carlo simulations 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 weighting 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 expected annual damages (EAD) were totaled for each study area reach to obtain the total without-project EAD under base year conditions.

Table 14 shows the number and type of structures that are damaged by each of annual chance exceedance events for the year 2025 under without-project conditions.

Table 14. Structures Damaged by Category and Probability Event

Annual Chance Exceedance Event (ACE)	0.5	0.2	0.1	0.05	0.02	0.01	0.005	0.002
Residential	33	90	114	127	149	160	166	176
Apartment	0	1	1	1	1	3	4	8
Commercial	7	62	82	92	97	101	102	108
Industrial	1	1	2	2	2	3	3	3
Public	1	1	1	2	2	2	2	2
Ashley	5	9	9	10	10	14	16	18
Ashley Equipment	3	4	4	5	5	5	5	5
Ashley Autos	3	4	4	5	5	5	5	5
Vehicles	33	97	119	132	155	167	175	185
Total	86	269	336	376	426	460	478	510

Table 15 shows the without-project damages for the structure categories for each of the annual chance exceedance events for the year 2025.

Table 15. Expected Annual Damages by Probability Event (2019 price levels, thousands)

Structure Category	Annual Chance Exceedance Event (ACE)							
	0.5	0.2	0.1	0.05	0.02	0.01	0.005	0.002
Residential	$1,165	$3,234	$4,239	$4,916	$6,263	$7,292	$8,083	$9,250
Apartment	$0	$44	$79	$100	$147	$181	$226	$420
Commercial	$152	$1,925	$3,818	$5,494	$7,664	$9,084	$10,421	$12,171
Industrial	$234	$424	$528	$603	$668	$722	$785	$861
Public	$86	$193	$239	$843	$1,400	$1,732	$2,299	$2,626
Ashley	$316	$1,259	$1,825	$2,700	$3,412	$4,304	$5,952	$8,399
Ashley Equipment	$1,440	$4,730	$5,926	$7,237	$12,108	$14,786	$17,313	$19,640
Ashley Autos	$227	$794	$942	$1,077	$1,754	$2,416	$2,837	$3,268
Vehicles	$66	$237	$397	$508	$670	$798	$935	$1,121
Total	$3,686	$12,841	$17,993	$23,478	$34,085	$41,315	$48,850	$57,756

Expected Annual Damages and Benefits for the Project Alternatives. The HEC-FDA model was used to calculate the 2025 expected annual damages for the final array of plans. In addition to the without project plan, the final array included various levee heights corresponding to flood risk reduction at the following flows: 13,200 CFS, 15,500 CFS, 35,000 CFS, and 45,000 CFS. Table 16 shows the base year expected annual damages by plan and category.

Table 16. Expected Annual Damages by Plan and Category (2019 price level, thousands)

Structure Category	Plan				
	Without	13,200 CFS Levees	15,500 CFS Levees	35,000 CFS Levees*	45,000 CFS Levees
Residential	$454	$335	$235	$120	$121
Apartment	$19	$19	$11	$1	$1
Commercial	$613	$341	$192	$41	$40
Industrial	$46	$21	$10	$0	$0
Public	$126	$66	$35	$0	$0
Ashley	$381	$279	$178	$3	$0
Ashley Equipment	$889	$441	$234	$1	$0
Ashley Autos	$139	$68	$36	$0	$0
Vehicles	$54	$38	$25	$10	$10
Total	$2,720	$1,608	$956	$177	$172

* indicates Recommended Plan

Table 17 shows the base year expected annual damages reduced by plan and reach.

Table 17. Expected Annual Damages and Benefits by Plan and Reach (2019 price level, thousands)

Damage Reach Name	13,200 CFS Levees			15,500 CFS Levees		
	Total Without Project	Total With Project	Damage Reduced	Total Without Project	Total With Project	Damage Reduced
1	$4	$4	$0	$4	$4	$0
2	$95	$123	-$28	$95	$123	-$28
3	$17	$31	-$14	$17	$31	-$14
4	$2	$3	-$1	$2	$3	-$1
5	$3	$4	$0	$3	$4	$0
6	$1,528	$856	$672	$1,528	$482	$1,046
7	$1,015	$523	$492	$1,015	$266	$749
8	$57	$65	-$8	$57	$44	$13
Total	$2,720	$1,608	$1,112	$2,720	$956	$1,764
Damage Reach Name	**35,000 CFS Levees (Recommended Plan)**			**45,000 CFS Levees**		
	Total Without Project	**Total With Project**	**Damage Reduced**	**Total Without Project**	**Total With Project**	**Damage Reduced**
1	$4	$4	$0	$4	$4	$0
2	$95	$128	-$33	$95	$128	-$33
3	$17	$36	-$19	$17	$37	-$20
4	$2	$3	-$1	$2	$3	-$1
5	$3	$0	$3	$3	$0	$3
6	$1,528	$4	$1,524	$1,528	$0	$1,528
7	$1,015	$1	$1,014	$1,015	$0	$1,015
8	$57	$0	$57	$57	$0	$57
Total	$2,720	$177	$2,543	$2,720	$172	$2,548

6. PROJECT COSTS OF THE STRUCTURAL ALTERNATIVE PLANS EVALUATED

Construction Schedule. Construction of all levee alternatives are expected to take three full construction seasons to build. Construction will continue through the year 2025, which is established as the base year for analysis.

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 (2025). 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. Midyear discounting was used in the calculations.

The operations, maintenance, repair, rehabilitation, and replacement (OMRR&R) costs are very similar for all plans considered and are scalable for the larger plans, which require larger sized equipment (such as pumps). The FY 2020 Federal interest rate of 2.75 percent was used to discount the costs from the OMRR&R schedule to the base year and then amortize the costs over the 50-year period of analysis. Midyear discounting was used in the calculations. Please see the Engineering Appendix for more information about the individual tasks that make up the OMRR&R schedule. Table 18 shows a summary of the annualization of project costs by plan.

Table 18. Annualization of Project Costs by Plan (2019 price level, 2.75% interest rate, $ thousands)

13,200 CFS Levees

Project Year	Discounting/ Compounding Year	Calendar Year	Construction Costs	Compounded Value	Compound Factor
	2.5	2022	$7,170	$7,673	1.070
	1.5	2023	$7,170	$7,468	1.042
	0.5	2024	$7,170	$7,268	1.014
1	-0.5	2025	$0	$0	0.987
			…		
50	-49.5	2074	$0	$0	0.261
		Total:	$21,510	$22,409	

Federal Discount Rate:	0.0275	Total Construction Costs:	$22,409
Amortization Factor:	0.0370	Average Annual Construction Costs:	$830
Implementation Costs:	$21,510	Annual OMRR&R Costs:	$91
Interest During Construction:	$899	Total Average Annual Costs:	**$921**

15,500 CFS Levees

Project Year	Discounting/ Compounding Year	Calendar Year	Construction Costs	Compounded Value	Compound Factor
	2.5	2022	$7,215	$7,721	1.070
	1.5	2023	$7,215	$7,514	1.042
	0.5	2024	$7,215	$7,313	1.014
1	-0.5	2025	$0	$0	0.987
			…		
50	-49.5	2074	$0	$0	0.261
		Total:	$21,644	$22,548	

Federal Discount Rate:	0.0275	Total Construction Costs:	$22,548
Amortization Factor:	0.0370	Average Annual Construction Costs:	$835
Implementation Costs:	$21,644	Annual OMRR&R Costs:	$92
Interest During Construction:	$904	Total Average Annual Costs:	**$927**

35,000 CFS Levees (Recommended Plan)

Project Year	Discounting/ Compounding Year	Calendar Year	Construction Costs	Compounded Value	Compound Factor
	2.5	2022	$9,040	$9,674	1.070
	1.5	2023	$9,040	$9,415	1.042

	0.5	2024	$9,040	$9,163	1.014
1	-0.5	2025	$0	$0	0.987
			…		
50	-49.5	2074	$0	$0	0.261
		Total:	$27,120	$28,253	

Federal Discount Rate:	0.0275	Total Construction Costs:	$28,253
Amortization Factor:	0.0370	Average Annual Construction Costs:	$1,047
Implementation Costs:	$27,120	Annual OMRR&R Costs:	$133
Interest During Construction:	$1,133	Total Average Annual Costs:	**$1,180**

45,000 CFS Levees

Project Year	Discounting/ Compounding Year	Calendar Year	Construction Costs	Compounded Value	Compound Factor
	2.5	2022	$9,152	$9,794	1.070
	1.5	2023	$9,152	$9,532	1.042
	0.5	2024	$9,152	$9,277	1.014
1	-0.5	2025	$0	$0	0.987
			…		
50	-49.5	2074	$0	$0	0.261
		Total:	$27,455	$28,602	

Federal Discount Rate:	0.0275	Total Construction Costs:	$28,602
Amortization Factor:	0.0370	Average Annual Construction Costs:	$1,059
Implementation Costs:	$27,455	Annual OMRR&R Costs:	$140
Interest During Construction:	$1,147	Total Average Annual Costs:	**$1,200**

7. RESULTS OF THE ECONOMIC ANALYSIS

7.1. Net Benefit Analysis

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 35,000 CFS levee system to be the NED plan, which is also the PDT's Recommended Plan. Table 19 shows the net benefits for each plan.

After Plan 3 was selected as the NED Plan and Recommended Plan, the team refined the features and costs. The final Recommended Plan features, costs and benefits are documented in the main report. See section 3.10.9 of the main report for the final economic summary for the Recommended Plan.

Table 19. Total Expected Annual Net Benefits by Plan (2019 price level, 2.75% interest rate, $ thousands)

13,200 CFS Levees

Without Project Damages	With Project Damages	Benefits
$2,720	$1,608	$1,112

First Costs:	$21,510
Interest During Construction:	$899
Annual Operation & Maintenance Costs:	$91
Total Annual Costs:	$921
B/C Ratio:	**1.21**
Expected Annual Net Benefits:	**$191**

15,500 CFS Levees

Without Project Damages	With Project Damages	Benefits
$2,720	$956	$1,764

First Costs:	$21,644
Interest During Construction:	$904
Annual Operation & Maintenance Costs:	$92
Total Annual Costs:	$927
B/C Ratio:	**1.90**
Expected Annual Net Benefits:	**$837**

35,000 CFS Levees (Recommended Plan)

Without Project Damages	With Project Damages	Benefits
$2,720	$177	$2,543

First Costs:	$27,120
Interest During Construction:	$1,133
Annual Operation & Maintenance Costs:	$133
Total Annual Costs:	$1,180
B/C Ratio:	**2.16**
Expected Annual Net Benefits:	**$1,363**

45,000 CFS Levees

Without Project Damages	With Project Damages	Benefits
$2,720	$172	$2,548

First Costs:	$27,455
Interest During Construction:	$1,147
Annual Operation & Maintenance Costs:	$140
Total Annual Costs:	$1,200

B/C Ratio:	**2.12**
Expected Annual Net Benefits:	**$1,348**

7.2. Risk Analysis

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 20 shows the expected annual damages 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. This is the chance that the benefit-cost ratio is greater than one and the net benefits are positive.

Table 20. Probability that Expected Annual Benefits Exceed Annual Costs by Plan (2019 price levels, 2.75% interest rate, $ thousands)

Plan	Expected Annual Benefits	Probability Damage Reduced Exceeds Values			Annual Costs	Probability Benefits Exceed Costs
		75%	50%	25%		
13,200 CFS Levees	$1,112	$17	$211	$1,208	$921	Between 25% and 50%
15,500 CFS Levees	$1,764	$168	$621	$2,023	$927	Between 25% and 50%
35,000 CFS Levees*	$2,543	$246	$903	$2,946	$1,180	Between 25% and 50%
45,000 CFS Levees	$2,548	$246	$904	$2,947	$1,200	Between 25% and 50%

* indicates Recommended Plan

Project Performance. The HEC-FDA model was used to calculate expected project performance for each of the alternatives. The model identified a damage target stage for each reach, which indicates the stage at which significant damages occur. The target stage annual exceedance probability is the probability that the target stage would be exceeded in any given year. The long-term risk is displayed by 10, 30, and 50 year periods. This is the probability that the target stage will be exceeded in the given period of time. These project performance statistics are presented by plan and HEC-FDA reach in Table 21. Only the reaches receiving reduced flood risk from the proposed levee system (reaches 5-8) are displayed.

Table 21. Project Performance by HEC-FDA Reach

Without Project						
HEC-FDA Reach	Target Stage	Target Stage Annual Exceedance Probability		Long-Term Risk (years)		
		Median	Expected	10	30	50
5	726.85	0.0197	0.1367	0.7701	0.9879	0.9994
6	729.62	0.0197	0.0534	0.4223	0.8072	0.9357
7	729.84	0.0222	0.0571	0.4445	0.8286	0.9471
8	738.39	0.0200	0.0394	0.3309	0.7005	0.8659
13,200 CFS Levees						
HEC-FDA Reach	Target Stage	Target Stage Annual Exceedance Probability		Long-Term Risk (years)		
		Median	Expected	10	30	50
5	726.95	0.0186	0.1239	0.7334	0.9811	0.9987
6	730.71	0.0112	0.0227	0.2053	0.4981	0.6830
7	731.19	0.0105	0.0204	0.1858	0.4603	0.6423
8	738.50	0.0178	0.0385	0.3246	0.6919	0.8594
15,500 CFS Levees						
HEC-FDA Reach	Target Stage	Target Stage Annual Exceedance Probability		Long-Term Risk (years)		
		Median	Expected	10	30	50
5	727.18	0.0098	0.0915	0.6170	0.9438	0.9918
6	731.37	0.0051	0.0107	0.1018	0.2754	0.4155
7	731.88	0.0039	0.0092	0.0880	0.2414	0.3690
8	738.95	0.0083	0.0250	0.2233	0.5314	0.7173
35,0000 CFS Levees (Recommended Plan)						
HEC-FDA Reach	Target Stage	Target Stage Annual Exceedance Probability		Long-Term Risk (years)		
		Median	Expected	10	30	50
5	730.18	0.0001	0.0003	0.0029	0.0087	0.0145

HEC-FDA Reach	Target Stage	Target Stage Annual Exceedance Probability		Long-Term Risk (years)		
		Median	Expected	10	30	50
6	734.87	0.0001	0.0002	0.0022	0.0067	0.0112
7	735.38	0.0001	0.0002	0.0021	0.0063	0.0105
8	742.45	0.0001	0.0002	0.0016	0.0048	0.0079
45,000 CFS Levees						
HEC-FDA Reach	Target Stage	Target Stage Annual Exceedance Probability		Long-Term Risk (years)		
		Median	Expected	10	30	50
5	740.76	0.0001	0.0002	0.0019	0.0056	0.0094
6	736.20	0.0001	0.0002	0.0019	0.0056	0.0094
7	736.65	0.0001	0.0002	0.0019	0.0057	0.0094
8	743.50	0.0001	0.0001	0.0010	0.0031	0.0051

The HEC-FDA model also computed conditional non-exceedance probabilities by frequency event. This is the probability that the target stage will not be exceeded by the given frequency event. In the table below, there is a 66.51% chance that the target stage will not be exceeded by a 0.10 annual exceedance probability event. These project performance statistics are presented by plan and HEC-FDA reach in Table 22. Only the reaches receiving reduced flood risk from the proposed levee system (reaches 5-8) are displayed.

Table 22. Project Performance by HEC-FDA Reach (cont.)

Without Project							
HEC-FDA Reach	Target Stage	Conditional Non-Exceedance Probability by Events					
		0.10	0.04	0.02	0.01	0.004	0.002
5	726.85	0.6651	0.5734	0.4898	0.3976	0.2849	0.2313
6	729.62	0.8316	0.6485	0.4901	0.3404	0.1965	0.1369
7	729.84	0.8126	0.6205	0.4658	0.3297	0.2002	0.1491
8	738.39	0.8912	0.6398	0.4757	0.3540	0.2393	0.1826
13,200 CFS Levees							
HEC-FDA Reach	Target Stage	Conditional Non-Exceedance Probability by Events					
		0.10	0.04	0.02	0.01	0.004	0.002
5	726.95	0.6897	0.5895	0.4999	0.4098	0.3097	0.2610
6	730.71	0.9677	0.8393	0.6564	0.4480	0.2385	0.1613

7	731.19	0.9761	0.8576	0.6775	0.4722	0.2722	0.2014
8	738.50	0.8903	0.6626	0.5001	0.3758	0.2553	0.1941
15,500 CFS Levees							
HEC-FDA Reach	Target Stage	Conditional Non-Exceedance Probability by Events					
		0.10	0.04	0.02	0.01	0.004	0.002
5	727.18	0.7659	0.6757	0.5901	0.4998	0.3941	0.3411
6	731.37	0.9933	0.9475	0.8454	0.6813	0.4620	0.3620
7	731.88	0.9955	0.9575	0.8651	0.7145	0.5202	0.4358
8	738.95	0.9455	0.7851	0.6403	0.5150	0.3840	0.3137
35,000 CFS Levees (Recommended Plan)							
HEC-FDA Reach	Target Stage	Conditional Non-Exceedance Probability by Events					
		0.10	0.04	0.02	0.01	0.004	0.002
5	730.18	0.9998	0.9996	0.9991	0.9978	0.9947	0.9923
6	734.87	1.0000	1.0000	1.0000	0.9995	0.9965	0.9930
7	735.38	1.0000	1.0000	1.0000	0.9997	0.9977	0.9955
8	742.45	1.0000	0.9998	0.9991	0.9980	0.9966	0.9956
45,000 CFS Levees							
HEC-FDA Reach	Target Stage	Conditional Non-Exceedance Probability by Events					
		0.10	0.04	0.02	0.01	0.004	0.002
5	740.76	0.9999	0.9999	1.0000	0.9999	0.9997	0.9996
6	736.20	1.0000	1.0000	1.0000	1.0000	0.9998	0.9997
7	736.65	1.0000	1.0000	1.0000	1.0000	0.9998	0.9997
8	743.50	1.0000	1.0000	1.0000	0.9998	0.9998	0.9998

7.3. Induced Damages

Right Bank Inducements. All plans were found to cause low level inducements in reaches 1-4, which do not receive structural risk reduction measures. To analyze the inducements for the recommended plan, overall induced damages were analyzed as well as inducements resulting in either new first floor flooding or worsened first floor flooding. This analysis was conducted structure-by-structure using the Structure Detail Output from the HEC-FDA model. These inducements are captured in all benefit calculations. Table 23 below shows the overall number of structures inundated and total induced damages by AEP and category. Inundations specific to the first floor are displayed in Table 24. It should be noted that these tables differ from section 3.9.3 of the Main Report as they do not incorporate uncertainty or the effectiveness of Willow Street as a barrier to flooding.

Table 23. Structures Inundated by the Recommended Plan by AEP and Category (2019 price level, $ thousands)

35,000 CFS Levees (Recommended Plan)								
Annual Exceedance Probability (AEP)	Apartment		Residential		Commercial		Total Structures Induced Upon	Total Induced Damages
	Induced Structures	Total Induced Damages	Induced Structures	Total Induced Damages	Induced Structures	Total Induced Damages		
0.5	0	$0	0	$0	0	$0	0	$0
0.2	0	$0	5	$1	2	$2	7	$3
0.1	0	$0	5	$7	2	$6	7	$12
0.05	0	$0	13	$168	3	$12	16	$181
0.02	0	$0	23	$261	6	$86	29	$347
0.01	0	$0	30	$432	6	$83	36	$516
0.005	0	$0	41	$822	7	$111	48	$933
0.002	1	$12	55	$1,455	11	$295	67	$1,762
Expected Annual Inducements								$28

Table 24. Structures with New or Increased First Floor Flooding with the Recommended Plan by AEP and Category

35,000 CFS Levees (Final Recommended Plan)						
Annual Exceedance Probability (AEP)	Inducements Impacting the First Floor		Increased First Floor Flooding		Newly Impacting First Floor	
	Induced Structures	Avg. Inducement (feet)	Induced Structures	Avg. Inducement (feet)	Induced Structures	Avg. Inducement (feet)
0.5	0	0.00	0	0.00	0	0.00
0.2	2	0.02	2	0.02	0	0.00
0.1	2	0.10	2	0.10	0	0.00
0.05	5	0.17	5	0.17	0	0.00
0.02	13	0.45	8	0.37	5	0.57
0.01	18	0.67	12	0.57	6	0.86
0.005	21	0.91	14	0.75	7	1.22
0.002	36	1.37	18	1.23	18	1.50

8. FINAL BENEFIT-COST ANALYSIS

Refined Cost. After optimization, costs associated with real estate and components related to the railroad were refined to provide better detail than in previous iterations of analysis. While these cost increases were substantial and only provided for the Recommended Plan, the increase was determined qualitatively to be of a similar scale across all plans analyzed during the optimization process. For this reason, the 35,000 CFS Levees plan remains both the Recommended Plan and the NED Plan. Tables 25-27 below show the annualization of project costs, net benefit analysis, and benefit exceedance probability relationship for the Final Recommended Plan.

Table 25. Annualization of Project Costs for Final Recommended Plan (2019 price level, 2.75% interest rate, $ thousands)

35,000 CFS Levees (Final Recommended Plan)

Project Year	Discounting/ Compounding Year	Calendar Year	Construction Costs	Compounded Value	Compound Factor
	2.5	2022	$12,281	$13,142	1.070
	1.5	2023	$12,281	$12,791	1.042
	0.5	2024	$12,281	$12,448	1.014
1	-0.5	2025	$0	$0	0.987
			…		
50	-49.5	2074	$0	$0	0.261
		Total:	$36,842	$38,382	

Federal Discount Rate:	0.0275	Total Construction Costs:	$38,382
Amortization Factor:	0.0370	Average Annual Construction Costs:	$1,422
Implementation Costs:	$36,842	Annual OMRR&R Costs:	$133
Interest During Construction:	$1,540	Total Average Annual Costs:	**$1,555**

Table 26. Total Expected Annual Net Benefits for Final Recommended Plan (2019 price level, 2.75% interest rate, $ thousands)

35,000 CFS Levees (Final Recommended Plan)		
Without Project Damages	With Project Damages	Benefits
$2,720	$177	$2,543

First Costs:	$36,842
Interest During Construction:	$1,540
Annual Operation & Maintenance Costs:	$133
Total Annual Costs:	$1,555
B/C Ratio:	**1.64**
Expected Annual Net Benefits:	**$988**

Table 27. Probability that Expected Annual Benefits Exceed Annual Costs for Final Recommended Plan (2019 price levels, 2.75% interest rate, $ thousands)

Plan	Expected Annual Benefits	Probability Damage Reduced Exceeds Values			Annual Costs	Probability Benefits Exceed Costs
		75%	50%	25%		
35,000 CFS Levees	$2,543	$246	$903	$2,946	$1,555	Between 25% and 50%

Attachment 1 – Depth-Damage Tables

Tables 28-44 show the damage relationships for structure and contents. The tables contain the damage percentages at each depth of flooding along with the uncertainty surrounding the damage percentages.

Table 28. Depth-Damage Relationships for Structures & Contents

Residential		
One Story without Basement		
RS-OS-NB		
Depth in Structure	Structure Percent Damage	Structure Standard Deviation
-9	0	0
-8	0	0
-7	0	0
-6	0	0
-5	0	0
-4	0	0
-3	0	0
-2	0	0
-1	2.5	2.7
0	13.4	2
1	23.3	1.6
2	32.1	1.6
3	40.1	1.8
4	47.1	1.9
5	53.2	2
6	58.6	2.1
7	63.2	2.2
8	67.2	2.3
9	70.5	2.4
10	73.2	2.7
11	75.4	3
12	77.2	3.3
13	78.5	3.7
14	79.5	4.1

Residential		
One Story with Basement		
RS-OS-WB		
Depth in Structure	Structure Percent Damage	Structure Standard Deviation
-9	0	0
-8	0	0
-7	0.7	1.34
-6	0.8	1.06
-5	2.4	0.94
-4	5.2	0.91
-3	9	0.88
-2	13.8	0.85
-1	19.4	0.83
0	25.5	0.85
1	32	0.96
2	38.7	1.14
3	45.5	1.37
4	52.2	1.63
5	58.6	1.89
6	64.5	2.14
7	69.8	2.35
8	74.2	2.52
9	77.7	2.66
10	80.1	2.77
11	81.1	2.88
12	81.1	2.88
13	81.1	2.88
14	81.1	2.88

15	80.2	4.5
16	80.7	4.9

15	81.1	2.88
16	81.1	2.88

Depth in Structure	Contents Percent Damage	Contents Standard Deviation
-9	0	0
-8	0	0
-7	0	0
-6	0	0
-5	0	0
-4	0	0
-3	0	0
-2	0	0
-1	2.4	2.1
0	8.1	1.5
1	13.3	1.2
2	17.9	1.2
3	22	1.4
4	25.7	1.5
5	28.8	1.6
6	31.5	1.6
7	33.8	1.7
8	35.7	1.8
9	37.2	1.9
10	38.4	2.1
11	39.2	2.3
12	39.7	2.6
13	40	2.9
14	40	3.2
15	40	3.5
16	40	3.8

Depth in Structure	Contents Percent Damage	Contents Standard Deviation
-9	0	0
-8	0.1	1.6
-7	0.8	1.16
-6	2.1	0.92
-5	3.7	0.81
-4	5.7	0.78
-3	8	0.76
-2	10.5	0.74
-1	13.2	0.72
0	16	0.74
1	18.9	0.83
2	21.8	0.98
3	24.7	1.17
4	27.4	1.39
5	30	1.6
6	32.4	1.81
7	34.5	1.99
8	36.3	2.13
9	37.7	2.25
10	38.6	2.35
11	39.1	2.45
12	39.1	2.45
13	39.1	2.45
14	39.1	2.45
15	39.1	2.45
16	39.1	2.45

Table 29. Depth-Damage Relationships for Structures & Contents

Residential		
Two Story with Basement		
RS-TS-WB		
Depth in Structure	Structure Percent Damage	Structure Standard Deviation
-9	0	0
-8	1.7	2.7
-7	1.7	2.7
-6	1.9	2.11
-5	2.9	1.8
-4	4.7	1.66
-3	7.2	1.56
-2	10.2	1.47
-1	13.9	1.37
0	17.9	1.32
1	22.3	1.35
2	27	1.5
3	31.9	1.75
4	36.9	2.04
5	41.9	2.34
6	46.9	2.63
7	51.8	2.89
8	56.4	3.13
9	60.8	3.38
10	64.8	3.71
11	68.4	4.22
12	71.4	5.02
13	73.7	6.19
14	75.7	7.79
15	76.4	9.84
16	76.4	12.36

Residential		
Split Level without Basement		
RS-SL-NB		
Depth in Structure	Structure Percent Damage	Structure Standard Deviation
-2	0	0
-1	6.4	2.9
0	7.2	2.1
1	9.4	1.9
2	12.9	1.9
3	17.4	2
4	22.8	2.2
5	28.9	2.4
6	35.5	2.7
7	42.3	3.2
8	49.2	3.8
9	56.1	4.5
10	62.6	5.3
11	68.6	6
12	73.9	6.7
13	78.4	7.4
14	81.7	7.9
15	83.8	8.3
16	84.4	8.7

Residential	
Mobile Home	
RS-MH	
Depth in Structure	Structure Percent Damage
0	0
1	38.6
2	42.2
3	59.2
4	76.2
5	93.2
6	93.2
Depth in Structure	Contents Percent Damage
0	0
1	26.6
2	53.2
3	62.4
4	71.5
5	80.6
6	80.6

Depth in Structure	Contents Percent Damage	Contents Standard Deviation
-9	0	0
-8	0	0
-7	1	2.27
-6	2.3	1.76
-5	3.7	1.49
-4	5.2	1.37
-3	6.8	1.29
-2	8.4	1.21
-1	10.1	1.13
0	11.9	1.09
1	13.8	1.11
2	15.7	1.23
3	17.7	1.43
4	19.8	1.67
5	22	1.92
6	24.3	2.15
7	26.7	2.36
8	29.1	2.56
9	31.7	2.76
10	34.4	3.04
11	37.2	3.46
12	40	4.12
13	43	5.08
14	46.1	6.39
15	49.3	8.08
16	52.6	10.15

Depth in Structure	Contents Percent Damage	Contents Standard Deviation
-2	0	0
-1	2.2	2.2
0	2.9	1.5
1	4.7	1.2
2	7.5	1.3
3	11.1	1.4
4	15.3	1.5
5	20.1	1.6
6	25.2	1.8
7	30.5	2.1
8	35.7	2.5
9	40.9	3
10	45.8	3.5
11	50.2	4.1
12	54.1	4.6
13	57.2	5
14	59.4	5.4
15	60.5	5.7
16	60.5	6

Table 30. Depth-Damage Relationships for Structures & Contents (cont.)

Apartment			
Apartment			
APT-E			
Depth in Structure	Structure Percent Damage	Structure Lower Percent	Structure Upper Percent
-1	0	0	0.7
-0.5	0	0	0.7
0	0	0	1.9
0.5	6.4	4.5	11.3
1	9.5	7.6	16.8
1.5	12.7	9.7	21.6
2	19.1	13.9	27.6
3	21.8	18.1	34
4	30.5	22.3	39.2
5	32.6	29.2	45.2
6	35	29.6	45.2
7	35.5	29.9	56.1
8	41.4	31.1	58.9
9	43.8	34.2	64.3
10	45.5	39.2	70.4
Depth in Structure	Contents Percent Damage	Contents Lower Percent	Contents Upper Percent
-1	0	0	0
-0.5	0	0	0
0	0	0	0
0.5	14.3	10	18
1	21.7	15	25
1.5	26.6	20	32
2	30.4	25	37
3	39	30	45

Commercial			
Clothing Store			
CLOTH-E			
Depth in Structure	Structure Percent Damage	Structure Lower Percent	Structure Upper Percent
-1	0	0	0.8
-0.5	0	0	0.8
0	0	0	1.9
0.5	7	4.4	12.3
1	9.6	7	18
1.5	12.8	8.8	23.5
2	18.4	11.4	28.9
3	20	14	34.6
4	32	19.2	43.1
5	34.9	28	49.2
6	39.5	30.8	51.5
7	42	33	62.7
8	45.5	33.2	65.4
9	50.2	39	66.9
10	52	43.6	69.2
Depth in Structure	Contents Percent Damage	Contents Lower Percent	Contents Upper Percent
-1	0	0	0
-0.5	0	0	0
0	0	0	0
0.5	12.3	8	18
1	29	17.8	37.8
1.5	38.4	27.8	45.5
2	46.3	35.5	54.5
3	55.4	48	65

4	45	37.5	53
5	47.9	42	55
6	51.9	45	60
7	55.7	50	65
8	59.3	55	70
9	60.6	58	75
10	63.4	60	80

4	70	60	80
5	79	67.5	85
6	89	78	96
7	95.7	88	98
8	97.9	94	100
9	97.9	94	100
10	99.3	96	100

Table 31. Depth-Damage Relationships for Structures & Contents (cont.)

Commercial			
Convenience Store			
CONV-E			
Depth in Structure	Structure Percent Damage	Structure Lower Percent	Structure Upper Percent
-1	0	0	0.7
-0.5	0	0	0.7
0	0	0	1.7
0.5	8.6	5.6	13.3
1	11.7	8.7	20
1.5	15.4	11.2	26.7
2	20.4	14.3	30
3	25.8	19.2	38.3
4	37.6	26	48.3
5	42.7	34.7	53.3
6	47.6	38.4	56
7	51.6	42.1	68
8	58	45.8	70
9	60.1	50.8	71.3
10	61.6	53.9	73.3
Depth in Structure	Contents Percent Damage	Contents Lower Percent	Contents Upper Percent
-1	0	0	0

Commercial			
Electronics Store			
ELEC-E			
Depth in Structure	Structure Percent Damage	Structure Lower Percent	Structure Upper Percent
-1	0	0	0.8
-0.5	0	0	0.9
0	0	0	2.2
0.5	5.8	3.4	11.3
1	8.3	5.8	16.5
1.5	11.7	7.6	21.9
2	16.7	10.3	27.5
3	18.5	13.4	33.8
4	29.2	16.5	40
5	31.5	24.4	45.4
6	35.5	26.4	47.3
7	38.3	28.3	60.2
8	44.5	30.1	63.4
9	48.1	35.8	65.1
10	50	40.8	67.5
Depth in Structure	Contents Percent Damage	Contents Lower Percent	Contents Upper Percent
-1	0	0	0

-0.5	0	0	0
0	0	0	0
0.5	11.6	5	15
1	23.1	12.7	28
1.5	32.1	20	38
2	39.9	30	45
3	52.9	40	60
4	70.7	60	78
5	79.3	70	85
6	88	80	95
7	94.1	90	100
8	95.7	92	100
9	97.1	95	100
10	98.6	97	100

-0.5	0	0	0
0	0	0	0
0.5	10.9	5	15
1	23	15	30
1.5	28.7	20	36
2	34.1	28	45
3	44.3	36	52
4	67	58	75
5	77.7	68	85
6	86.7	75	92.5
7	95.4	82.5	98
8	97.4	90	100
9	98.6	95	100
10	98.6	97.5	100

Table 32. Depth-Damage Relationships for Structures & Contents (cont.)

Commercial			
Fast Food Restaurant			
FFR-E			
Depth in Structure	Structure Percent Damage	Structure Lower Percent	Structure Upper Percent
-1	0	0	0.5
-0.5	0	0	0.5
0	0	0	1.2
0.5	7.5	4	12.6
1	13.5	9.7	20.8
1.5	17.5	13.3	26.8
2	23.5	16.8	32.9
3	27.5	20.4	40.5
4	42.5	31.8	53.3
5	48.1	40.8	61
6	54.7	46	65.1
7	60	51.2	75
8	62.2	53.8	78.6

Commercial			
Furniture Store			
FURN-E			
Depth in Structure	Structure Percent Damage	Structure Lower Percent	Structure Upper Percent
-1	0	0	0.9
-0.5	0	0	0.9
0	0	0	2.3
0.5	5.8	3.4	10.8
1	8.5	6	16.7
1.5	11.7	7.8	22.3
2	17.5	10.6	28.5
3	19.2	13.7	34.6
4	28.3	16.3	40
5	30.1	23.6	45.1
6	32.9	24.6	46.1
7	33.3	25.1	57
8	38.7	26.3	60

9	68.9	60.1	79.5
10	70	63.8	81

9	41.4	30.7	62.1
10	43.3	35.1	64.9

Depth in Structure	Contents Percent Damage	Contents Lower Percent	Contents Upper Percent
-1	0	0	0
-0.5	0	0	0
0	0	0	0
0.5	10.6	5	15
1	21.3	15	28
1.5	29.4	20	36
2	38.6	30	50
3	52.7	44	60
4	62.6	54	72.5
5	73	65	80
6	79.3	72.5	85
7	88.3	80	95
8	94.9	85	100
9	98.6	90	100
10	98.6	92	100

Depth in Structure	Contents Percent Damage	Contents Lower Percent	Contents Upper Percent
-1	0	0	0
-0.5	0	0	0
0	0	0	0
0.5	39.9	25	45
1	46.9	33	55
1.5	53.3	44	64
2	61.9	50	70
3	68.1	55	75
4	79.1	70	86
5	85.7	75	95
6	90.7	82	95
7	97.1	85	100
8	99.3	93	100
9	99.3	95	100
10	99.3	98	100

Table 33. Depth-Damage Relationships for Structures & Contents (cont.)

Commercial			
Grocery Store			
GROC-E			
Depth in Structure	Structure Percent Damage	Structure Lower Percent	Structure Upper Percent
-1	0	0	0
-0.5	0.1	0	0.8
0	0.3	0	0.8
0.5	0.4	0	1.9
1	7	3.8	11.2
1.5	10.1	6	16.2
2	14.6	8.6	22.3

Commercial			
Medical Office			
MED-E			
Depth in Structure	Structure Percent Damage	Structure Lower Percent	Structure Upper Percent
-1	0	0	0.6
-0.5	0	0	0.6
0	0	0	1.4
0.5	6.2	4	10
1	10.2	6.6	17.2
1.5	14.9	10.7	22.2
2	20.6	14.2	28.6

3	17.7	10.9	27.5
4	21.1	14	34.2
5	27	17.7	41.7
6	31.6	25	47.4
7	36.1	28	50.8
8	39.6	31	62.1
9	44.8	33	65.4
10	47.9	38	66.9

Depth in Structure	Contents Percent Damage	Contents Lower Percent	Contents Upper Percent
-1	0	0	0
-0.5	0	0	0
0	0	0	0
0.5	24	10	30
1	30.7	20	38
1.5	36.8	25	44
2	40.9	27	50
3	52.9	35	60
4	64	48	75
5	75.4	60	82
6	87.3	70	95
7	98.9	80	100
8	100	100	100
9	100	100	100
10	100	100	100

3	24.5	19.4	35.8
4	36.3	26.6	46.1
5	40.3	32.5	52.8
6	50.5	40.8	60
7	53.2	43.9	69.4
8	56.7	47	75
9	60.9	51	76.1
10	64.2	58.1	77.8

Depth in Structure	Contents Percent Damage	Contents Lower Percent	Contents Upper Percent
-1	0	0	0
-0.5	0	0	0
0	0	0	0
0.5	9	5	15
1	14.3	10	20
1.5	18.4	14	30
2	26.9	20	34
3	40.4	30	50.5
4	57.1	44	70
5	67.3	50	80
6	75.4	65	90
7	82.3	75	100
8	91.3	80	100
9	96.3	85	100
10	96.9	92.5	100

Table 34. Depth-Damage Relationships for Structures & Contents (cont.)

Commercial			
Engineered Office Building			
OFF-E			
Depth in Structure	Structure Percent Damage	Structure Lower Percent	Structure Upper Percent
-1	0	0	0.5
-0.5	0	0	0.5
0	0	0	1.3
0.5	8.7	3.9	12.4
1	10.9	7.4	17.4
1.5	14.9	10.2	22.4
2	17.9	11.3	27.4
3	22.3	15.9	33.9
4	27.4	18.1	37.4
5	30.5	24.7	42.4
6	35.6	27.1	45.8
7	42.2	34.1	58.8
8	51.8	38.8	69.5
9	58.4	46.2	75.3
10	59.6	51.2	76.9
Depth in Structure	Contents Percent Damage	Contents Lower Percent	Contents Upper Percent
-1	0	0	0.1
-0.5	0	0	0.9
0	0	0	0.9
0.5	10	5	20
1	20	12.2	25
1.5	25	20	32.2
2	30	28	42.5
3	40	35	55

Commercial			
Pre-Engineered Office Building			
OFF-P			
Depth in Structure	Structure Percent Damage	Structure Lower Percent	Structure Upper Percent
-1	0	0	0
-0.5	0	0	0
0	0	0	2.1
0.5	9.2	3.5	12.9
1	12.8	7.6	17.9
1.5	15.6	10.2	22.9
2	18.4	12.6	27.9
3	25.6	18.9	34.6
4	25.6	20.2	37.9
5	30.6	25.2	42.9
6	36.7	27.7	55.5
7	45.3	35.5	62.9
8	56.8	43.1	78.6
9	62.4	50.6	84.3
10	62.4	55.6	88.6
Depth in Structure	Contents Percent Damage	Contents Lower Percent	Contents Upper Percent
-1	0	0	0.1
-0.5	0	0	0.9
0	0	0	0.9
0.5	10	5	20
1	20	12.2	25
1.5	25	20	32.2
2	30	28	42.5
3	40	35	55

4	57.5	45	65	4	57.5	45	65
5	70	54	72.5	5	70	54	72.5
6	80	65	81	6	81	65	80
7	83.8	70	95	7	95	70	83.8
8	100	78	100	8	100	78	100
9	100	80	100	9	100	80	100
10	100	87.5	100	10	100	87.5	100

Table 35. Depth-Damage Relationships for Structures & Contents (cont.)

Commercial			
Restaurant			
REST-E			
Depth in Structure	Structure Percent Damage	Structure Lower Percent	Structure Upper Percent
-1	0	0	0.6
-0.5	0	0	0.6
0	0	0	1.6
0.5	8.5	4.6	13.6
1	11.6	8.6	20.4
1.5	15.3	10.4	26.3
2	22	14.2	33.9
3	27.3	19.1	39.3
4	37.3	25.8	49.3
5	42.3	34.5	54.3
6	47.2	38.2	56.1
7	51.1	42.7	68.4
8	57.5	45.5	71.1
9	59.6	50.5	72.4
10	61.1	54.5	74.3
Depth in Structure	Contents Percent Damage	Contents Lower Percent	Contents Upper Percent
-1	0	0	0

Commercial			
Service Station			
SERV-E			
Depth in Structure	Structure Percent Damage	Structure Lower Percent	Structure Upper Percent
-1	0	0	0.8
-0.5	0	0	0.8
0	0	0	1.9
0.5	6	3.3	11.2
1	8.6	5.7	16.2
1.5	12	7.1	21.7
2	17	9.4	27.3
3	18	12	32.3
4	28	14.6	39.4
5	28.9	22	43.7
6	34.5	22.9	45.8
7	37.2	25	58.1
8	42.3	25.7	60.8
9	46.2	32.1	65.1
10	50	37.1	68.8
Depth in Structure	Contents Percent Damage	Contents Lower Percent	Contents Upper Percent
-1	0	0	0

-0.5	0	0	0
0	0	0	0
0.5	17.1	10	21
1	27.7	20	33
1.5	35.9	28	42.5
2	48.9	36	55
3	57.3	47.5	64
4	71.9	65	76
5	79.7	70	85
6	84.9	74	90
7	92.9	80	95
8	93.4	86	100
9	94.3	90	100
10	94.3	90	100

-0.5	0	0	0
0	0.4	0	1
0.5	11.7	5	17.5
1	16.4	10	25
1.5	21.9	14	30
2	28.9	20	38
3	40.9	30	50
4	57.7	45	65
5	63.3	55	75
6	70.7	60	80
7	79.3	70	90
8	84.3	75	95
9	87.1	80	98
10	87.1	80	100

Table 36. Depth-Damage Relationships for Structures & Contents (cont.)

Industrial			
Engineered Light Industrial			
LT-E			
Depth in Structure	Structure Percent Damage	Structure Lower Percent	Structure Upper Percent
-1	0	0	0.7
-0.5	0	0	0.7
0	0	0	1.9
0.5	6.2	3.4	11.3
1	8.9	6	16.8
1.5	12.4	7.8	22.6
2	17.4	10.4	28.4
3	19.8	13	35.2
4	29	16.2	40.2
5	31.8	24.4	46.7
6	36.7	26	49.1
7	37.1	27	60.6
8	45.3	29.2	64.7

Industrial			
Pre-Engineered Light Industrial			
LT-P			
Depth in Structure	Structure Percent Damage	Structure Lower Percent	Structure Upper Percent
-1	0	0	0
-0.5	0	0	0
0	0	0	3.3
0.5	6.5	2.7	11.7
1	11.5	6.2	17.3
1.5	12.9	7.3	23.3
2	17.9	12.3	29.3
3	24.4	17.3	36.7
4	26.5	19.2	41.7
5	32.4	25.1	48.7
6	38.8	26.9	65
7	40.9	28.1	67.5
8	51.8	34.5	77.5

9	51.4	36	68.1
10	53.1	41	70.4

9	56.2	41.5	80
10	56.2	46.5	86.7

Depth in Structure	Contents Percent Damage	Contents Lower Percent	Contents Upper Percent
-1	0	0	0
-0.5	0	0	0
0	0	0	0
0.5	12.1	5	18
1	19.3	12	25
1.5	26.6	20	35
2	31	25	45
3	42.3	33	50
4	52.3	40	66
5	60.7	50	70
6	72	60	80
7	82.1	75	90
8	90.7	80	96
9	94.3	85	100
10	95	90	100

Depth in Structure	Contents Percent Damage	Contents Lower Percent	Contents Upper Percent
-1	0	0	0
-0.5	0	0	0
0	0	0	0
0.5	12.1	5	18
1	19.3	12	25
1.5	26.6	20	35
2	31	25	45
3	42.3	33	50
4	52.3	40	66
5	60.7	50	70
6	72	60	80
7	82.1	75	90
8	90.7	80	96
9	94.3	85	100
10	95	90	100

Table 37. Depth-Damage Relationships for Structures & Contents (cont.)

Industrial			
Engineered Warehouse			
WH-E			
Depth in Structure	Structure Percent Damage	Structure Lower Percent	Structure Upper Percent
-1	0	0	0.8
-0.5	0	0	0.8
0	0	0	1.9
0.5	6	3.3	11.2
1	9.2	6	17.5
1.5	12	7.3	23

Industrial			
Pre-Engineered Warehouse			
WH-P			
Depth in Structure	Structure Percent Damage	Structure Lower Percent	Structure Upper Percent
-1	0	0	0
-0.5	0	0	0
0	0	0	3.5
0.5	6.3	2.5	11.5
1	12	6.2	18.3
1.5	12.5	6.7	23.9

2	18	9.7	29
3	19.2	12.6	34.6
4	30	16	40.8
5	30.9	23.4	46
6	35.5	24.3	48.1
7	38	25.7	59.2
8	42.5	26.6	62.5
9	48.2	32.9	65.8
10	50	37.1	68.8

Depth in Structure	Contents Percent Damage	Contents Lower Percent	Contents Upper Percent
-1	0	0	0
-0.5	0	0	0
0	0	0	0
0.5	13.4	7	20
1	20.7	15	25
1.5	27.6	20	35
2	33.7	25	45
3	47.4	35	55
4	56.9	40	66
5	65.6	50	75
6	73.6	60	85
7	81.3	70	90
8	88.4	76	100
9	91.6	84	100
10	93.6	90	100

2	18.8	11.7	30.3
3	24	17.2	36
4	27.5	19.2	42.5
5	31.3	24	47.8
6	37.5	25	64.5
7	42.3	26.7	66
8	48.8	31.8	75.3
9	52.5	38.3	77.5
10	52.5	42.5	85.4

Depth in Structure	Contents Percent Damage	Contents Lower Percent	Contents Upper Percent
-1	0	0	0
-0.5	0	0	0
0	0	0	0
0.5	13.4	7	20
1	20.7	15	25
1.5	27.6	20	35
2	33.7	25	45
3	47.4	35	55
4	56.9	40	66
5	65.6	50	75
6	73.6	60	85
7	81.3	70	90
8	88.4	76	100
9	91.6	84	100
10	93.6	90	100

Table 38. Depth-Damage Relationships for Structures & Contents (cont.)

Public			
Protective Services			
PS-E			
Depth in Structure	Structure Percent Damage	Structure Lower Percent	Structure Upper Percent
-1	0	0	0.8
-0.5	0	0	0.8
0	0	0	2
0.5	5.8	3.4	11
1	8.3	6	16
1.5	11.6	7.8	21
2	16.6	10.4	26.3
3	17.4	13	32
4	28.9	17.6	40
5	29.9	24.8	45.5
6	33.5	26	47
7	37.3	29.6	59.7
8	42.3	31.3	63
9	45	35.8	65.1
10	48.5	41	67.6
Depth in Structure	Contents Percent Damage	Contents Lower Percent	Contents Upper Percent
-1	0	0	0
-0.5	0	0	0
0	0	0	0
0.5	5	2.8	10
1	15	10	20
1.5	20	15	27.5
2	25	18.8	34
3	40	30	50

Public			
Engineered Recreation Facility			
REC-E			
Depth in Structure	Structure Percent Damage	Structure Lower Percent	Structure Upper Percent
-1	0	0	0.7
-0.5	0	0	0.7
0	0	0	1.7
0.5	6.5	3.6	11.6
1	11	7.6	18.1
1.5	13	9	23.1
2	20.5	13.7	29.7
3	24.1	17.8	36.2
4	35.7	23.9	44.3
5	41	34.1	52.4
6	44.8	36.2	54
7	46.4	37.6	64.5
8	51.3	39.1	69
9	56.7	44.9	70.3
10	58.3	49.1	72.4
Depth in Structure	Contents Percent Damage	Contents Lower Percent	Contents Upper Percent
-1	0	0	0
-0.5	0	0	0
0	0	0	0
0.5	16.9	10	20
1	25.7	17.5	31.5
1.5	31.4	23.8	35
2	43.7	37.5	50
3	62.7	50	67.5

4	50	40	62.5
5	58	48.8	67.5
6	65	58.8	77.5
7	78	70	85
8	90	81.3	97.5
9	90	85	98.8
10	92	88.5	100

4	72.9	66.5	80
5	80	75	87.5
6	84	80	92.5
7	91.1	85	95
8	95	90	100
9	95	91	100
10	95	91.5	100

Table 39. Depth-Damage Relationships for Structures & Contents (cont.)

Public			
Pre-Engineered Recreation Facility			
REC-P			
Depth in Structure	Structure Percent Damage	Structure Lower Percent	Structure Upper Percent
-1	0	0	0
-0.5	0	0	0
0	0	0	3
0.5	6.8	3	12
1	13.7	7.9	18.9
1.5	13.7	8.8	23.9
2	21.6	15.8	30.9
3	29.2	22.2	37.8
4	34.7	27.5	46.7
5	43.4	36	55.7
6	48.4	38.3	69.8
7	51.8	40	71.7
8	58.4	45	81.7
9	62.1	50.8	81.7
10	62.1	55	87.8
Depth in Structure	Contents Percent Damage	Contents Lower Percent	Contents Upper Percent

Public			
Religious Facility			
RF-E			
Depth in Structure	Structure Percent Damage	Structure Lower Percent	Structure Upper Percent
-1	0	0	0.6
-0.5	0	0	0.6
0	0	0	1.4
0.5	8	4.6	12.9
1	12.6	9.5	19.4
1.5	17.7	12.9	26.2
2	23.6	17.4	32.8
3	27.9	22	41.1
4	40	29.3	50.6
5	44.9	38.2	57.8
6	51.1	42.7	62.2
7	55.7	47.3	72.4
8	60.4	51.8	75
9	64.4	56.3	76.1
10	65.7	60.2	77.8
Depth in Structure	Contents Percent Damage	Contents Lower Percent	Contents Upper Percent

-1	0	0	0	-1	0	0	0
-0.5	0	0	0	-0.5	0	0	0
0	0	0	0	0	0	0	0
0.5	16.9	10	20	0.5	19.7	15	25
1	25.7	17.5	31.5	1	29.3	25	35
1.5	31.4	23.8	35	1.5	41.3	35	47.5
2	43.7	37.5	50	2	48.4	42.5	56.3
3	62.7	50	67.5	3	60	50	68
4	72.9	66.5	80	4	69.3	61.3	77.5
5	80	75	87.5	5	76.4	68	85
6	84	80	92.5	6	81.4	75	90
7	91.1	85	95	7	88.4	79	93.8
8	95	90	100	8	94.3	87.5	99
9	95	91	100	9	97.1	90	100
10	95	91.5	100	10	97.1	92.5	100

Table 40. Depth-Damage Relationships for Structures & Contents (cont.)

Public			
Engineered School			
SCH-E			
Depth in Structure	Structure Percent Damage	Structure Lower Percent	Structure Upper Percent
-1	0	0	0.4
-0.5	0	0	0.4
0	0	0	1
0.5	7.6	4.1	12.9
1	11.8	8.9	20.8
1.5	15.3	11	25.8
2	22.9	14.7	31.4
3	28.2	21.1	38.8
4	35.6	27.6	46.7
5	38.8	33.9	51.7
6	40.3	33.9	51.7
7	40.6	33.9	60.6

Public			
Pre-Engineered School			
SCH-P			
Depth in Structure	Structure Percent Damage	Structure Lower Percent	Structure Upper Percent
-1	0	0	0
-0.5	0	0	0
0	0	0	1.7
0.5	8	3.8	13.3
1	13.6	9.2	21.7
1.5	16	11	26.7
2	24	16	32.3
3	32	24	40
4	35	30	48.3
5	40	35	53.3
6	42	35	60
7	43.2	35	64

8	48	36.7	72.5
9	49.5	41.7	73.3
10	50.6	44.4	74.6

Depth in Structure	Contents Percent Damage	Contents Lower Percent	Contents Upper Percent
-1	0	0	0
-0.5	0	0	0
0	0	0	0
0.5	14.3	10	20
1	21.7	15	25
1.5	26.6	20	33
2	30.4	25	40
3	39	30	50
4	45	40	55
5	47.9	45	66
6	51.9	50	72.5
7	55.7	55	75
8	59.3	58	85
9	60.6	59	90
10	63.4	60	90

8	52	40	80
9	52	45	80
10	52	47.6	83.3

Depth in Structure	Contents Percent Damage	Contents Lower Percent	Contents Upper Percent
-1	0	0	0
-0.5	0	0	0
0	0	0	0
0.5	14.3	10	20
1	21.7	15	25
1.5	26.6	20	33
2	30.4	25	40
3	39	30	50
4	45	40	55
5	47.9	45	66
6	51.9	50	72.5
7	55.7	55	75
8	59.3	58	85
9	60.6	59	90
10	63.4	60	90

Table 41. Depth-Damage Relationships for Structures & Contents (cont.)

Ashley			
Light Industrial Manufacturing			
A-LT-E			
Depth in Structure	Structure Percent Damage	Structure Lower Percent	Structure Upper Percent
-1	0	0	0.7
-0.5	0	0	0.7
0	0	0	1.9
0.5	6.2	3.4	11.3
1	8.9	6	16.8

Ashley			
Office			
A-OFF-E			
Depth in Structure	Structure Percent Damage	Structure Lower Percent	Structure Upper Percent
-1	0	0	0.5
-0.5	0	0	0.5
0	0	0	1.3
0.5	8.7	3.9	12.4
1	10.9	7.4	17.4

1.5	12.4	7.8	22.6
2	17.4	10.4	28.4
3	19.8	13	35.2
4	29	16.2	40.2
5	31.8	24.4	46.7
6	36.7	26	49.1
7	37.1	27	60.6
8	45.3	29.2	64.7
9	51.4	36	68.1
10	53.1	41	70.4

Depth in Structure	Contents Percent Damage	Contents Lower Percent	Contents Upper Percent
-1	0	0	0
-0.5	0	0	0
0	0	0	0
0.5	12.1	5	18
1	19.3	12	25
1.5	26.6	20	35
2	31	25	45
3	42.3	33	50
4	52.3	40	66
5	60.7	50	70
6	72	60	80
7	82.1	75	90
8	90.7	80	96
9	94.3	85	100
10	95	90	100

1.5	14.9	10.2	22.4
2	17.9	11.3	27.4
3	22.3	15.9	33.9
4	27.4	18.1	37.4
5	30.5	24.7	42.4
6	35.6	27.1	45.8
7	42.2	34.1	58.8
8	51.8	38.8	69.5
9	58.4	46.2	75.3
10	59.6	51.2	76.9

Depth in Structure	Contents Percent Damage	Contents Lower Percent	Contents Upper Percent
-1	0	0	0.1
-0.5	0	0	0.9
0	0	0	0.9
0.5	10	5	20
1	20	12.2	25
1.5	25	20	32.2
2	30	28	42.5
3	40	35	55
4	57.5	45	65
5	70	54	72.5
6	80	65	81
7	83.8	70	95
8	100	78	100
9	100	80	100
10	100	87.5	100

Table 42. Depth-Damage Relationships for Structures & Contents (cont.)

Ashley			
Restaurant			
A-REST-E			
Depth in Structure	Structure Percent Damage	Structure Lower Percent	Structure Upper Percent
-1	0	0	0.6
-0.5	0	0	0.6
0	0	0	1.6
0.5	8.5	4.6	13.6
1	11.6	8.6	20.4
1.5	15.3	10.4	26.3
2	22	14.2	33.9
3	27.3	19.1	39.3
4	37.3	25.8	49.3
5	42.3	34.5	54.3
6	47.2	38.2	56.1
7	51.1	42.7	68.4
8	57.5	45.5	71.1
9	59.6	50.5	72.4
10	61.1	54.5	74.3
Depth in Structure	Contents Percent Damage	Contents Lower Percent	Contents Upper Percent
-1	0	0	0
-0.5	0	0	0
0	0	0	0
0.5	17.1	10	21
1	27.7	20	33
1.5	35.9	28	42.5
2	48.9	36	55
3	57.3	47.5	64

Ashley			
Pre-Engineered Warehouse			
A-WH-P			
Depth in Structure	Structure Percent Damage	Structure Lower Percent	Structure Upper Percent
-1	0	0	0
-0.5	0	0	0
0	0	0	3.5
0.5	6.3	2.5	11.5
1	12	6.2	18.3
1.5	12.5	6.7	23.9
2	18.8	11.7	30.3
3	24	17.2	36
4	27.5	19.2	42.5
5	31.3	24	47.8
6	37.5	25	64.5
7	42.3	26.7	66
8	48.8	31.8	75.3
9	52.5	38.3	77.5
10	52.5	42.5	85.4
Depth in Structure	Contents Percent Damage	Contents Lower Percent	Contents Upper Percent
-1	0	0	0
-0.5	0	0	0
0	0	0	0
0.5	13.4	7	20
1	20.7	15	25
1.5	27.6	20	35
2	33.7	25	45
3	47.4	35	55

4	71.9	65	76
5	79.7	70	85
6	84.9	74	90
7	92.9	80	95
8	93.4	86	100
9	94.3	90	100
10	94.3	90	100

4	56.9	40	66
5	65.6	50	75
6	73.6	60	85
7	81.3	70	90
8	88.4	76	100
9	91.6	84	100
10	93.6	90	100

Table 43. Depth-Damage Relationships for Structures & Contents (cont.)

Ashley			
Engineered Warehouse			
A-WH-E			
Depth in Structure	Structure Percent Damage	Structure Lower Percent	Structure Upper Percent
-1	0	0	0.8
-0.5	0	0	0.8
0	0	0	1.9
0.5	6	3.3	11.2
1	9.2	6	17.5
1.5	12	7.3	23
2	18	9.7	29
3	19.2	12.6	34.6
4	30	16	40.8
5	30.9	23.4	46
6	35.5	24.3	48.1
7	38	25.7	59.2
8	42.5	26.6	62.5
9	48.2	32.9	65.8
10	50	37.1	68.8
Depth in Structure	Contents Percent Damage	Contents Lower Percent	Contents Upper Percent
-1	0	0	0

Ashley Equipment			
Ashley Furniture Contents			
RKD			
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	12.1	5	18
1	19.3	12	25
1.5	26.6	20	35
2	31	25	45
3	42.3	33	50
4	52.3	40	66
5	60.7	50	70
6	72	60	80
7	82.1	75	90
8	90.7	80	96
9	94.3	85	100
10	95	90	100

-0.5	0	0	0
0	0	0	0
0.5	13.4	7	20
1	20.7	15	25
1.5	27.6	20	35
2	33.7	25	45
3	47.4	35	55
4	56.9	40	66
5	65.6	50	75
6	73.6	60	85
7	81.3	70	90
8	88.4	76	100
9	91.6	84	100
10	93.6	90	100

Table 44. Depth-Damage Relationships for Vehicles

Ashley Autos		
Ashley Furniture Vehicle		
PIV		
Depth in Structure	Structure Percent Damage	Structure Standard Deviation
0	0	0
0.2	1	1
1	30	1.84
2	46.2	1.51
3	80	1.45
4	83.8	1.57
5	87.6	1.74
6	100	1.92
7	100	2.06
8	100	2.06

Vehicles		
Vehicles		
AUTO		
Depth in Structure	Structure Percent Damage	Structure Standard Deviation
0	0	0
0.5	7.6	2.42
1	28	1.84
2	46.2	1.51
3	62.2	1.45
4	76	1.57
5	87.6	1.74
6	97	1.92
7	100	2.06
8	100	2.06