Appendix D
Economics

FY: 2024
Project Title: Beattyville, KY FRM Project
Project No.: 498982
Location: Lee County, Kentucky

TABLE OF CONTENTS

FIGURES

TABLES

1 INTRODUCTION

This appendix documents the economic analysis conducted for the Kentucky River, Beattyville, General Investigation Feasibility Study and the methodologies and assumptions made therein. The purpose of this analysis is to illustrate the effectiveness of the proposed structural and nonstructural alternatives in reducing flood risk to threatened homes and businesses as well as to life safety in the project area.

The final step of this study phase is to determine the National Economic Development (NED) plan. The economic analysis is a critical input in the development of the final recommendation, but not the sole determining factor. For further information regarding alternative development and plan selection, see the Main Report.

1.1 PROJECT AREA

The city of Beattyville is in Lee County, Kentucky, at the confluence of the north and south forks of the Kentucky River, shown in Figure 1.

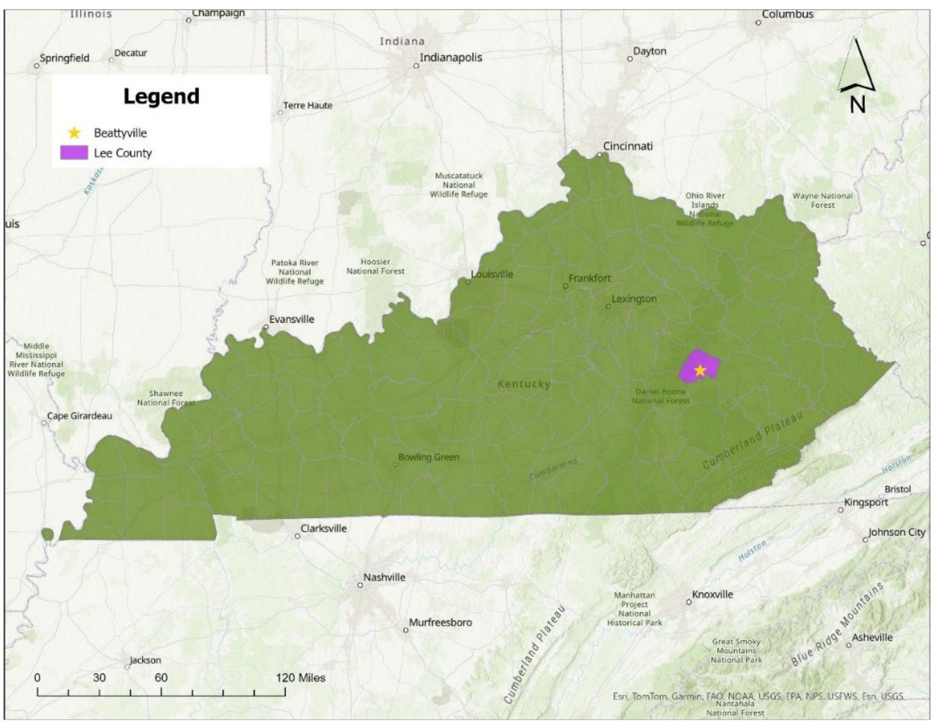

Figure 1: Beattyville is located in Lee County in Eastern Kentucky.

The extent of the project area is approximated by the expected inundation extent of a 0.2% annual exceedance probability (AEP) event, commonly referred to as a 500-year event, shown in Figure 2. An event of this magnitude would flood the entire downtown area of Beattyville on the right bank of the North Fork Kentucky River with significant backwater flooding along Crystal Creek and Silver Creek. The left bank extent of the project area extends only as far as the city limits of Beattyville.

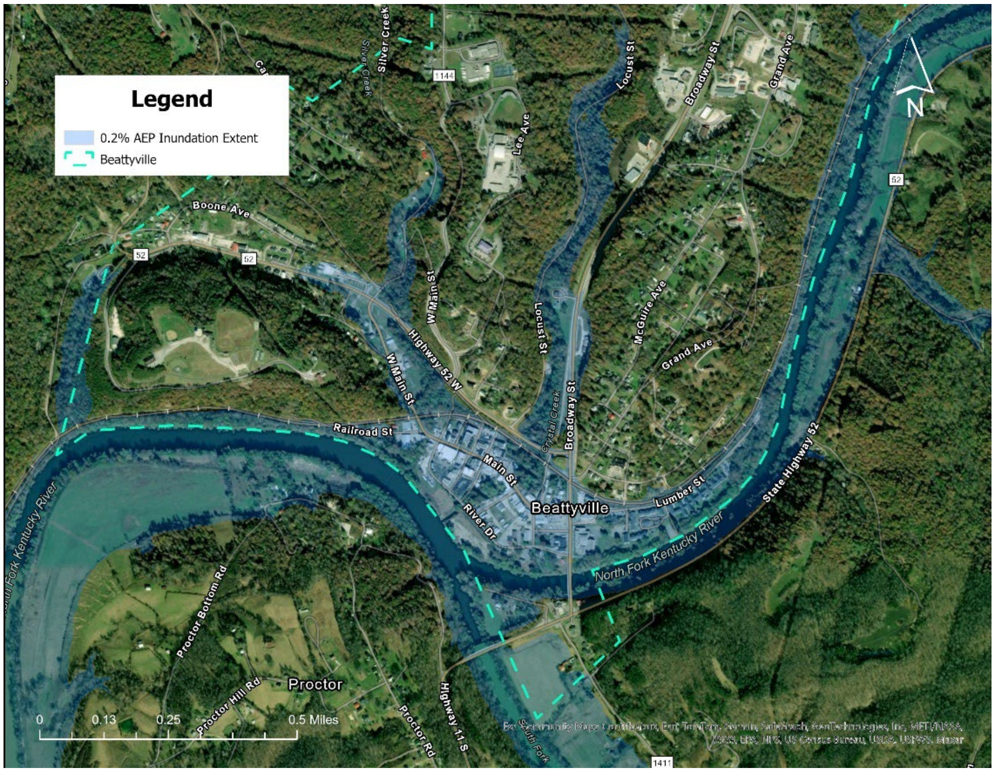

Figure 2: The approximate project area for this effort was delineated by the Kentucky River 0.2% AEP event at Beattyville

1.1.1 Population Characteristics

According to the Census Bureau's American Community Survey (2018-2022), the population of Beattyville is 1,956. Of this total, approximately 88% of the population is white, 4% is black or African American, 1% is American Indian, and 7% are two or more races. Of the total population, 5.6% are of Hispanic or Latino ethnicity.

Among Beattyville's residents 25 years of age or older, approximately 66% are high school graduates, compared with 89% nationally, and 4.2% have a bachelor's degree or higher, compared with 34% nationally.

Only 24.5% of the population 16 years and older is in the civilian labor force, compared to 56.1% in Kentucky and 59.6% nationally. Median household income is significantly lower than both the state and national averages, and nearly half of the residents of Beattyville are in poverty – notably including 68% of children under the age of 5 years. The number of persons with a disability is more than twice the national rate.

The community also has a deficit of connectivity, with 68% of households having a broadband connection, compared to 88% nationally, and 2.2% of households have no telephone service, more than double the national proportion.

Table 1 displays population characteristics for Beattyville as compared to Kentucky and the United States.

Table 1: Beattyville Population Characteristics

	Beattyville	Kentucky	United States
Population	1,956	4,502,935	331,097,593
Population Characteristics			
Persons Under 18	21.0%	22.5%	22.1%
Persons 65 and over	10.4%	16.8%	16.5%
Female Persons	32.2%	50.3%	50.4%
Persons with a disability	26.9%	17.6%	12.9%
Race			
White	87.8%	84.8%	65.9%
Black or African American	3.9%	8.0%	12.5%
American Indian and Alaska Native	0.7%	0.2%	0.8%
Asian	0.0%	1.5%	5.8%
Native Hawaiian and Other Pacific Islander	0.0%	0.1%	0.2%
Two or more Races	7.6%	4.2%	8.8%
Ethnicity			
Hispanic or Latino	5.6%	4.0%	18.7%
Education and Employment			
High school graduate or Higher (age 25+)	65.8%	88.2%	89.1%
Bachelor's Degree or Higher (age 25+)	4.2%	26.5%	34.3%
Employment rate	24.5%	56.1%	59.6%
Unemployment rate	11.4%	5.1%	5.3%
Income			
Per capita income (dollars)	11,251	33,515	41,261
Median Household Income (dollars)	23,423	60,183	75,149
Persons in Poverty	49.2%	16.1%	12.5%
Under 5 years	68.4%	23.3%	18.1%
Under 18 years	55.8%	21.1%	16.7%
Connectivity			
Households with Broadband	67.8%	85.6%	88.3%
No telephone service available	2.2%	1.2%	1.0%
Source: U.S. Census Bureau, 2018-2022 American Community Survey 5-Year Estimates			

Table 2 displays the types of industries that employ residents of Beattyville as compared to Kentucky and the United States.

Table 2: Employment in Beattyville by Industry

Industry (civilian employed population, 16 years and over)	Beattyville	Kentucky	United States
Agriculture, forestry, fishing and hunting, and mining	2.3%	1.8%	1.6%
Construction	13.4%	6.2%	6.9%
Manufacturing	4.9%	14.2%	10.0%
Wholesale trade	5.9%	2.3%	2.4%
Retail trade	22.2%	11.8%	11.0%
Transportation and warehousing, and utilities	8.0%	6.8%	5.8%
Information	0.8%	1.4%	1.9%
Finance and insurance, and real estate and rental and leasing	0.8%	5.6%	6.7%

Industry (civilian employed population, 16 years and over)	Beattyville	Kentucky	United States
Professional, scientific, and management and administrative and waste management services	5.2%	9.0%	12.1%
Educational services, and health care and social assistance	19.8%	24.0%	23.3%
Arts, entertainment, and recreation, and accommodation and food services	0.0%	8.1%	9.0%
Other services, except public administration	1.3%	4.5%	4.7%
Public Administration	15.5%	4.3%	4.7%
Source: U.S. Census Bureau, 2018-2022 American Community Survey 5-Year Estimates			

1.1.2 Historic Flooding

Beattyville has a long history of nuisance flooding in addition to a few significant, damaging floods due to its location at or near the confluences of three forks of the Kentucky River. Flooding in the basins has been experienced at some point in every month of the year. Table 3 summarizes the three largest flood events recorded by USGS gages referenced, and further discussion of these floods can be found in Section 3.3.2 of the Engineering Appendix.

Table 3: Major Flood Events

Date	*Peak Inflow (cubic feet per second)*	*Elevation (ft-NAVD88)*	*Gage Height (ft)*
USGS Gage 03280000 – North Fork			
July 29, 2022*	54,400	739.70	42.00
May 8, 1984*	53,500	739.67	41.97
January 30, 1957	53,500	738.11	40.41
USGS Gage 03281000 – Middle Fork			
January 30, 1957	52,700	684.88	43.33
February 1939	37,300	682.05	40.50
February 2, 1951	35,300	681.62	40.07
USGS Gage 03281500 – South Fork			
January 30, 1957	66,100	685.31	43.40
February 28, 1962	54,700	682.65	40.74
May 8, 1984	51,600	683.03	41.12
USGS Gage 03282000 – Kentucky River Lock 14			
February 04, 1939	120,000	660.99	35.60
January 30, 1957	116,000	660.39	35.00
March 24, 1929	113,000	659.79	34.40
USGS Gage 03284000 – Kentucky River Lock 10			
December 10, 1978*	101,000	596.25	40.15
February 05, 1939	92,400	590.90	34.80
March 01, 1962*	91,500	592.17	36.07
USGS Gage 03287500 – Kentucky River Lock 4			
December 09, 1978*	118,000	510.05	48.47
January 25, 1937	115,000	509.04	47.46
February 16, 1989*	105,000	505.75	44.17

**Events occurred after regulation of the respective USGS gage*

1.2 Economic Framework

The economic analysis described here follows the framework and methodology prescribed by the United States Army Corps of Engineers (USACE) Policy for Conducting Civil Works Planning Studies (ER 1105-2-103) dated 7 December 2023 and Principles and Requirements for Federal Investments in Water Resources, dated March 2013, as appropriate.

USACE follows a conceptual flood risk model which is a function of hazard, performance, and consequences. The hazard, or potential cause for harm, in the case of this study refers to a flood originating from the Kentucky River. Performance refers to how the proposed flood risk management measure is anticipated to handle the hazard. Finally, consequences refer to the harm—economic or otherwise—resulting from the hazard. Each of these terms are discussed more completely in Engineering Regulation (ER) 1105-2-101 "Risk Assessment for Flood Risk Management Studies" dated 15 July 2019 and depicted in Figure 3.

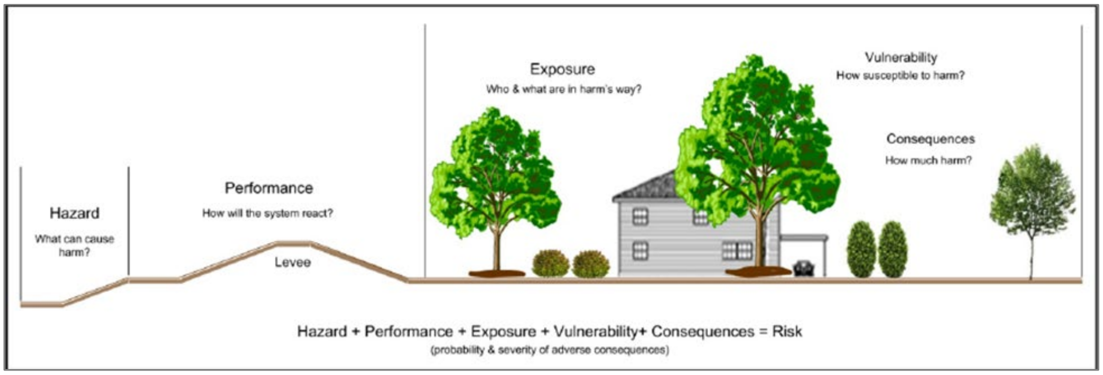

Figure 3: Flood Risk Conceptualized

The hazard inputs incorporated in the economic analyses are developed by hydrologic engineers. Brief descriptions are included within this appendix and additional information can be found in the Hydrology & Hydraulics (H&H) appendix.

This analysis incorporates risk and uncertainty as directed by ER 1105-2-101, Risk-Based Analysis for Evaluation of Hydrology/Hydraulics, Geotechnical Stability, and Economics in Flood Damage Reduction Studies (1 March 1996) and Engineering Manual (EM) 1110-2-1619, Risk-Based Analysis for Flood Damage Reduction Studies (August 1996). Uncertainty is inherent in all economic related input variables used in a typical flood damage analysis. These input variables refer to ground elevations, first floor elevations, valuation of structures, generic depth-damage functions, content values based on content-structure value ratios, or assignment of occupancy type to structures for purposes of depth-damage calculations. Key hydrologic and hydraulic inputs such as frequency-discharge and stage-discharge relationships also possess their own elements of uncertainty.

The analyses of without-project and with-project damages include damages or costs incurred from a range of categories, such as damage to residential and nonresidential structures and their contents, as well as damage to vehicles associated with those structures. These categories are intended to capture a substantial portion of the financial burden incurred by a flood event; however, they are not comprehensive enough to capture every cost or damage that could result from flooding in the area.

To estimate without-project and with-project expected annual damages (EADs) from flooding, eight flooding events were modeled, representing a range of recurrence probabilities from a 99 percent-chance (1-year) flood event to a 0.2 percent-chance (500-year) flood event. These modeling efforts included uncertainty present in the input variables

The difference between with-project EAD and without-project EAD represents expected annual benefits. Whether an alternative can be considered economically justified is determined by comparing expected annual benefits to average annual costs. If expected annual benefits for an alternative exceed the average annual costs, then the alternative is considered economically justified. All plans with positive average annual benefits will yield a benefit-to-cost ratio (BCR) greater than or equal to 1.0.

The analyses described herein utilize risk-based estimates to objectively evaluate alternatives and the associated contributions to NED.

Further important assumptions employed in the evaluation of alternatives are:

(1) All inputs in this analysis are estimates, and therefore subject to varying degrees of uncertainty. As such, an attempt has been made to quantify this uncertainty and better inform interested parties, including decision-makers.

(2) The FY25 discount rate of 3.0% (Engineering Guidance Memorandum 25-01) is used for present value calculation. Costs and benefits are expressed in 2025 price levels. Note that the alternatives comparison analysis was conducted in FY24, and an updated cost analysis was not performed for all screened alternatives, so results from that stage of the feasibility study continue to be presented in 2024 price level and using the FY24 discount rate of 2.75% (EGM 24-01).(3) The project period of evaluation is estimated to be 50 years, including necessary costs for operation, maintenance, repair, replacement, and rehabilitation activities.

(4) All structural computations are based on industrial, commercial, and residential depreciated replacement values (DRVs) and do not include land values.

(5) Resources have potential alternative uses and, consequently, opportunity costs.

(6) Individuals are risk neutral and rational economic agents.

(7) All elevations are expressed in feet and are understood to represent “Ft. NAVD88” (Feet North American Vertical Datum 1988).

(8) The project area is developed and will remain so throughout the period of analysis.

(9) For consistency, all annualized benefits and costs were calculated using an end of year discounting method, including interest during construction.

1.2.1 Without Project Condition

According to ER 1105-2-103, potential project alternatives are to be compared to the future without project (FWOP) condition. For this analysis, the FWOP is assumed to closely mirror the existing condition. The project area is relatively small but completely developed. Publicly available historic imagery shows that the primary structural features (roads, ditches, and buildings) within the area have been in the same location for decades. While the future precipitation in Eastern Kentucky may change in intensity and frequency over time, such impacts were not quantified for this study.

1.2.2 Impact Areas

In the initial stages of formulation, the Project Delivery Team (PDT) aggregated the community’s structures based upon structure and hydraulic characteristics. These groupings were maintained as impact areas for purposes of the economic modeling, delineated as shown in Figure 4.

The first group is bound generally by the Kentucky River, Silver Creek, and the railroad. Group two is bound by the Kentucky River, Silver Creek, Crystal Creek, and the railroad. Group three and four are both bound by the Kentucky River, Crystal Creek, and the railroad. The age of the buildings, the elevations of the first floors, and the geographic locations were contributing factors to dividing these two groups. Group five includes all structures south of the Kentucky River. Group six includes the structures north of the railroad along Silver Creek, and group seven is north of the railroad along Crystal Creek.

It is important to note that only three larger groupings were deemed necessary to account for differences in hydraulic characteristics at the confluence of the forks of the Kentucky River. Those groups are Impact areas 1,2 and 6; Impact areas 3,5, and 7, and Impact Area 4.

Furthermore, by the time of final analysis, the project area had been simplified to consist of only one impact area or reach, described further in Section 3.1.1.

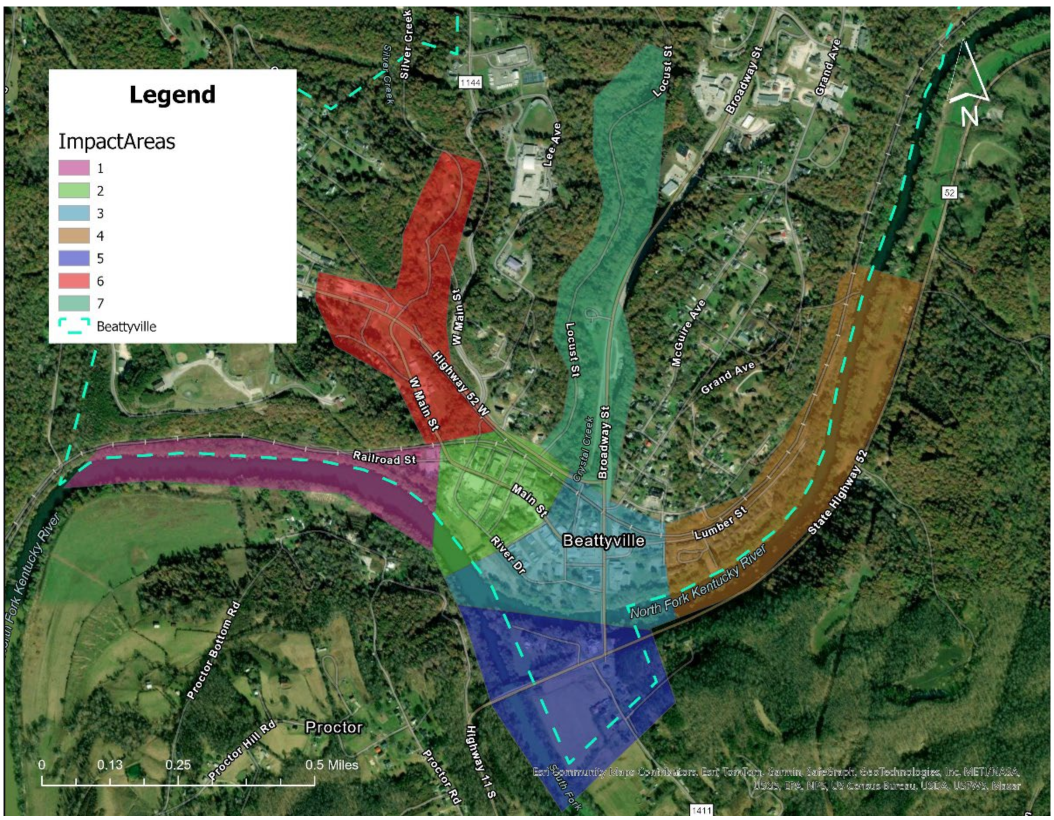

Figure 4: The project area was divided into seven impact areas.

1.2.3 Hazard

The Kentucky River water surface profiles (WSPs) for the economic analysis were provided by Louisville District H&H engineers. The values below represent mean WSPs for a given exceedance probability at stations that would be representative for each grouping of impact areas.

Table 4: Future Without Project Condition Water Surface Profiles

Impact Areas	Station	Stage by Annual Exceedance Probability							
		0.99	0.5	0.2	0.1	0.04	0.02	0.01	0.002
1,2,6	Kentucky River Reach 1 - 257.5189	640.15	649.32	653.55	655.73	664.88	669.86	672.38	678.8
3,5,7	North Fork Kentucky River Reach 3 – 0.101	640.15	649.32	653.55	655.73	664.88	669.86	672.38	678.8
4	North Fork Kentucky River Reach 3 – 0.574	640.17	649.48	653.84	656.11	665.21	670.09	672.6	678.95
[1] *Mean modeled river stages in feet NAVD88*									

Flood damages from riverine flooding increase significantly as the annual exceedance probability (AEP) moves from more frequent to less frequent events.

The without project condition performance statistics help inform the risk of a flood event at a specific flood frequency. The target stage is the stage typically associated with the start of significant damage for the without project condition. The long-term risk is the probability that flooding occurs in a period of 10, 30, or 50 years, and the assurance probability is the chance of containing the specific exceedance probability event within the target stage should that event occur. Table 5 displays these statistics by impact area for the without project condition.

Table 5: Without Project Condition Long Term Risk and Assurance

Impact Area	Threshold Value	Annual Exceedance Probability		Long Term Exceedance Probability			Assurance of Threshold				
		Mean	Median	10 Years	30 Years	50 Years	0.1	0.04	0.02	0.01	0.004
1	662.37	0.050	0.049	0.404	0.789	0.925	0.990	0.250	0.030	0.020	0.000
2	662.60	0.049	0.048	0.397	0.780	0.920	0.990	0.280	0.040	0.020	0.000
3	659.86	0.066	0.065	0.496	0.872	0.967	0.960	0.030	0.000	0.000	0.000
4	668.41	0.026	0.024	0.231	0.546	0.732	1.000	0.850	0.300	0.120	0.020
5	667.75	0.028	0.023	0.248	0.574	0.759	1.000	0.720	0.360	0.130	0.020
6	658.76	0.073	0.072	0.532	0.897	0.977	0.920	0.060	0.000	0.000	0.000
7	664.74	0.037	0.040	0.313	0.676	0.847	1.000	0.500	0.120	0.090	0.010

1.2.4 Consequences Analysis Inputs

The Hydrologic Engineering Center's Flood Damage Analysis (HEC-FDA) 2.0 program was used to estimate damages to residential and non-residential structures and their contents for without-project and with-project alternatives. Performing flood damage reduction analysis using HEC-FDA requires a series of inputs, both geospatial and text-based. The following sections explain the sources and development of those inputs.

1.2.4.1 Terrain

The terrain grid is a digital elevation model that represents the topographic surface of the earth and defines the ground elevation at each structure. It is the same file that was used to produce the hydraulic data, which ensures that the ground elevation applied to the study's structures matches the resolution of the hydraulic inputs. First floor elevations of structures are also defined relative to the terrain.

1.2.4.2 Hydraulics

Hydraulics for existing conditions and four floodwall alternatives were modeled using the Hydrologic Engineering Center's River Analysis System (HEC-RAS). For analysis within HEC-FDA, Hierarchical Data Format (HDF) files representing the eight flood frequency events were required for all five scenarios. HDF files contain depth and velocity for each time step in the simulation. Further information on the hydraulic modeling performed can be found in the H&H appendix, Section 4.9.

H&H also provided text-based stage-discharge data for all scenarios at each frequency event at the three stations presented in Table 3.

1.2.4.3 Structure Inventory

The structure inventory developed for this feasibility study relied heavily on detailed records from the Lee County assessor, GIS data, and in-person visual assessment and photography of structures to determine characteristics.

The distribution of structures across the project area is shown in Figure 5.

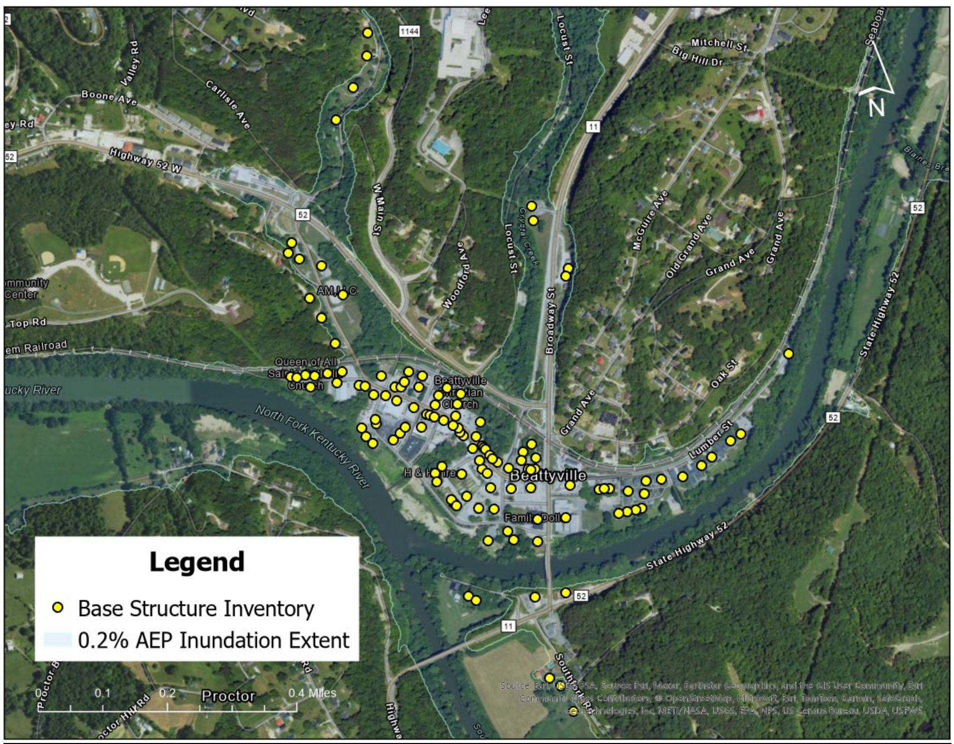

Figure 5: Beattyville Structure Inventory

1.2.4.3.1 Structure Values

Depreciated replacement values (based on structure type, features, quality, and effective age) were determined using Marshall and Swift valuation service, dated May 2020. Prices were inflated from 2020 to 2024 using the Civil Works Construction Cost Index System (CWCCIS) general construction cost index.

Structure count and total estimated values by damage category are presented in the following table. This represents the base inventory created for economic analysis and may differ marginally from structure counts in the main report or other appendices.

Table 6: Estimated Value of Structures in Project Area

Damage Category	Number of Structures	Estimated Total Structure Value (dollars)
Residential	43	9,475,000
Commercial	69	11,200,000
Industrial	1	3,000
Public	11	5,986,000
Total	**124**	**26,661,000**
Values are in 2024 price levels		

1.2.4.3.2 Content Values
Structure content values include all damages caused to a structure's contents. Structure contents are usually defined as everything within the structure that is not permanently installed and can range from furniture, rugs, appliances, and personal possessions for residences to industrial machinery, electronic equipment, and store or warehouse inventories for commercial properties. Content values are established by application of a specified content-to-structure value ratio (CSVR) to the respective structure's value, and damages are estimated similarly to structure damages. More detailed information on this methodology can be found in sections 1.2.4.4.1 and 1.2.4.4.2.

1.2.4.3.3 Vehicle Values
Vehicles were assumed to have a value of approximately $30,000, based on data of average used car sales (iSeeCars, 2022, Average Used Car Prices by State). Approximately 65% of structures do not have associated vehicles.

All single-family homes and mobile homes were assumed to have one vehicle present (assuming that there are two vehicles per household, one evacuates, one is left behind). Using the same logic, multi-family homes are assumed to have one vehicle per unit, and senior living facilities are assumed to have one-half vehicle per unit.

Note that for structures where nonstructural measures are expected to elevate foundation height, new vehicle points were created within the inventory to prevent erroneous elevation of the vehicle within the model.

Commercial structures were assigned an estimated count of vehicles based on review of historic aerial imagery, and with each valued at $30,000, total estimated vehicle values were assigned as shown in Table 7.

The number of vehicles remaining after the population in Beattyville attempts to evacuate is uncertain. For example, there may be no vehicles left in the path of floodwaters at the grocery store, but conversely, none may be able to be removed from the auto lot if time to evacuate is limited. To simplify estimation, the same assumption used for residential structures – that half of the vehicles would not be present during a flood – was applied to all commercial structures.

Table 7: Vehicles at Commercial Structures

Commercial entity	Estimated Vehicle Value (dollars)	Estimated Vehicle Value present during flood (dollars)
IGA grocery Store	400,000	200,000
Don Begley Auto Sales	400,000	200,000
Nursing Home	400,000	200,000
Courthouse	240,000	120,000
City Hall	120,000	60,000
Health Department	120,000	60,000
Values are in 2024 price levels		

1.2.4.3.4 *Structure First Floor Elevation*

First floor elevations were calculated using the foundation height of each structure within the National Structure Inventory, version 2022, relative to that structure's location on the terrain grid.

The National Structure Inventory is a point-based dataset containing estimated information regarding the locations, building types, population, structure values, and other relevant information for all residential, commercial, industrial, agricultural, public, and private structures across the nation

Foundation height was established by surveys of each structure's first floor elevation and lowest adjacent ground elevation during site visit.

1.2.4.3.5 Population in Structures

Population distribution within structures, necessary for life safety analysis, was based on the NSI 2022 and manually adjusted for reasonableness.

1.2.4.4 Structure Depth Damage Functions

Each structure in the inventory was grouped into an appropriate damage category and then assigned a specific occupancy type. Upon determination of the appropriate occupancy type for each structure in the project area, an applicable depth damage function (DDF) was assigned. These DDFs estimate economic loss as a percentage of the value of the structure or contents based on the depth of flooding. Since these relationships are expressed as a percentage, DDFs can be applied to any number of structures within an inventory, so long as the structures are within the same occupancy type. A variety of depth-damage functions, based on damage category and occupancy type, were used for this analysis and are further explained in the following sections.

1.2.4.4.1 Residential

All structure and content DDFs assigned to residential structures were developed by the Institute of Water Resources (IWR) as referenced in Economic Guidance Memorandum (EGM) 04-01. These DDFs are considered generic and are appropriate for use throughout the United States. The DDFs are divided into multiple categories based on the type of structure (e.g., number of stories, foundation type). Separate DDFs represent damages to the structure and the contents, and uncertainty is expressed with a normal probability distribution. The IWR residential DDFs were developed to estimate content damages based on the structure value. The residential content-to-structure value ratio (CSVR) utilized in this analysis is 100 percent, per EGM 04-01 guidelines.

As the lone exception to the methodology explained above, mobile homes (while residential properties), are not included in EGM 04-01. As such, the DDF used for mobile homes in this analysis is a Flood Emergency Management Agency (FEMA) National Flood Insurance depth damage function. Uncertainty in mobile home DDFs is defined by a normal probability distribution from Table 6-4 of EM 1110-2-1619 and CSVR is 100 percent.

1.2.4.4.2 Nonresidential

Nonresidential structures in this study fall within one of three categories: commercial, industrial, or public structures. The nonresidential DDFs used in this analysis are a combination of functions from two different sources: 1) draft IWR report "Non-Residential Flood Depth Damage Functions Derived from Expert Elicitation" dated April 2009, revised 2013 and 2) the New Orleans District "Depth-Damage Relationships for Structures, Contents, and Vehicles and Content-to-Structure Value Ratios (CSVRs) in Support of the Jefferson and Orleans Flood Control Feasibility Studies" report, dated 1996.

Both the IWR and New Orleans nonresidential DDFs were developed by expert elicitation and have been employed continuously in USACE economic analyses since their development. The IWR functions were jointly developed by IWR and FEMA to be nationally relevant and are specific in their application. There are fewer New Orleans functions, and they are more general than the IWR functions. For this analysis, the IWR nonresidential DDFs will generally be applied with priority when applicable. The New Orleans functions will be used for categories of properties not addressed by the IWR functions or when a more general function is appropriate. Uncertainty in the IWR and New Orleans nonresidential depth-damage functions is defined by a triangular probability distribution for each occupancy type. In this analysis, content-to-structure value ratios for each occupancy type developed by New Orleans were applied to all nonresidential structures.

The damage category, occupancy type, description, and respective source of all depth-damage functions utilized in this model are shown in Table 8.

Table 8: Damage Category, HAZUS Occupancy Type Names, Descriptions, and DDF source

Damage Category	Occupancy Type	Description	DDF Source - Name
Residential -	RES1-1SNB	SF, 1 story, no basement	EGM 04-01
Single Family	RES1-1SWB	SF, 1 story, w/ basement	EGM 04-01
	RES1-2SNB	SF, 2 story, no basement	EGM 04-01
	RES1-2SWB	SF, 2 story, w/ basement	EGM 04-01
	RES1-3SNB	SF, 3 story, no basement	EGM 04-01
	RES1-3SWB	SF, 3 story, w/ basement	EGM 04-01
	RES1-SLNB	SF, split level, no basement	EGM 04-01
	RES1-SLWB	SF, split level, w/ basement	EGM 04-01
	RES2	Mobile Home	FEMA NFI DDF
Residential -	RES3AI	MF - duplex	IWR - APT-E
Multi-Family	RES3BI	MF - 3-4 units	IWR - APT-E
	RES3CI	MF - 5-9 units	IWR - APT-E
	RES3DI	MF - 10-19 units	IWR - APT-E
	RES3EI	MF - 20-49 units	IWR - APT-E
	RES3FI	MF - 50+ units	IWR - APT-E
	RES4	Hotel or Motel	IWR - HTL-E
	RES5	Institutional Dormitory/Jail	IWR - CF-E
	RES6	Nursing Home	IWR - HTL-P
Nonresidential -	COM1	Retail trade	NO - RET-A
Commercial	COM2	Wholesale trade/Warehouse	IWR - WH-P
	COM3	Personal/Repair Service	NO - REP-A
	COM4	Professional/Tech Service Office	IWR - OFF-E
	COM5	Bank	IWR - OFF-E
	COM6	Hospital	IWR - HOSP-E
	COM7	Medical Office/Clinic	IWR - MED-E
	COM8	Restaurant/Bar/Entertainment	IWR - REST-P
	COM9	Theater	NO - EAT
	COM10	Parking Garage	IWR - WH-P
	AGR1	Agriculture	IWR - WH-P
Nonresidential -	IND1	Heavy Industrial	IWR - LT-E
Industrial	IND2	Light Industrial	IWR - LT-E
	IND3	Food/Drug/Chemicals	IWR - LT-E
	IND4	Metal/Mineral Processing	IWR - LT-E
	IND5	High Technology	IWR - LT-E
	IND6	Construction Office	IWR - LT-E
Nonresidential -	GOV1	General Government Services/Office	IWR - OFF-E
Public	GOV2	Emergency Response	IWR - PS-E
	EDU1	Primary/Secondary School	IWR - SCH-E
	EDU2	College/University	IWR - SCH-E
	REL1	Church or Non-Profit	IWR - RF-P

1.2.4.5 Vehicle Depth Damage Functions

The depth damage function applied to all vehicles in the inventory is that for sedans, from Economic Guidance Memorandum 09-04, Generic Depth-Damage Relationships for Vehicles, dated 22 June 2009.

1.2.4.6 Other Categories

Transportation delays, traffic diversion costs, and emergency costs were not calculated for this analysis because it was not anticipated their inclusion would affect the decision.

1.2.5 FDA Analysis

For this study effort, data for residential and nonresidential structures were incorporated into HEC-FDA, version 2.0. HEC-FDA uses modeled flooding events to estimate damages to affected structures based on data associated with each structure. HEC-FDA was used to estimate the damages for structures and the contents therein. The HEC-FDA program compiles data generated during the H&H analyses, as well as the structure inventory and associated data described above.

Use of 2D data from HEC-RAS allows for the flood stage at each structure to be compared to that structure's foundation height, the difference applied the structure's individual depth-damage functions (content and structure), and percent damages computed using these functions. Dollar damages are computed by simply multiplying the percent damage by the total structure value. These total dollar damages are then aggregated to the impact area. HEC-FDA uses a Monte Carlo simulation to quantify uncertainty and calculate expected annual damages. This random sampling approach computes multiple thousands of successive iterations of each computation for which there is uncertainty, using the assigned standard deviations of error, and averages the results.

Typically, with-project and without-project damages are estimated for both the initial baseline conditions and future conditions, which account for any growth in development and runoff in the project area. As the hydrologic condition of the project area is not anticipated to increase over the period of analysis, the HEC-FDA model was run only for the initial baseline condition, with the resulting annual damages expected to prevail over the 50-year period of analysis.

1.2.5.1 Average Annual Damages

When evaluating flood damages, it is useful to relate the amount of damage to the water surface elevation in the river. In turn, each water surface elevation is related to certain amount of flow, and each flow is related to a frequency probability of exceedance. Therefore, each level of damage can be associated with a probability of exceedance, resulting in a damage-frequency curve. Average annual damage (AAD) is defined as the area under the damage-frequency curve.

Typically, AAD does not incorporate uncertainty in flows, water surface elevations, or damages. However, the term is often confused with expected annual damages. For the purposes of this report, AAD will represent the deterministic area under the damage-frequency curve (with no uncertainty).

AAD represents the average amount of damage expected to occur in any given year, based solely on the deterministic relationship between flood frequency and damage. No other probabilistic variables are factored into the calculation of AAD.

1.2.5.2 Expected Annual Damages

Expected annual damages (EAD) consider uncertainties in stage-damage, stage-flow, and flow-frequency relationships. EAD is the mean value of AAD, given the uncertainty associated with each damage, stage, and flow relationship. AAD and EAD are often confused due to the similarity in the terms "average" and "expected." For the purposes of this report, expected annual damages refers to the probabilistic definition offered above. EAD are computed using HEC-FDA 2.0, which utilizes Monte Carlo simulation for evaluating mean values.

Expected annual damage represents the mean amount of damage that would occur in any given year, accounting for uncertainty, if the probabilistic conditions were repeated infinitely. The mean value is based on the frequency of recurrence for each flood event, as well as the uncertainties in stage-damage, stage flow, and flow-frequency relationships.

AAD has no uncertainty calculated and EAD does calculate uncertainty around the damage-exceedance probability function (which is derived from the discharge-exceedance probability, stage-discharge probability, and damage-stage functions).

EAD can vary by year, depending on changes in hydraulic, hydrologic, and economic conditions.

Expected annual benefit (EAB) for any alternative is the difference between EAD without the alternative in place and EAD with the alternative in place.

1.2.5.3 Annual Equivalent Cost and Benefit Analysis

All project costs and benefits for U.S. Army Corps of Engineers studies are expressed in annual equivalent terms to enable fair and consistent comparisons between alternatives. This approach ensures that long-term projects can be evaluated based on their overall economic performance, regardless of when specific costs or benefits occur over time. Converting total costs and benefits into annual equivalent values allows decision-makers and the public to clearly understand a project's expected value and economic efficiency over its lifespan.

The annual equivalent cost includes all aspects of a project's financial requirements, such as construction, land acquisition, relocations, and other upfront investments. It also includes interest during construction, as well as recurring operation, maintenance, repair, and replacement costs. These costs are discounted to present value using the applicable federal discount rate and then annualized over the project's period of analysis to produce a uniform annual cost.

Likewise, all project benefits—such as reduced flood damages, ecosystem improvements, or recreational enhancements—are also converted to annual equivalent benefits. These are calculated using established economic evaluation methods that estimate the present value of each benefit type, adjusted for its timing and duration, and then annualized using the same discount rate and analysis period.

The resulting net annual equivalent benefits—calculated as annual equivalent benefits minus annual equivalent costs—and the corresponding benefit-cost ratio (BCR) provide a consistent basis for determining whether a project offers a positive economic return to the nation.

1.2.5.4 HEC-FDA Uncertainty

USACE requires the use of risk-based analysis to evaluate flood damages and flood damage reduction measures, as described in ER 1105-2-101, Risk Analysis for Flood Damage Reduction Studies. HEC-FDA uses a Monte Carlo simulation to quantify uncertainty and derive EADs. This random sampling approach computes successive iterations of each computation for which there is uncertainty, using the assigned standard deviations of error, and averages the results.

Various measures of uncertainty can be incorporated into the HEC-FDA models. For this study, uncertainty was incorporated into the results of the H&H analysis, the depth damage functions (DDF), first floor elevations (FFE), structure values, and content to structure value ratios (CSVR).

1.2.5.4.1 Uncertainty in H&H

Uncertainty associated with the H&H analysis was incorporated into the flow exceedance probability in the equivalent record lengths and the stage discharge functions in accordance with EM 1110-2-1619 (August 1, 1996). The H&H Appendix further discusses the uncertainty associated with the exceedance probability functions and the stage discharge functions.

1.2.5.4.2 Uncertainty in Depth-Damage Functions

The actual damage induced by specific flood depths is not known with certainty. The residential and non-residential depth-damage functions include uncertainty in the damage estimation to structure and contents. For all residential structures, the uncertainty was defined through a normal probability distribution for each unique depth-damage function as presented in EGM 04-01. Meanwhile, for both IWR and New Orleans nonresidential depth-damage functions, a triangular probability distribution was utilized for each occupancy type.

1.2.5.4.3 Uncertainty in First Floor Elevations

Elevations associated with each residential and nonresidential structure within the project area were calculated using surveyed foundation height of each structure relative to that structure's location on the terrain grid. Locations were assigned geospatially and verified against aerial imagery. Uncertainty for FFEs was defined through a normal probability distribution with a standard deviation of 0.3 feet. This is a standard assumption employed by the Louisville District for FRM feasibility level analyses, and no new information was obtained by the PDT that would indicate a need for deviation from this assumption.

1.2.5.4.4 Uncertainty in Structure Values

Residential and nonresidential values were estimated (as previously described) using Marshall and Swift valuation service methodology and were inflated to reflect 2024 prices using the USACE Civil Works Construction Cost Index System (CWCCIS). To account for the uncertainty associated with these values, a normal probability distribution with a standard deviation of 10% was applied to both residential and nonresidential structure values. This is a standard assumption employed by the Louisville District for FRM feasibility level analyses, and no new information was obtained by the PDT that would indicate a need for deviation from this assumption.

1.2.5.4.5 Uncertainty in Content-Structure Value Ratios

The uncertainty associated with residential content values is captured in each residential depth-damage function, in accordance with EGM 04-01. For nonresidential structures, a normal probability distribution with a standard deviation of 10% CSVR was applied.

2 ALTERNATIVES COMPARISON

The following sections outline the analysis that was performed from the study's initiation to selection of the recommended plan. Note that because all analysis was conducted in FY24 and updated cost analysis was not performed for all alternatives, benefits continue to be presented here in FY24 prices. The recommended plan and associated analysis are presented in FY25 prices in Section 3 of this appendix.

2.1 Initial Alternative Formulation and Analysis

Alternative formulation was a collaborative effort by the entire PDT. After without project conditions were developed, the PDT examined potential structural and nonstructural measures. Full descriptions of the structural and nonstructural measures considered can be found in the main report.

A preliminary array of alternatives was developed, which included a no-action alternative, a floodwall, nonstructural measures, and a Flood Warning and Emergency Evacuation Plan (FWEEP). That suite of structural and nonstructural alternatives was expanded, based on target elevations. That is, four floodwall alternatives (alternatives 2A-2D), each with a different elevation, and nonstructural alternatives (3A-3D) that aimed to apply nonstructural measures to structures aggregated based on those same four elevations.

Each alternative was evaluated for likelihood of success, efficiency, and potential for environmental impacts. The expanded array of alternatives is shown in Table 9.

Table 9: Expanded Array of Alternatives

Alternative	Description (NAVD88)
1	Without Project
2A	Floodwall – Elevation 672.2’
2B	Floodwall – Elevation 669.2’
2C	Floodwall – Elevation 666.5’
2D	Floodwall – Elevation 663.0’
3A	Nonstructural – Elevation 672.2’
3B	Nonstructural – Elevation 669.2’
3C	Nonstructural – Elevation 666.5’
3D	Nonstructural – Elevation 663.0’
4	Flood Warning and Evacuation Emergency Plan

After an initial analysis, the PDT found the following flaws in the expanded array of alternatives. Floodwalls were inefficient and ineffective in the NED, EQ, and OSE accounts and were subsequently screened from further analysis. Nonstructural plans were poorly aggregated, that is, the selection of structures to which nonstructural measures were to be applied based solely on first floor elevation led to some plans having inflated inventory and some missing important community assets. The FWEEP provided a positive impact on life safety, but alone did not represent a complete plan.

Based on these observations, a final series of alternatives, built in increments, was established, beginning with the already mentioned FWEEP-only Alternative 4, shown in Table 10.

Table 10: Final Array of Alternatives

Alternative	Description
4	Flood Warning and Evacuation Emergency Plan
5A	FWEEP + Floodway Acquisition + Recreation Features
5B	5A + Nonstructural Measures for Essential Structures
5C	5B + Nonstructural Measures for Historic Structures

The analysis will be presented in the order in which it was completed. Discussion of the final array analysis begins in Section 1.4 of this appendix.

2.1.1 Preliminary Alternatives Defined

The alternatives are described in the following sections. It should be noted that Alternative 4, the Flood Warning and Evacuation Emergency Plan was not separately evaluated in HEC-FDA as the FWEEP by itself is not expected to have a measurable impact on flood damages incurred. However, every other alternative does include a FWEEP, which will impact that alternative's cost as well as its impact to life safety risk.

2.1.1.1 Alternative 1: Without Project Condition, or No Action Plan

This alternative reflects the current, or baseline condition. The purpose of including the no action alternative is to provide a consistent baseline for comparison against other alternatives, and to describe the flood impacts associated with not developing a flood risk management project. Consideration of the No Action Plan is required by USACE guidance.

2.1.1.2 Alternative 2A: Floodwall – Elevation 672.2' NAVD88

This alternative includes a floodwall to elevation 672.2' NAVD88. The proposed alignment would consist of two segments in downtown Beattyville, one on either side of Crystal Creek, is shown in Figure 6. For structures outside of the floodwall, nonstructural flood risk management measures, including floodproofing, elevation, and acquisition of structures would be applied to those structures whose first-floor elevation is 672.2' NAVD88 or below. A FWEEP (described in Section 1.4.1.1) is also included in this alternative.

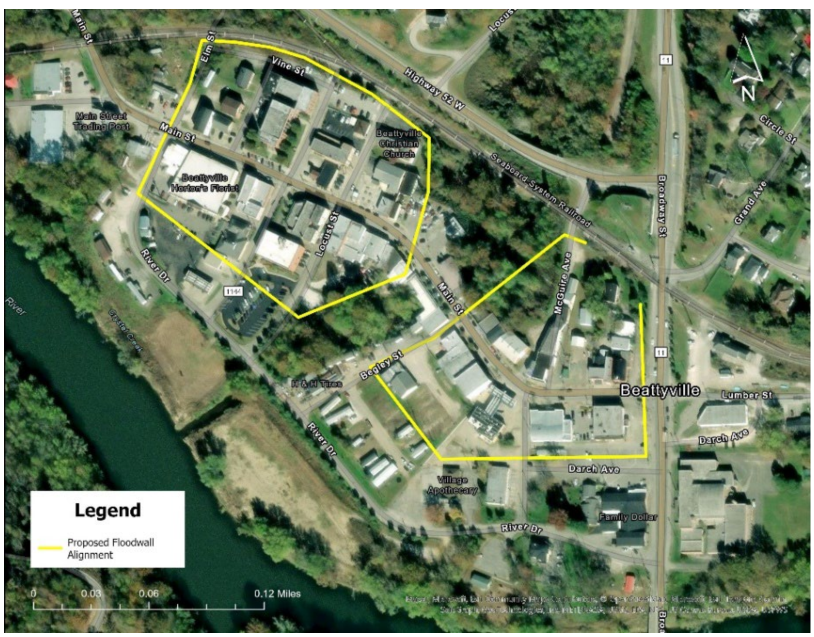

Figure 6: Proposed Floodwall Alignment at Beattyville

2.1.1.3 Alternative 2B: Floodwall – Elevation 669.2' NAVD88

This alternative includes a floodwall to elevation 669.2' NAVD88. The proposed alignment would consist of two segments in downtown Beattyville, one on either side of Crystal Creek, is shown in Figure 6. For structures outside of the floodwall, nonstructural flood risk management measures, including floodproofing, elevation, and acquisition of structures would be applied to those structures whose first-floor elevation is 669.2’ NAVD88 or below. A FWEEP (described in Section 1.4.1.1) is also included in this alternative.

2.1.1.4 Alternative 2C: Floodwall – Elevation 666.5’ NAVD88

This alternative includes a floodwall to elevation 666.5’ NAVD88. The proposed alignment would consist of two segments in downtown Beattyville, one on either side of Crystal Creek, is shown in Figure 6. For structures outside of the floodwall, nonstructural flood risk management measures, including floodproofing, elevation, and acquisition of structures would be applied to those structures whose first-floor elevation is 666.5’ NAVD88 or below. A FWEEP (described in Section 1.4.1.1) is also included in this alternative.

2.1.1.5 Alternative 2D: Floodwall – Elevation 663.0’ NAVD88

This alternative includes a floodwall to elevation 663.0’ NAVD88. The proposed alignment would consist of two segments in downtown Beattyville, one on either side of Crystal Creek, is shown in Figure 6. For structures outside of the floodwall, nonstructural flood risk management measures, including floodproofing, elevation, and acquisition of structures would be applied to those structures whose first-floor elevation is 663.0’ NAVD88 or below. A FWEEP (described in Section 1.4.1.1) is also included in this alternative.

2.1.1.6 Alternative 3A: Nonstructural – Elevation 672.2’ NAVD88

This alternative would apply nonstructural flood risk management measures, including floodproofing, elevation, and acquisition of structures to all structures in the project area whose first floor elevation is 672.2’ NAVD88 or below. A FWEEP (described in Section 1.4.1.1) is also included in this alternative.

2.1.1.7 Alternative 3B: Nonstructural – Elevation 669.2’ NAVD88

This alternative would apply nonstructural flood risk management measures, including floodproofing, elevation, and acquisition of structures to all structures in the project area whose first floor elevation is 669.2’ NAVD88 or below. A FWEEP (described in Section 1.4.1.1) is also included in this alternative.

2.1.1.8 Alternative 3C: Nonstructural – Elevation 666.5’ NAVD88

This alternative would apply nonstructural flood risk management measures, including floodproofing, elevation, and acquisition of structures to all structures in the project area whose first floor elevation is 666.5’ NAVD88 or below. A FWEEP (described in Section 1.4.1.1) is also included in this alternative.

2.1.1.9 Alternative 3D: Nonstructural – Elevation 663.0’ NAVD88

This alternative would apply nonstructural flood risk management measures, including floodproofing, elevation, and acquisition of structures to all structures in the project area whose first floor elevation is 663.0’ NAVD88 or below. A FWEEP (described in Section 1.4.1.1) is also included in this alternative.

2.1.1.10 Alternative 4: Flood Warning and Evacuation Emergency Plan (FWEEP)

Alternative 4 is the creation of a Flood Warning and Evacuation Emergency Plan (FWEEP) for the city of Beattyville. This would serve to shorten delays in warning issuance, warning diffusion, and mobilization of the population and would contribute to the reduction of life safety risk. Because this alternative would have no or little impact on damages to property, it is not included in the remainder of the FDA modeling discussion but is included in the life safety analysis, which begins in Section 1.5.

2.1.2 Model input modifications for Nonstructural Alternatives

The nonstructural alternatives were developed on a conceptual level, using modeled flood depths to identify which measures would be applicable to which structures. There are three basic nonstructural measures which were considered for the project area. The first measure, dry floodproofing, would result in the modification of the exterior of a structure so that it could withstand low levels of inundation (less than three feet above the first floor). The second measure would be to evacuate/ buyout the structures if the mean inundation was estimated to exceed three feet above the first floor. The third measure would elevate the structure to bring the first floor up to the target elevation in each nonstructural alternative.

Every Future With Project alternative modeled includes some nonstructural measures; therefore, all alternatives *except* Future Without Project, required modifications to the base structure inventory (for acquisition and elevation) and depth damage functions (for floodproofing).

2.1.2.1 Structure Inventory Modifications

In each alternative's new inventory, structures identified for acquisition were deleted, and structures identified for elevation were raised to elevation 672.2' NAVD88. Originally foundation heights were estimated by subtracting observed LAG from observed FFE. To obtain new foundation height, the observed LAG was subtracted from 672.2' NAVD88.

2.1.2.2 Depth Damage Function Modifications

Because floodproofing prevents damage up to the target depth, depth damage functions had to be modified to reflect this. For this analysis, floodproofing was assumed to provide three feet of protection. Structures identified for floodproofing were given a new occupancy type indicating the measure, which corresponds with new DDFs wherein no damage occurs until depths are higher than three feet. At points above three feet, the DDFs are identical to those in the base inventory.

2.1.3 Preliminary Alternative Evaluation and Comparison (HEC-FDA 2.0)

The alternative evaluation and comparison planning steps require an examination of the potential risk across several categories (economic, engineering, and environmental). The following sections describe the alternative impacts based on monetary damages and damage reductions, while other impacts are discussed in the main report.

The following table shows the damages by impact area and damage category at each flood frequency event in the without project condition. Note that events more frequent than the 0.04 AEP are not shown as there were no damages in any category during these events.

Table 11: Damages by Damage Category and Reach

Impact Area	Damage Category	0.04AEP	0.02AEP	0.01AEP	0.002AEP
1	Commercial	608,250	677,260	756,135	787,510
	Residential	135,676	297,022	406,296	579,012
	Public	145,644	670,569	906,020	1,083,059
	Industrial	-	-	-	-
	Total	889,569	1,644,852	2,068,451	2,449,581
2	Commercial	1,266,427	6,462,410	7,672,817	9,536,556
	Residential	212,275	460,433	569,789	684,103
	Public	430,063	1,683,100	2,232,724	2,601,930
	Industrial	-	-	-	-

Impact Area	Damage Category	0.04AEP	0.02AEP	0.01AEP	0.002AEP
	Total	1,908,765	8,605,943	10,475,330	12,822,590
3	Commercial	2,638,910	3,712,319	4,767,140	5,340,635
	Residential	356,792	904,037	1,120,330	1,393,582
	Public	268,289	408,635	1,123,635	2,174,794
	Industrial	-	-	-	-
	Total	3,263,991	5,024,991	7,011,105	8,909,011
4	Commercial	-	550,353	628,994	736,310
	Residential	-	1,613,581	3,779,306	6,516,371
	Public	-	-	-	-
	Industrial	-	2,660	4,532	8,001
	Total	-	2,166,594	4,412,832	7,260,682
5	Commercial	-	-	-	-
	Residential	-	294,162	483,156	839,502
	Public	-	-	-	-
	Industrial	-	-	-	-
	Total	-	294,162	483,156	839,502
6	Commercial	111,969	130,177	132,162	132,162
	Residential	94,364	155,371	277,311	587,764
	Public	-	-	-	-
	Industrial	-	-	-	-
	Total	206,333	285,549	409,473	719,925
7	Commercial	1,507,687	2,219,613	2,512,582	2,610,669
	Residential	-	-	-	-
	Public	-	-	-	-
	Industrial	-	-	-	-
	Total	1,507,687	2,219,613	2,512,582	2,610,669
Total		7,776,345	20,241,703	27,372,929	35,611,959

Expected annual damages associated with the ten modeled alternatives are presented in Table 12.

Table 12: Mean Expected Annual Damages by Damage Category

Alternative	Description (NAVD88)	Commercial	Residential	Public	Industrial	Total Damage
1	Without Project	473,647	233,451	112	136,069	843,279
3D	Nonstructural – Elevation 663.0’	347,985	225,494	112	89,137	662,727
3C	Nonstructural – Elevation 666.5’	126,726	166,839	112	25,672	319,349
3B	Nonstructural – Elevation 669.2’	62,600	116,058	112	7,447	186,216
3A	Nonstructural – Elevation 672.2’	27,503	60,099	116	-	87,718
2D	Floodwall – Elevation 663.0’	439,431	250,541	138	135,431	825,541
2C	Floodwall – Elevation 666.5’	275,650	174,918	112	85,021	535,701
2B	Floodwall – Elevation 669.2’	257,762	123,391	120	71,349	452,622
2A	Floodwall – Elevation 672.2’	102,326	54,728	116	21,458	178,628
Values are presented in FY24 price levels and were annualized over a period of 50 years using the FY24 discount rate (2.75%).						

Table 13: Total Expected Annual Damage by Alternative (with Uncertainty)

Alternative	Description (NAVD88)	Expected Annual Damage (Mean)	Expected Annual Damage (25th to 75th percentile)		
		Mean	Q1	Median	Q3
1	Without Project	842,705	498,313	740,168	1,060,804
3D	Nonstructural – Elevation 663.0’	662,227	367,205	568,724	839,928
3C	Nonstructural – Elevation 666.5’	319,093	168,018	263,283	397,658
3B	Nonstructural – Elevation 669.2’	186,059	94,049	149,914	239,982
3A	Nonstructural – Elevation 672.2’	87,648	36,879	64,409	117,003
2D	Floodwall – Elevation 663.0’	824,936	439,075	688,511	1,062,554
2C	Floodwall – Elevation 666.5’	535,309	295,981	465,525	672,619
2B	Floodwall – Elevation 669.2’	452,311	258,047	396,266	567,629
2A	Floodwall – Elevation 672.2’	178,448	78,714	134,463	225,026
Values are presented in FY24 price levels and were annualized over a period of 50 years using the FY24 discount rate (2.75%).					

The following table shows the average annual equivalent damages under each alternative broken down by the impact areas described in Section 1.2.2.

Table 14: Average Annual Equivalent Damages by Impact Area

Impact Area	Average Annual Equivalent Damages ($)								
	Without Project	Nonstructural Only Alternatives (Elevations in feet-NAVD88)				Nonstructural + Floodwall Alternatives (Elevations in feet-NAVD88)			
		663	666.5	669.2	672.2	663	666.5	669.2	672.2
1	68,500	67,900	50,600	49,000	48,900	67,700	50,700	49,100	52,600
2	281,100	269,300	207,100	200,600	196,100	266,800	213,900	219,400	88,100
3	259,400	199,100	174,400	146,900	134,500	202,300	164,900	133,100	65,300
4	79,300	79,500	79,500	71,400	61,400	100,300	79,100	73,000	61,900
5	22,100	22,000	22,200	22,200	21,900	21,900	21,900	21,800	21,300
6	21,500	17,300	15,100	12,900	12,700	17,000	14,900	12,700	13,100
7	70,800	66,300	35,600	34,800	35,600	65,300	33,500	33,600	33,400

Table 15: Estimated Damages by Damage Category and Event

		Frequency Event							
Alternative	Damage Category	0.99	0.5	0.2	0.1	0.04	0.02	0.01	0.002
1 – Without Project	Commercial	-	-	-	-	6,184,207	13,485,505	16,025,041	18,600,753
	Residential	-	-	-	-	799,275	4,183,101	6,766,464	10,680,948
	Industrial	-	-	-	-	-	2,660	4,532	8,001
	Public	-	-	-	-	1,083,996	2,936,230	4,440,819	6,039,783
	Total	-	-	-	-	8,067,477	20,607,496	27,236,856	35,329,486
3D Nonstructural – Elevation 663.0’ NAVD88	Commercial	-	-	-	-	4,090,895	10,911,879	12,952,191	15,284,107
	Residential	-	-	-	-	681,600	4,087,010	6,840,179	10,806,820
	Industrial	-	-	-	-	-	2,660	4,532	8,001
	Public	-	-	-	-	390,911	1,881,073	3,297,869	4,888,101
	Total	-	-	-	-	5,163,407	16,882,621	23,094,771	30,987,029
	Commercial	-	-	-	-	1,356,655	3,330,661	4,528,294	5,583,123

		Frequency Event							
Alternative	**Damage Category**	**0.99**	**0.5**	**0.2**	**0.1**	**0.04**	**0.02**	**0.01**	**0.002**
3C Nonstructural – Elevation 666.5' NAVD88	Residential	-	-	-	-	287,971	3,175,485	5,839,978	9,848,664
	Industrial	-	-	-	-	-	2,660	4,532	8,001
	Public	-	-	-	-	-	231,022	1,029,046	2,213,425
	Total	-	-	-	-	1,644,627	6,739,829	11,401,849	17,653,213
3B Nonstructural – Elevation 669.2' NAVD88	Commercial	-	-	-	-	1,086,664	1,493,942	1,876,087	2,465,668
	Residential	-	-	-	-	188,826	1,577,792	3,436,779	6,100,514
	Industrial	-	-	-	-	-	2,660	4,532	8,001
	Public	-	-	-	-	-	207,150	309,954	443,174
	Total	-	-	-	-	1,275,490	3,281,544	5,627,351	9,017,358
3A Nonstructural – Elevation 672.2' NAVD88	Commercial	-	-	-	-	606,358	686,927	764,707	819,721
	Residential	-	-	-	-	188,826	657,070	1,100,367	2,286,444
	Industrial	-	-	-	-	-	2,660	4,532	8,001
	Public	-	-	-	-	-	-	-	-
	Total	-	-	-	-	795,184	1,346,656	1,869,606	3,114,166
2D Floodwall – Elevation 663.0' NAVD88	Commercial	-	-	-	-	5,426,993	12,714,128	15,165,737	17,776,910
	Residential	-	-	-	-	722,252	3,942,979	6,818,883	10,893,376
	Industrial	-	-	-	-	-	2,671	4,548	8,001
	Public	-	-	-	-	1,044,507	2,960,141	4,489,554	6,105,725
	Total	-	-	-	-	7,193,753	19,619,919	26,478,722	34,784,012
2C Floodwall – Elevation 666.5' NAVD88	Commercial	-	-	-	-	883,756	9,603,386	11,905,676	14,329,666
	Residential	-	-	-	-	283,134	3,227,779	6,068,558	10,062,268
	Industrial	-	-	-	-	-	2,665	4,542	8,001
	Public	-	-	-	-	-	2,184,190	3,524,429	4,934,583
	Total	-	-	-	-	1,166,890	15,018,020	21,503,205	29,334,519
2B Floodwall – Elevation 669.2' NAVD88	Commercial	-	-	-	-	605,982	8,937,242	10,523,976	12,742,261
	Residential	-	-	-	-	188,585	1,859,045	3,753,630	6,306,293
	Industrial	-	-	-	-	-	2,651	4,535	8,001
	Public	-	-	-	-	-	2,155,203	2,746,879	3,117,741
	Total	-	-	-	-	794,567	12,954,141	17,029,020	22,174,296
2A Floodwall – Elevation 672.2' NAVD88	Commercial	-	-	-	-	605,982	686,884	892,459	12,719,932
	Residential	-	-	-	-	188,584	653,741	1,034,117	2,437,086
	Industrial	-	-	-	-	-	2,674	4,545	8,001
	Public	-	-	-	-	-	-	-	3,117,741
	Total	-	-	-	-	794,566	1,343,298	1,931,121	18,282,761

Values are presented in FY24 price levels and were annualized over a period of 50 years using the FY24 discount rate (2.75%).

The damages reduced, or expected annual benefits, are shown in Table 16.

Table 16: Damages and Benefits by Alternative

Alternative	**Description (NAVD88)**	**Expected Annual Damage (Mean)**			**Expected Annual Damage (25th to 75th percentile)**		
		Total Without Project	Total With Project	Damage Reduced	Q1	Median	Q3
3D	Nonstructural – Elevation 663.0'	842,964	662,484	180,480	367,350	568,974	840,175
3C	Nonstructural – Elevation 666.5'	842,964	319,352	523,612	168,223	263,531	397,872
3B	Nonstructural – Elevation 669.2'	842,964	186,513	656,451	94,412	150,334	240,471
3A	Nonstructural – Elevation 672.2'	842,964	88,106	754,858	37,240	64,871	117,509
2D	Floodwall – Elevation 663.0'	842,964	825,193	17,771	439,278	688,884	1,062,864
2C	Floodwall – Elevation 666.5'	842,964	535,568	307,396	296,187	465,777	673,042
2B	Floodwall – Elevation 669.2'	842,964	452,765	390,199	258,415	396,722	568,105
2A	Floodwall – Elevation 672.2'	842,964	178,709	664,255	78,929	134,708	225,395

Values are presented in FY24 price levels and were annualized over a period of 50 years using the FY24 discount rate (2.75%).

2.1.4 Preliminary Array Cost Calculations

An overview of all project first costs is presented in the following tables. All cost figures are presented in FY24 price levels. For further details, refer to the Cost Engineering Appendix.

Interest during construction for each alternative was based on an estimated time frame particular to that alternative, as shown in Table 17. The summation of first costs and interest during construction provides the total investment cost for the plan. To annualize charges, each impact area's total investment cost was amortized over a 50-year period of analysis at the FY24 Federal discount rate of 2.75%.

Durations shown in the table below were estimated by the PDT's cost engineer using cost-estimating software to establish construction durations and allowing time for appropriate real estate actions.

Table 17: Estimated Construction Duration

Alternative	Description	Estimated Construction Duration (months)
3D	Nonstructural – Elevation 663.0' NAVD88	25
3C	Nonstructural – Elevation 666.5' NAVD88	59
3B	Nonstructural – Elevation 669.2' NAVD88	74
3A	Nonstructural – Elevation 672.2' NAVD88	83
2D	Floodwall – Elevation 663.0' NAVD88	25
2C	Floodwall – Elevation 666.5' NAVD88	59
2B	Floodwall – Elevation 669.2' NAVD88	74
2A	Floodwall – Elevation 672.2' NAVD88	83
4	FWEEP	24

2.1.4.1 Project First Costs

For the total project, project investment costs were also calculated via the sum of first costs and interest during construction. First costs consist of construction, real estate, environmental mitigation, preconstruction, engineering, and design (PED), and construction management. The addition of first costs and interest during construction provides the total investment cost for the plan. To annualize charges, the project's total investment cost was amortized over a 50-year period of analysis at the FY24 Federal discount rate of 2.75%.

Table 18: Project First Costs by Alternative

Alternative	Description (NAVD88)	PED, Env Mitigation, Cultural Resources, Construction Management	Construction Cost ($)	Real Estate Cost ($)	FWEEP Cost ($)	Total Cost ($)
3D	Nonstructural – Elevation 663.0'	4,081,922	12,997,140	3,995,400	2,500,000	23,574,462
3C	Nonstructural – Elevation 666.5'	9,369,086	30,684,550	7,968,600	2,500,000	50,522,236
3B	Nonstructural – Elevation 669.2'	13,203,427	44,519,800	9,075,600	2,500,000	69,298,827
3A	Nonstructural – Elevation 672.2'	15,632,841	53,687,400	9,162,600	2,500,000	80,982,841
2D	Floodwall – Elevation 663.0'	8,373,232	29,145,480	4,012,800	2,500,000	44,031,512
2C	Floodwall – Elevation 666.5'	14,897,278	51,953,200	6,532,800	2,500,000	75,883,278
2B	Floodwall – Elevation 669.2'	21,894,761	77,797,700	7,643,400	2,500,000	109,835,861
2A	Floodwall – Elevation 672.2'	27,208,329	97,594,900	7,732,800	2,500,000	135,036,029
4	FWEEP	-	-	-	2,500,000	2,500,000

Values are presented in FY24 price levels.

2.1.5 Expanded Alternative Array Results

A summary of annual benefits and costs for each impact area is presented in Table 19.

Table 19: Summary of Annual Benefits and Costs by Alternative

Beattyville, KY General Investigation Summary of Annual Benefits and Costs FY 2024 Price Levels 2.75% Interest Rate								
Investment Cost	**Alternative 03d - Full NS to ELEV 663 Plan 2**	**Alternative 03c - Full NS to ELEV 666.5 Plan 3**	**Alternative 03b - Full NS to ELEV 669.2 Plan 4**	**Alternative 03a - Full NS to ELEV 672.2 Plan 5**	**Alternative 02d - Floodwall w/ NS to Elev 663 Plan 6**	**Alternative 02c - Floodwall w/ NS to Elev 666.5 Plan 7**	**Alternative 02b - Floodwall w/ NS to Elev 669.2 Plan 8**	**Alternative 02a - Floodwall w/ NS to Elev 672.2 Plan 9**
Construction First Cost	23,574,462	50,522,236	69,298,827	80,982,841	44,031,512	75,883,278	109,835,861	135,036,029
Interest During Construction	678,916	3,524,320	6,133,834	8,096,162	1,268,055	5,293,451	9,721,880	13,500,065
Total Investment Cost	24,253,378	54,046,556	75,432,661	89,079,003	45,299,567	81,176,729	119,557,741	148,536,094
Annual Charges								
Interest & Amortization	898,367	2,001,934	2,794,095	3,299,568	1,677,938	3,006,861	4,428,529	5,501,913
Operation & Maintenance	0	0	0	0	5,000	5,000	5,000	5,000
Total Annual Charges	898,367	2,001,934	2,794,095	3,299,568	1,682,938	3,011,861	4,433,529	5,506,913
Annual Benefits								
Flood Risk Management	81,479	218,496	265,741	291,909	61,579	224,659	260,250	467,817
Total Annual Benefits	81,479	218,496	265,741	291,909	61,579	224,659	260,250	467,817
Benefit vs. Cost Ratio	**0.09**	**0.11**	**0.10**	**0.09**	**0.04**	**0.07**	**0.06**	**0.08**
Net Benefits	-816,888	-1,783,439	-2,528,354	-3,007,659	-1,621,358	-2,787,202	-4,173,278	-5,039,097

**ELEV in feet NAVD88 Datum.*
*** "Annual" costs (or charges) and benefits shown in this table refer to average annual equivalent (AAE) values unless otherwise noted.*

Following this analysis, all floodwall alternatives were screened from further consideration.

2.1.6 Expanded Array Regional Economic Development Benefits

The Principles and Guidelines (1983) established the Regional Economic Development (RED) account to register changes in the distribution of regional economic activity that result from each alternative plan. In addition to the benefits accounted for within the NED account, the implementation of the Recommended Plan would result in local economic activity which is accounted for within the RED account.

The USACE Regional Economic System (RECONS) is a regional economic impact modeling tool that was developed to provide accurate and defendable estimates of regional economic impacts associated with USACE spending. It is the only USACE Regional Economic Development model certified for use across the enterprise. RECONS incorporates impact area data, as well as multipliers, direct ratios (jobs to sales, income to sales, etc.), and geographic capture rates to estimate jobs, labor income, and other critical impacts to the local, state, and national economy. The following table provides an overview of the impact areas utilized for the RED analysis.

Streamlined RECONS Definitions:

- Output: Economic output or total industry output is the value of production by industry for a given time period. It is also known as gross revenues or sales.
- Labor Income: Labor income represents all forms of employment earnings.
- Jobs (Employment): The work in which one is engaged; an occupation by which a person earns income. Employment includes both part-time and full-time jobs. All jobs are presented in full- time equivalence (FTE).
- Value Added: These are payments made by industry to workers, which also include interest, profits, and indirect business taxes. Value-added is an estimate of the gross regional or state product.

The nonstructural alternatives were analyzed for impacts to the regional economy, the results of which are presented in Table 20.

Table 20: Expanded Array RED Impact Summary

	Alternatives and Construction Costs							
	3D: Nonstructural – Elevation 663.0' NAVD88, $12,997,140		**3C: Nonstructural – Elevation 666.5' NAVD88, $30,684,550**		**3B: Nonstructural – Elevation 669.2' NAVD88, $44,519,800**		**3A: Nonstructural – Elevation 672.2' NAVD88, $53,687,400**	
Area	**Output**	**Jobs***	**Output**	**Jobs***	**Output**	**Jobs***	**Output**	**Jobs***
Local								
Direct Impact	$8,530,000	100	$17,990,000	210	$26,101,000	304	$31,476,000	367
Secondary Impact	$3,734,000	23	$7,566,000	47	$10,978,000	68	$13,238,000	82
Total Impact	$12,264,000	123	$25,556,000	257	$37,079,000	372	$44,714,000	449
State								
Direct Impact	$10,305,000	118	$23,024,000	254	$33,406,000	368	$40,285,000	444
Secondary Impact	$8,923,000	52	$19,916,000	116	$28,895,000	169	$34,845,000	203
Total Impact	$19,227,000	170	$42,940,000	370	$62,301,000	537	$75,130,000	648
US								
Direct Impact	$12,402,000	131	$29,281,000	310	$42,483,000	450	$51,231,000	542
Secondary Impact	$22,909,000	106	$54,085,000	249	$78,471,000	362	$94,630,000	436
Total Impact	$35,311,000	237	$83,365,000	559	$120,954,000	812	$145,860,000	979

* Jobs are presented in full-time equivalence (FTE)
Values are presented in FY 2024 price levels.

2.2 Final Array of Alternatives Formulation and Analysis

As described previously, flaws in the initial array of alternatives led the PDT to develop a new suite of alternatives. It is important to note that some minor changes to the base structure inventory occurred between the analysis of the preliminary array and the final array so the without project conditions between the two arrays can be expected to contain some minor discrepancies.

2.2.1 Final Array of Alternatives Defined

2.2.1.1 Alternative 4: Flood Warning and Evacuation Emergency Plan (FWEEP)

Alternative 4 was maintained from the initial array and it represents a Flood Warning and Evacuation Emergency Plan (FWEEP) for the city of Beattyville. This would serve to shorten delays in warning issuance, warning diffusion, and mobilization of the population and would contribute to the reduction of life safety risk. While it is reasonable to expect additional warning time would enable the removal of contents and vehicles that might not be saved in the without project condition, those benefits are expected to be minimal and thus they were not calculated in the FDA modeling but were included in the life safety analysis, which begins in Section 2.3.

Further, attempting to quantify this reduction in damages presents a series of problems, chief among which is the uncertainty in establishing how many additional vehicles could be saved. Any attempt to assign value without a proper analysis would be arbitrary and ultimately would imply an unreal level of precision to the damage estimate. The team expects additional FRM benefits provided by the FWEEP to be minor, and even a proper accounting of those benefits would not change the decision.

2.2.1.2 Alternative 5A: Floodway Acquisition + Recreation Features

Alternative 5A is the acquisition of several structures with footprints lying in the FEMA regulatory floodway. This alternative also includes beneficial reuse of those acquired parcels to provide recreation features to the community. These recreation features are discussed in Section 1.4.4. A FWEEP (described in Section 1.4.1.1) is also included in this alternative.

2.2.1.3 Alternative 5B: 5A + Nonstructural Measures for Essential Structures

Alternative 5B builds on Alternative 5A by adding nonstructural FRM measures to essential, or anchor, structures in the community. These include grocery, health, and other community services. The nonstructural measures applied are dry- and wet-floodproofing. A FWEEP (described in Section 1.4.1.1) is also included in this alternative.

2.2.1.4 Alternative 5C: 5B + Nonstructural Measures for Historic Structures

Alternative 5C builds on Alternative 5B by adding nonstructural FRM measures to those structures that allow Beattyville to maintain its historic integrity. The nonstructural measures applied are dry- and wet-floodproofing, and in one case, elevation. A FWEEP (described in Section 1.4.1.1) is also included in this alternative.

2.2.2 Model input modifications for Nonstructural Alternatives

The nonstructural alternatives were developed on a conceptual level, using modeled flood depths to identify which measures would be applicable to which structures. There are a few basic nonstructural measures that were considered for the project area. The first measure, acquisition, includes the evacuation and buyout of certain structures within the FEMA regulatory floodway. Another measure, dry floodproofing, would result in the modification of the exterior of a structure so that it could withstand low levels of inundation (less than three feet above the first floor). The third measure is wet floodproofing, which makes a structure resilient to inundation up to a determined height. Because wet floodproofing allows water to flow into the interior of a structure, any contents stored below the target height would not be protected. The fourth measure would elevate the structure to bring the first floor up to the target elevation.

Every Future With Project alternative modeled includes some nonstructural measures; therefore, all alternatives *except* Future Without Project, required modifications to the base structure inventory (for acquisition and elevation) and depth damage functions (for floodproofing).

2.2.2.1 Structure Inventory Modifications
In each alternative's new inventory, structures identified for acquisition were deleted, and structures identified for elevation were raised to have a first-floor elevation of 672.2' NAVD88. Originally foundation heights were estimated by subtracting observed LAG from observed FFE. To obtain new foundation height, the observed LAG was subtracted from 672.2' NAVD88.

2.2.2.2 Depth Damage Function Modifications
Because floodproofing prevents damage up to the target depth, depth damage functions had to be modified to reflect this. For this analysis, the target height for all dry floodproofing measures was assumed to be three feet. Structures identified for floodproofing were given a new occupancy type indicating the measure, which corresponds with new DDFs wherein no damage occurs until depths are higher than three feet. At points above three feet, the DDFs are identical to those in the base inventory.

For those structures targeted for wet floodproofing, the target height of the floodproofing measure was eight feet. For these structures, the depth damage functions for the structure itself were shifted to make damages start at eight feet. The depth damage functions for contents and vehicles were unchanged because the PDT determined contents were unlikely to be elevated.

2.2.3 Final Array Evaluation and Comparison (HEC-FDA 2.0)
The alternative evaluation and comparison planning steps require an examination of the potential risk across several categories (economic, engineering, and environmental). The following sections describe the alternative impacts based on monetary damages and damage reductions, while other impacts are discussed in the main report.

Expected annual damages associated with the modeled alternatives are presented in Table 21.

Note that while in the following table Alternative 4, the FWEEP, is shown as having no measurable reduction in damages when compared to the without project condition, it can reasonably be expected that some FRM benefits would be realized with improved warning time.

Table 21: Mean Expected Annual Damages by Damage Category

Alternative	Description	Commercial	Residential	Public	Industrial	Total Damage
1	Without Project	482,938	226,061	132,200	112	841,310.87
4	Flood Warning and Evacuation Emergency Plan	482,938	226,061	132,200	112	841,310.87
5A	FWEEP + Floodway Acquisition + Recreation Features	455,563	197,130	131,937	112	784,741.44
5B	5A + Nonstructural Measures for Essential Structures	405,304	196,893	96,437	112	698,746.46
5C	5B + Nonstructural Measures for Historic Structures	377,847	191,209	84,071	112	653,238.53

Values are presented in FY24 price levels and were annualized over a period of 50 years using the FY24 discount rate (2.75%).

The following table shows the average annual equivalent damages under each alternative broken down by the impact areas described in Section 1.2.2.

Table 22: Average Annual Equivalent Damages by Impact Area

Impact Area	Average Annual Equivalent Damages ($)			
	Alt 1	Alt 5A	Alt 5B	Alt 5C
	Without Project	FWEEP + Floodway Acquisition + Recreation Features	5A + Nonstructural Measures for Essential Structures	5B + Nonstructural Measures for Historic Structures
1	74,600	74,500	62,700	62,700
2	298,400	287,000	228,600	208,100
3	254,800	211,800	201,300	176,600
4	93,700	93,600	93,600	93,600
5	23,200	23,200	23,200	23,200
6	24,400	22,200	22,200	22,000
7	71,700	71,700	66,500	66,400

Table 23: Total Expected Annual Damage by Alternative (with Uncertainty)

Alternative	Description	Expected Annual Damage (Mean)	Expected Annual Damage (25th to 75th percentile)		
		Mean	Q1	Median	Q3
1	Without Project	840,741	500,399	741,357	1,051,220
5A	FWEEP + Floodway Acquisition + Recreation Features	784,216	468,285	691,530	976,942
5B	5A + Nonstructural Measures for Essential Structures	698,242	403,133	611,143	870,879
5C	5B + Nonstructural Measures for Historic Structures	652,772	370,584	568,004	813,837

Values are presented in FY24 price levels and were annualized over a period of 50 years using the FY24 discount rate (2.75%).

Table 24: Estimated Damages by Damage Category and Event

		Frequency Event							
Alternative	**Damage Category**	**0.99**	**0.5**	**0.2**	**0.1**	**0.04**	**0.02**	**0.01**	**0.002**
1 – Without Project	Commercial	-	-	-	-	6,133,242	13,752,132	16,469,830	19,143,841
	Residential	-	-	-	-	799,107	3,724,606	6,636,188	10,600,333
	Industrial	-	-	-	-	-	2,660	4,532	8,001
	Public	-	-	-	-	843,996	2,762,305	4,262,380	5,859,783
	Total	-	-	-	-	7,776,345	20,241,703	27,372,929	35,611,959
5A – FWEEP + Floodway Acquisition + Recreation Features	Commercial	-	-	-	-	5,856,175	13,283,109	15,798,536	18,405,104
	Residential	-	-	-	-	589,091	3,091,063	5,696,632	9,352,979
	Industrial	-	-	-	-	-	2,660	4,532	8,001
	Public	-	-	-	-	578,812	2,316,915	3,768,318	5,365,721
	Total	-	-	-	-	7,024,078	18,693,747	25,268,018	33,131,805
5B – 5A + Nonstructural Measures for Essential Structures	Commercial	-	-	-	-	5,784,992	12,570,540	14,987,017	18,022,010
	Residential	-	-	-	-	589,091	3,091,063	5,696,632	9,352,979
	Industrial	-	-	-	-	-	2,660	4,532	8,001
	Public	-	-	-	-	517,366	1,672,594	2,810,892	4,761,450
	Total	-	-	-	-	6,891,449	17,336,857	23,499,072	32,144,441
5C – 5B + Nonstructural Measures for Historic Structures	Commercial	-	-	-	-	5,516,701	11,935,969	14,281,937	17,627,051
	Residential	-	-	-	-	528,824	2,959,384	5,588,282	9,312,347
	Industrial	-	-	-	-	-	2,660	4,532	8,001
	Public	-	-	-	-	424,689	1,325,871	2,440,857	4,594,685
	Total	-	-	-	-	6,470,214	16,223,883	22,315,608	31,542,084

Values are presented in FY24 price levels and were annualized over a period of 50 years using the FY24 discount rate (2.75%).

The damages reduced, or expected annual benefits, are shown in Table 25, below.

Table 25: Damages and Benefits by Alternative

Alternative	**Description**	**Average Annual Equivalent Damage (Mean)**			**Average Annual Equivalent Damage Reduced (25th to 75th percentile)**		
		Total Without Project	Total With Project	Damage Reduced	Q1	Median	Q3
5A	FWEEP + Floodway Acquisition + Recreation Features	840,741	784,216	56,579	31,194	50,008	72,064
5B	5A + Nonstructural Measures for Essential Structures	840,741	698,242	142,577	94,860	131,450	176,737
5C	5B + Nonstructural Measures for Historic Structures	840,741	652,772	188,084	128,547	174,808	232,023

Values are presented in FY24 price levels and were annualized over a period of 50 years using the FY24 discount rate (2.75%).

2.2.4 Recreation

Because Alternative 5A includes the creation of recreation features, a benefits analysis was required for the proposed features. NED benefits from a project's recreation features are measured in terms of a visitor's 'willingness to pay' for the recreation opportunity.

Based on Engineer Regulation 1105-2-100, the Planning Guidance Notebook, when the expected costs of recreation features exceed 25 percent of expected total projects costs, as in this project, it is recommended to develop a regional model or conduct a site-specific study to determine willingness to pay. However, Economic Guidance Memorandum 24-02, Unit Day Method, specifies that if either of those methods is not feasible or justified, the Unit Day Value method may be used. For this study, it was determined that the time and cost required for proper development of a regional model or site-specific study were not feasible; thus, the UDV method was used.

2.2.4.1 Unit Day Value Assessment

The UDV method relies on informed opinion and judgment, considering both the quality of recreation experience and visitation rates and uses the 'unit day values for recreation' contained in EGM 24-02.

To score alternatives, point values are assigned based on measurement standards described for five criteria: recreational experience; availability of opportunity; carrying capacity; accessibility; and environmental quality.

For the proposed concept, the category of 'general recreation' was used, and the guidelines for assigning points and dollar values in the EGM were followed.

The PDT evaluated the future without project condition and the proposed recreation features. A subsequent elicitation was conducted with representatives from the City of Beattyville to validate the scoring.

The guidelines for assigning points for general recreation are shown in Table 26.

Table 26: Guidelines for Assigning Points for General Recreation

Criteria	Judgement Factors				
Recreation Experience	Two general activities	Several general activities	Several general activities: one high quality value activity	Several general activities; more than one high quality activity	Numerous high quality value activities; some general activities
Point Value	0-4	5-10	11-16	17-23	24-30
Availability of Opportunity	Several within 1-hour travel time; a few within 30 min. travel time	Several within 1-hour travel time; none within 30 min. travel time	One or two within 1 hour travel time; none within 45 min. travel time	None within 1 hour travel time	None within 2-hour travel time
Point Value	0-3	4-6	7-10	11-14	15-18
Carrying Capacity	Minimum facility for development for public health and safety	Basic facility to conduct activity(ies)	Adequate facilities to conduct without deterioration of the resource or activity experience	Optimum facilities to conduct activity at site potential	Ultimate facilities to achieve intent of selected alternative
Point Value	0-2	3-5	6-8	9-11	12-14

Criteria	Judgement Factors				
Accessibility	Limited access by any means to site or within site	Fair access, poor quality roads to site; limited access within site	Fair access, fair road to site; fair access, good roads within site	Good access, good roads to site; fair access, good roads within site	Good access, high standard road to site; good access within site
Point Value	0-3	4-6	7-10	11-14	15-18
Environmental Quality	Low aesthetic factors that significantly lower quality	Average aesthetic quality; factors exist that lower quality to a minor degree	Above average aesthetic quality; any limiting factors can be reasonably rectified	High aesthetic quality; no factors exist that lower quality	Outstanding aesthetic quality; no factors exist that lower quality
Point Value	0-2	3-6	7-10	11-15	16-20

Once scored, the total points for each alternative can be converted to a dollar value, known as the Unit Day Value, representing the value of the proposed features per visitor per day.

The FY 2024 values for general recreation, shown in Table 27, were applied for this study.

Table 27: Conversion of UDV Points to Dollar Values

Point Values	General Recreation Values (1)	General Fishing and Hunting Values (1)	Specialized Fishing and Hunting Values (2)	Specialized Recreation Values other than Fishing and Hunting (2)
0	$5.05	$7.26	$35.36	$20.52
10	$6.00	$8.21	$36.30	$21.78
20	$6.63	$8.84	$36.93	$23.36
30	$7.58	$9.79	$37.88	$25.25
40	$9.47	$10.73	$38.83	$26.83
50	$10.73	$11.68	$42.62	$30.31
60	$11.68	$12.94	$46.41	$33.46
70	$12.31	$13.57	$49.25	$40.41
80	$13.57	$14.52	$53.03	$47.04
90	$14.52	$14.84	$56.82	$53.67
100	$15.15	$15.15	$59.98	$59.98

The evaluation of each site’s proposed recreation features is presented in the following sections.

2.2.4.1.1 Future Without Project

Currently the area of interest in Beattyville along the shoreline of the Kentucky River is underutilized, lacks recreational opportunities, and experiences frequent nuisance flooding.

While it is anticipated that a future without project would include measures by the non-Federal sponsor to prevent further loss of shoreline to erosion, there is no aesthetic or functional improvement expected in a FWOP condition.

Scoring decisions were made based on the following factors.

Recreation Experience: The existing condition of the site is a barren stretch along the Kentucky River. There is a playground and picnic pavilion; however, due to the frequent flooding, the facilities are often impacted by buildup of mud and silt. The difficulty of maintaining these facilities leads to them being unusable for significant periods of time. The apparent kayak rental and RV park facilities are unmanned and therefore not considered available for this analysis. There is parking available. While there is a boat ramp, the river is inaccessible for activities such as fishing from the bank. Silver Creek and Crystal Creek are entirely inaccessible. Score: 3

Availability of Opportunity: There is ample opportunity for similar low-quality experiences along the riverbanks in Beattyville. Score: 1

Carrying Capacity: There are basic facilities (playground, parking, and picnic shelter), but they are often deteriorated by frequent flooding and unavailable for use. Other areas of the recreation site footprint have no development that would allow for safe use. Score: 3

Accessibility: The existing condition has fair access to playground, picnic shelter, and parking when mud/silt are not a problem, but there is limited to no access to Crystal Creek and Silver Creek. Score: 3

Environmental Quality: The site along the Kentucky River is of low aesthetic quality. The mud and silt that frequently impact the existing playground significantly lower quality of resource. Score: 1

The PDT scored the site as shown in Table 28.

Table 28: Unit Day Value estimate for Future Without Project condition

Criteria	Future Without Project
Recreation Experience	3
Availability of Opportunity	1
Carrying Capacity	3
Accessibility	3
Environmental Quality	1
Total Recreation Points	11
Value	$6.06

2.2.4.1.2 Future With Project

The proposed concept for recreation features in alternatives 5A (and by extension, 5B and 5C), includes a walking trail made up of a mix of both elevated boardwalk and an asphalt path, relocation of the frequently flooded playground to higher elevation, picnic tables, and historical markers and educational signage.

Scoring decisions were made based on the following factors.

Recreation Experience: In the with-project condition, there will be a walking trail that extends along the Kentucky river between both creeks and connects with the historic downtown/Main Street area. Creeks will be accessible for fishing, crawdad catching, and experiencing greenspace. The playground will be relocated to sponsor-preferred, resilient site at higher elevation, so similar facilities will be more available due to reduced flooding. The areas along the creeks will include native riparian plants and trees to enhance the natural aesthetic and, in some places, elevated boardwalks will ensure access to trails. Score: 15

Availability of Opportunity: The nature of the high-quality walking trail incorporated with the historic downtown district of Beattyville is unique within at least an hour's travel time. Score: 12

Carrying Capacity: New facilities will be adequate to support activities without deterioration of the experience. Score: 8

Accessibility: The new walking trail will provide good access within site to creeks, the Kentucky River, and Main Street. Score: 12

Environmental Quality: New walking trails that incorporate creek access with historic downtown will have above average aesthetic quality, and relocated playground will not incur same frequency of flood inundation. Native riparian plants and trees will enhance environmental quality of the site. Score: 10

The PDT scored the site as shown in Table 29.

Table 29: Unit Day Value estimate for Future With Project

Criteria	Future With Project
Recreation Experience	15
Availability of Opportunity	12
Carrying Capacity	8
Accessibility	12
Environmental Quality	10
Total Recreation Points	57
Value	$11.40

2.2.4.2 Visitation Estimate

To complete the recreation benefits estimate, annual visitation must be estimated for both the future with and without project scenarios. Because no direct estimate exists, similar day-use areas were examined for use as a potential proxy in lieu of specific data.

The Confluence Recreation Area, a day-use recreation at USACE's Buckhorn Lake, upstream of Beattyville on the Kentucky River, experienced visitation over 70,000 in 2023, according to the Visitation Estimation and Reporting System.

Carr Creek Lake, also upstream of Beattyville, has day use areas ranging from 25,000 to 97,000 visitors annually, though these sites are less comparable to the site at Beattyville.

Because Beattyville's Wooly Worm Festival receives an average of 30,000 visitors over a three-day period annually, the PDT determined that annual with-project visitation of 55,000 was both reasonable and likely conservative. Without project visitation was assumed to be 5,000 annually, to account for incidental use of the sub-adequate facilities.

2.2.4.3 Recreation Benefits

The estimated benefits provided by the addition of recreation features to the site at Beattyville are shown in below.

Table 30: Unit Day Value estimate for Future With Project

Recreation Input Variables	With Project	Without Project
Annual Visitors	55,000	5,000
Unit Day Value	$11.40	$6.06
Annual Recreation Benefits	$626,725	$30,315

Thus, the benefits provided to the nation in the alternatives including the proposed recreation features total $596,410 annually.

2.2.5 Cost Calculations

An overview of all project first costs for each alternative is presented in the following table. All cost figures are presented in FY24 price levels. For further details, refer to the Cost Engineering Appendix.

The summation of project first costs and interest during construction provides the total investment cost for the plan. To annualize charges, each impact area's total investment cost was amortized over a 50-year period of analysis at the FY24 Federal discount rate of 2.75%. The assumed construction duration for each alternative was 24 months.

2.2.5.1 Project First Costs

Project investment costs were also calculated via the sum of first costs and interest during construction. First costs consist of construction, real estate, environmental mitigation, preconstruction, engineering, and design (PED), and construction management. The addition of first costs and interest during construction provides the total investment cost for the plan. To annualize charges, the project's total investment cost was amortized over a 50-year period of analysis at the FY24 Federal discount rate of 2.75%.

Table 31: Final Array Project First Costs by Alternative

Alternative	Description	PED, Env Mitigation, Cultural Resources, Construction Management	Construction Cost	Real Estate Cost	Total Cost
4	Flood Warning and Evacuation Emergency Plan	516,750	1,950,000	-	2,466,750
5A	FWEEP + Floodway Acquisition + Recreation Features	2,452,359	8,391,747	2,474,400	13,318,506
5B	5A + Nonstructural Measures for Essential Structures	4,197,252	8,965,903	9,193,900	22,357,055
5C	5B + Nonstructural Measures for Historic Structures	6,688,747	18,657,403	10,430,544	35,776,694
Values are presented in FY24 price levels.					

2.2.6 National Economic Development Results

A summary of annual benefits and costs for each alternative is presented in Table 32.

The NED cost estimates include remaining post-authorization planning and design costs, construction costs, construction contingencies costs, historical and archaeology mitigation costs. The full break down of the cost estimates can be found in Appendix C of this report.

Table 32: Final Array Summary of Annual Benefits and Costs by Alternative

Beattyville, KY
General Investigation
Summary of Annual Benefits and Costs
FY 2024 Price Levels
2.75% Interest Rate

	FWEEP Only	5A: FWEEP + Floodway Acquisition + Recreation Features	5B: 5A + Nonstructural Measures for Essential Structures	5C: 5B + Nonstructural Measures for Historic Structures
Project Cost				
Project First Cost	2,466,750	13,318,506	22,357,055	35,776,694
Interest During Construction	68,146	367,935	617,632	988,360
Total	2,534,896	13,686,441	22,974,687	36,765,054
Average Annual Equivalent Costs				
Project Implementation	93,895	506,958	851,004	1,361,811
Operation & Maintenance	5,000	15,000	15,000	15,000
Total	98,895	521,958	866,004	1,376,811
Average Annual Equivalent Benefits				
Flood Risk Management	0	56,569	142,564	188,072
Recreation	0	596,410	596,410	596,410
Total	0	652,979	738,974	784,482
Benefit vs. Cost Ratio	**0.00**	**1.25**	**0.85**	**0.57**
Net Benefits	-98,895	131,021	-127,029	-592,329

Assumptions
$5K O&M for FWEEP and $10K for 2nd Increment
24 month construction period for all increments
50 year period of analysis, Base Year 2030

Note that all calculations and benefit-cost ratios are based on cost estimates that were finalized for the Tentatively Selected Plan milestone in June 2024. Costs and benefit-cost ratios were updated for the final analysis in Section 3 of this appendix.

2.2.6.1 Major uncertainties in NED Benefits Analysis

2.2.6.1.1 Flood Risk Management

2.2.6.1.1.1 Nonstructural Measures Participation Rate

With the exception of the acquisition of structures in the floodway that takes place in the second increment of the recommended plan, all of the remaining proposed nonstructural measures are voluntary. The benefits analysis described heretofore assumes 100 percent participation of property owners; however, there remains the possibility, perhaps even likelihood of lesser participation which would reduce the flood risk management benefits provided by the recommended plan. The third and fourth increments of the recommended plan contain all of the voluntary measures. These increments actually have higher annual economic costs than annual economic benefits. Increments three and four are described in tables 18 and 19 in the main report. Based on the extremely low BCR of the third and fourth increments, it is unlikely that lack of participation by any one homeowner would further decrease the BCR. In fact, it is likely that any number of structure owners choosing not to participate in the project would cause the total project BCR to increase.

2.2.6.1.1.2 Residual Risk Inherent in Dry Floodproofing Measures

Dry floodproofing has been selected as the most appropriate nonstructural flood risk management measure for several of the structures in the recommended plan. It should be noted, however, that the effectiveness of dry floodproofing measures is reliant on the installation of panels, planks, or barriers that ultimately make the structure watertight to a prescribed elevation. Thus, these measures unavoidably entail a risk that these necessary installations will not take place, whether from lack of time, physical incapacity to complete installation, or some other factor. If the installation of dry floodproofing implements is not achieved before floodwaters arrive, the estimated flood risk management benefits would not be realized.

2.2.6.1.2 Recreation Visitation Estimate

The vast majority of NED benefits provided by the recommended plan are a result of the recreation features that will be constructed on acquired lands. As described in Section 2.2.4, recreation benefits in this study were estimated using the Unit Day Value methodology, which determines value in the with- and without-project conditions as a function of the quality of the experience provided and estimated visitation. Because there is no data available on without project visitation, the value chosen for calculation of recreation benefits (5,000 annually) is highly uncertain. In the case that actual annual visitation to the existing playground and shoreline is higher than 5,000, total benefits would be reduced (this would also be true if with-project visitation is ultimately lower than estimated). Conversely, if actual without-project visitation is lower than 5,000 annually, net recreation benefits would increase (likewise, if with-project visitation is higher than estimated, benefits will increase). The visitation numbers chosen were determined by the PDT to be reasonable and conservative in nature for the purposes of this analysis.

2.2.7 Regional Economic Development Benefits

The Principles and Guidelines (1983) established the Regional Economic Development (RED) account to register changes in the distribution of regional economic activity that result from each alternative plan. In addition to the benefits accounted for within the NED account, the implementation of the Recommended Plan would result in increased local economic activity due to construction expenditures, which is accounted for within the RED account. These benefits should not be considered as additive to the NED benefits described above but as regional transfers and therefore a net-zero contribution to national economic development.

The USACE Regional Economic System (RECONS) is a regional economic impact modeling tool that was developed to provide accurate and defendable estimates of regional economic impacts associated with USACE spending. It is the only USACE Regional Economic Development model certified for use across the enterprise. RECONS incorporates impact area data, as well as multipliers, direct ratios (jobs to sales, income to sales, etc.), and geographic capture rates to estimate jobs, labor income, and other critical impacts to the local, state, and national economy.

In the figure below, the impact areas for regional economic impacts are shown. Lee County is the local impact area, and the state impact area is Kentucky. State impacts include local impacts, and national impacts include both state and local impacts.

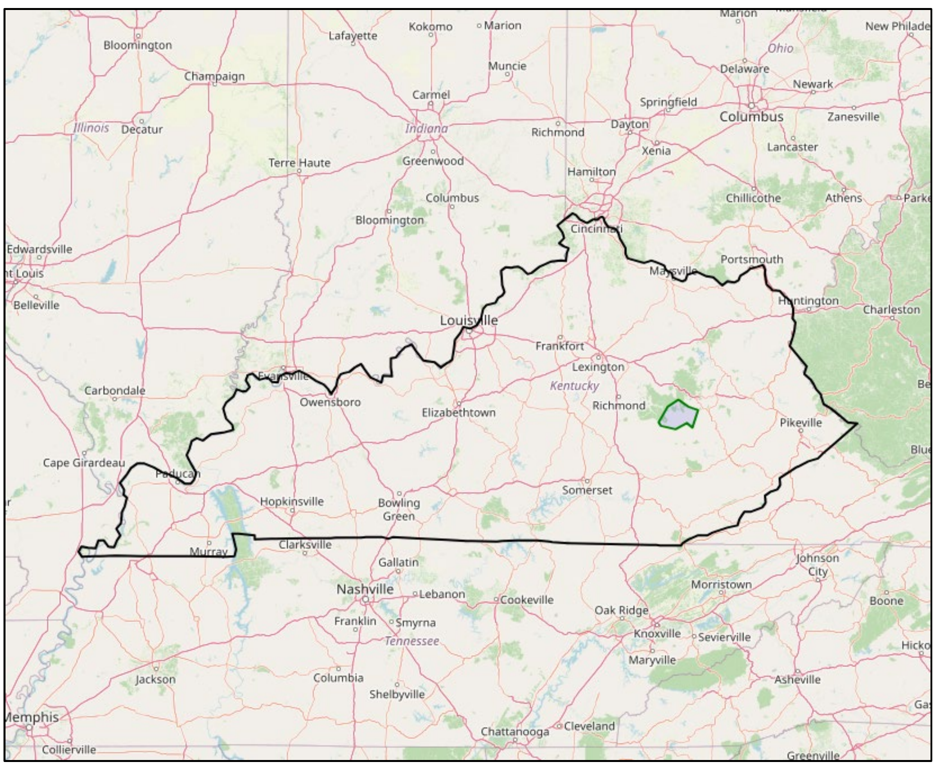

Figure 7: Regional Economic Impact Areas

Streamlined RECONS Definitions:

- Output: Economic output or total industry output is the value of production by industry for a given time period. It is also known as gross revenues or sales.
- Labor Income: Labor income represents all forms of employment earnings.
- Jobs (Employment): The work in which one is engaged; an occupation by which a person earns income. Employment includes both part-time and full-time jobs. All jobs are presented in full- time equivalence (FTE).
- Value Added: These are payments made by industry to workers, which also include interest, profits, and indirect business taxes. Value-added is an estimate of the gross regional or state product.

RECONS includes three categories of economic impacts:

- Direct impact is defined as expenditures made by USACE. In the impact area in which a project is located, direct impact represents that proportion of the expenditure that flows to material and service providers in the impact area. For employment and earnings measures, the direct impact represents the jobs associated with the work activity (e.g., onsite construction jobs that are likely to be filled by residents of the region [i.e., after adjustment for in-commuting by workers residing outside the region]).
- Secondary impact includes indirect impact, which includes the backward-linked suppliers for any goods and services used by the directly affected activities, and induced impact, which occurs from household expenditures associated with direct- and indirect-affected workers spending their income within the impact area. Economic impact measures reported are number of jobs, employment earnings, output, and value added.
- Total impact is equal to the sum of the direct, indirect, and induced effects for output, employment, value added, and labor income.

The nonstructural alternatives were analyzed to assess the impacts that their construction expenditures would have upon the regional economy, the results of which are presented in Table 33.

Table 33: Final Array RED Impact Summary

	Alternatives and Construction Costs									
	3A: Complete Nonstructural (672.2) - $ 53,687,400		4: FWEEP - $1,950,000		5A: FWEEP + Floodway Acquisition + Recreation Features - $8,392,000		5B: 5A + Nonstructural Measures for Essential Structures - $8,966,000		5C: 5B + Nonstructural Measures for Historic Structures - $18,657,000	
Area	**Output**	**Jobs**	**Output**	**Jobs***	**Output**	**Jobs***	**Output**	**Jobs***	**Output**	**Jobs***
Local- Lee County										
Direct Impact	$31,476,000	360	$1,143,000	13	$4,920,000	57	$5,257,000	61	$10,938,000	128
Secondary Impact	$13,238,000	80	$481,000	3	$2,069,000	13	$2,211,000	14	$4,601,000	29
Total Impact	$44,714,000	440	$1,624,000	16	$6,989,000	70	$7,467,000	75	$15,539,000	156
State - Kentucky										
Direct Impact	$40,285,000	440	$1,463,000	16	$6,297,000	69	$6,728,000	74	$14,000,000	154
Secondary Impact	$34,845,000	200	$1,266,000	7	$5,447,000	32	$5,819,000	34	$12,109,000	71
Total Impact	$75,130,000	640	$2,729,000	24	$11,743,000	101	$12,547,000	108	$26,109,000	225
US										
Direct Impact	$51,231,000	530	$1,861,000	20	$8,008,000	85	$8,556,000	91	$17,804,000	189
Secondary Impact	$94,630,000	430	$3,437,000	16	$14,791,000	68	$15,803,000	73	$32,886,000	152
Total Impact	**$145,860,000**	960	**$5,298,000**	36	**$22,799,000**	153	**$24,359,000**	163	**$50,689,000**	340

* Jobs are presented in full-time equivalence (FTE)
Values are presented in FY 2024 price levels.

2.2.8 Other Social Effects

In addition to the contributions to national and regional economic development, the recommended plan also provides positive impacts in many other social categories, especially important in this economically disadvantaged community.

The FWEEP provides a cost-effective improvement to life safety and supports resilience through floodplain management and improved response to flood events. The effects to life safety are quantified in Section 2.3.

The recommended plan includes floodproofing of structures supporting local services, assets, and anchor businesses such as police stations, courthouses, health centers, groceries, and cultural hubs. Floodproofing these structures will support community resilience by protecting the services that will allow the town to bounce back after a flood event.

Additionally, floodproofing or elevation measures will be applied to historic structures, supporting community cohesion, preserving Beattyville's aesthetic characteristics as well as its sense of community pride and history.

2.3 Life Safety Analysis

The life safety consequence modeling for this study was performed using USACE's life loss and direct property damage estimation software LifeSim version 2.1.3. To determine the percentage of population at risk (PAR) within a structure that is warned and mobilized over time, several parameters are used within LifeSim to estimate the probable values of warning and mobilization percentages at each time step. These include when hazards are identified and warnings will be issued (hazard identification and delays), how long they will take to become effective (warning diffusion), and the rate at which PAR will mobilize in response (mobilization or Protective Action Inhiation - PAI). Figure 7 is an example breach warning and response timeline.

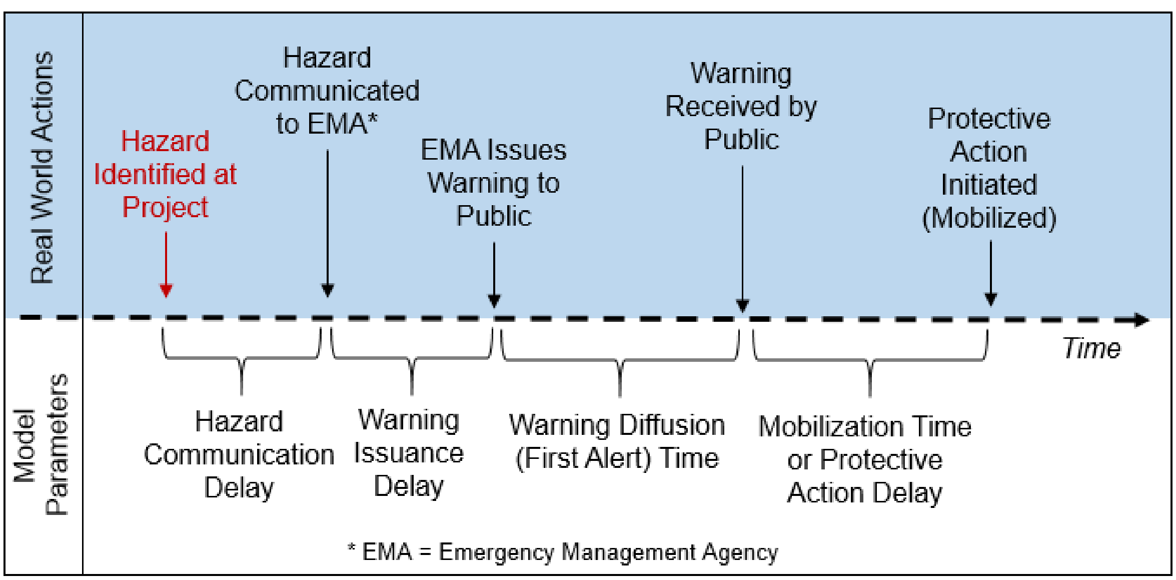

Figure 8: Warning and response timeline.

2.3.1 Life Loss Model Inputs and Parameters

2.3.1.1 Structure Inventory

The structure inventories used for life safety analysis are the same as those used for FDA analysis and are discussed in detail in Section 1.2.4.3.

2.3.1.2 Road Network and Destination Points

The road network was developed using data from OpenStreetMaps. The data contains information about road type, bridges, and directional attributes (one way). The road network was modified to account for overpasses and bridges so road segments will have the appropriate vertical offset relative to the ground elevation. The road network and destination points are shown in Figure 8.

Figure 9: Road network and destination points

2.3.1.3 Emergency Preparedness

Lee County has an all-hazards emergency operations plan that is currently under development; however, recent weather emergencies have shown little formal coordination as pertains to the issuance of first alerts and warnings.

The most recent major flood occurred in 2021 when Lee County officials stated water reached depths of six to seven feet downtown and affected 35 to 40 businesses. Multiple evacuations occurred, including one of approximately 20 people who were evacuated from a mobile home park downtown to an American Red Cross shelter (Chisenhall & Estep, 2021). There is evidence that many people had no advanced warning beyond law enforcement, or in some cases neighbors, knocking on the door and informing them they should evacuate immediately (Estep & Eads, 2021).

Since January 2009, Lee County has also experienced other significant weather emergencies including floods, ice storms, and a major windstorm. Each of these weather-related events initially paralyzed the county and required a well-coordinated recovery from the county's incident management team.

The Emergency Preparedness parameters within LifeSim are described in the sections below.

2.3.1.4 Relative Hazard Identification

The Hazard Identification time is the time at which a hazard is identified relative to when it occurs.

For Beattyville, the hazard was assumed to be when water begins to exceed the banks on Crystal Creek near McGuire Avenue between Main Street and the railroad.

It was assumed that for major floods—the 1% AEP event and the 0.2% AEP event—the hazard would be identified between six and 12 hours prior to Crystal Creek exceeding its banks. For the more frequent events—the 4% AEP event and the 2% AEP event—the hazard would be identified between zero and 12 hours prior to Crystal Creek exceeding its banks.

Table 34: Relative hazard identification times

AEP	Distribution Type	Minimum (hr)	Maximum (hr)
1%, 0.2%	Uniform	-12	-6
4%, 2%	Uniform	-12	-0

2.3.1.5 Hazard Communication Delay

The Hazard Communication Delay is the time that it would take from when the hazard is identified to when the emergency planning zone (EPZ) representatives would be notified. For example, if a breach occurs when no one is observing the project then the emergency managers could be notified after the hazard is identified. The hazard communication delay ranged between 0.01 and 0.5 hour and assumed a uniform distribution.

2.3.1.6 Warning Issuance Delay

The Warning Issuance Delay is the time it takes from when the emergency managers receive the notification of the imminent hazard to when they issue the first evacuation order to the public.

For the Future Without Project scenario, the LifeSim preset "Preparedness Unknown" warning issuance delay curves were used. Although the range of possible warning issuance delay is randomly sampled from 0 and 6 hours (300 minutes) after officials are notified of the flood hazard using a Lindell distribution, it is positively skewed so that results from 0 to 1.5 hours (90 minutes) are more likely.

For the with-project alternatives, all of which include a FWEEP, the LifeSim preset "Well Prepared" warning issuance delay curves were used. Like the FWOP condition, the range of possible warning issuance delay is randomly sampled from 0 and 6 hours (300 minutes) after officials are notified of the flood hazard, the Lindell distribution is positively skewed so that results from 0 to 0.5 hours (30 minutes) are more likely.

2.3.1.7 Warning Diffusion

For the Future Without Project scenario, the LifeSim preset "Preparedness Unknown" warning diffusion curves were used. The curves utilize a uniform distribution, and the warning diffusion curves are sampled during each Monte Carlo iteration in LifeSim. The upper bound of the curve reaches 100% diffusion just after 1.5 hours (100 minutes), and the lower bound reaches 100% diffusion after 6 hours (360 minutes).

For the with-project alternatives, the LifeSim preset "Fast" warning diffusion curves were used due to the assumption that the FWEEP will be in place. The curves utilize a triangular distribution and are sampled during each Monte Carlo iteration in LifeSim. The upper bound of the curve reaches 100% diffusion just after 1.5 hours (100 minutes), and the lower bound reaches 100% diffusion after 150 minutes.

2.3.1.8 Protective Action Initiation

Protective Action Initiation (PAI) is the rate at which PAR takes action after receiving an evacuation order (warning). Unlike the warning diffusion curves, the PAI "Preparedness Unknown" curve includes a perception element as well. The perception element describes a PAR as being aware of their flood risk (Perception = Likely to Impact) or generally unaware that they are at risk of being flooded (Perception = Unlikely to Impact). The "Preparedness Unknown, Perception Unknown" curve was used for all scenarios, because it is unclear what impact a FWEEP would have on the population's perception of their own risk and their likelihood to mobilize when warned, though it would be reasonable to assume there would be some improvement in both perception and preparedness.

Time	Initiated		
X	Min (a)	Most Likely (c)	Max (b)
0	0	0	0
15	1	29	75
30	4.0363	50	100
60	23	75	100
120	42	89	100
480	53	91	100
1,440	71	94	100
4,320	76.0323	97	100

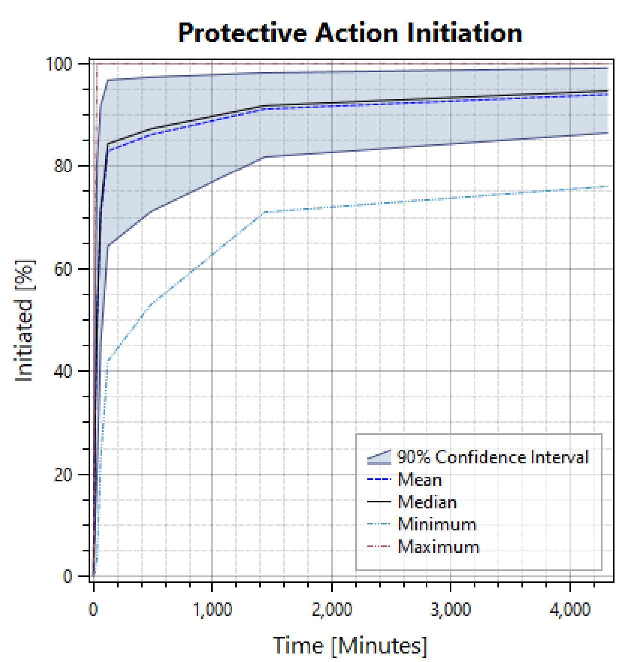

Figure 10. PAI curve for preparedness unknown, perception unknown.

2.3.2 Expanded Array of Alternatives Analysis

Life loss analysis was not completed on the expanded array of alternatives until after all floodwall alternatives had been screened from further consideration. Therefore, this section focuses on existing conditions, the FWEEP, and the four nonstructural alternatives that were aggregated by target elevations.

2.3.2.1 Population at Risk

Population at risk (PAR) is defined as the number of people within a project area that would be subject to inundation during a flood hazard event. Estimates of PAR were generated in LifeSim using the previously described inundation scenarios. The estimated number of inundated structures and PAR are summarized in Table 35 and Table 36, respectively.

Table 35: Expanded Array Estimated number of inundated structures

Alternative	Description (NAVD88)	Structures Inundated			
		0.2 % AEP	1% AEP	2% AEP	4% AEP
1	Without Project	129	129	123	84
3D	Nonstructural – Elevation 663.0’	112	109	106	69
3C	Nonstructural – Elevation 666.5’	97	91	91	57
3B	Nonstructural – Elevation 669.2’	93	90	88	57
3A	Nonstructural – Elevation 672.2’	94	91	89	57

Table 36: Expanded Array Estimated mean population at risk

Alternative	Description (NAVD88)		Population at Risk			
			0.2 % AEP	1% AEP	2% AEP	4% AEP
1	Without Project	Day	369	364	361	175
		Night	317	310	306	135
3D	Nonstructural – Elevation 663.0’	Day	338	333	330	147
		Night	309	303	299	125
3C	Nonstructural – Elevation 666.5’	Day	309	304	300	119
		Night	282	276	272	100
3B	Nonstructural – Elevation 669.2’	Day	296	291	289	116
		Night	270	264	262	97
3A	Nonstructural – Elevation 672.2’	Day	296	291	289	116
		Night	270	264	262	97

2.3.2.2 Direct Life Loss

Estimates of direct life loss were generated using LifeSim for the 4%, 2%, 1%, and 0.2% AEP inundation scenarios, for both with- and without-project. The more frequent scenarios were not modeled because structures in Beattyville are not expected to incur inundation in those cases.

LifeSim utilizes Monte Carlo uncertainty analysis, and 5,000 iterations were performed for each scenario. The estimated direct life loss by scenario is summarized in the following tables.

Table 37. Estimated direct life loss for Future Without Project

	0.2% AEP		1% AEP		2% AEP		4% AEP	
Statistic	**Day**	**Night**	**Day**	**Night**	**Day**	**Night**	**Day**	**Night**
Maximum	80	93	38	38	17	16	5	5
95th Percentile	27	22	10	9	5	4	2	1
75th Percentile	15	12	5	5	3	2	0	0
Mean	**11**	**9**	**4**	**3**	**2**	**1**	**0**	**0**
Median	**9**	**7**	**3**	**2**	**1**	**1**	**0**	**0**
25th Percentile	4	3	1	1	0	0	0	0
5th Percentile	0	0	0	0	0	0	0	0
Minimum	0	0	0	0	0	0	0	0

Table 38. Estimated direct life loss for FWEEP Only

	0.2% AEP		1% AEP		2% AEP		4% AEP	
Statistic	**Day**	**Night**	**Day**	**Night**	**Day**	**Night**	**Day**	**Night**
Maximum	59	70	15	15	10	7	4	4
95th Percentile	19	16	7	6	4	3	1	1
75th Percentile	10	9	3	3	2	1	0	0
Mean	**7**	**6**	**2**	**2**	**1**	**1**	**0**	**0**
Median	**6**	**5**	**1**	**1**	**0**	**0**	**0**	**0**
25th Percentile	2	2	0	0	0	0	0	0
5th Percentile	0	0	0	0	0	0	0	0
Minimum	0	0	0	0	0	0	0	0

Table 39. Estimated direct life loss for 663.0 + FWEEP

	0.2% AEP		1% AEP		2% AEP		4% AEP	
Statistic	**Day**	**Night**	**Day**	**Night**	**Day**	**Night**	**Day**	**Night**
Maximum	71	107	20	21	9	9	4	3
95th Percentile	20	18	9	8	4	3	1	1
75th Percentile	11	10	5	4	2	2	0	0
Mean	**8**	**7**	**3**	**3**	**1**	**1**	**0**	**0**
Median	**6**	**6**	**2**	**2**	**1**	**0**	**0**	**0**
25th Percentile	3	2	0	0	0	0	0	0
5th Percentile	0	0	0	0	0	0	0	0
Minimum	0	0	0	0	0	0	0	0

Table 40. Estimated direct life loss for 666.5 + FWEEP

	0.2% AEP		1% AEP		2% AEP		4% AEP	
Statistic	**Day**	**Night**	**Day**	**Night**	**Day**	**Night**	**Day**	**Night**
Maximum	58	81	17	28	15	10	5	4
95th Percentile	18	16	7	7	4	3	1	1
75th Percentile	10	9	3	3	2	2	0	0
Mean	**7**	**6**	**2**	**2**	**1**	**1**	**0**	**0**
Median	**5**	**5**	**1**	**1**	**0**	**0**	**0**	**0**
25th Percentile	2	2	0	0	0	0	0	0
5th Percentile	0	0	0	0	0	0	0	0
Minimum	0	0	0	0	0	0	0	0

Table 41. Estimated direct life loss for 669.2 + FWEEP

	0.2% AEP		1% AEP		2% AEP		4% AEP	
Statistic	**Day**	**Night**	**Day**	**Night**	**Day**	**Night**	**Day**	**Night**
Maximum	51	63	25	22	9	9	5	3
95th Percentile	17	14	7	6	4	3	1	0
75th Percentile	9	8	3	3	2	1	0	0
Mean	**6**	**5**	**2**	**2**	**1**	**1**	**0**	**0**
Median	**5**	**4**	**1**	**1**	**0**	**0**	**0**	**0**
25th Percentile	2	1	0	0	0	0	0	0
5th Percentile	0	0	0	0	0	0	0	0
Minimum	0	0	0	0	0	0	0	0

Table 42. Estimated direct life loss for 672.2 + FWEEP

	0.2% AEP		1% AEP		2% AEP		4% AEP	
Statistic	**Day**	**Night**	**Day**	**Night**	**Day**	**Night**	**Day**	**Night**
Maximum	60	70	16	21	11	7	4	3
95th Percentile	16	14	7	6	4	3	1	1
75th Percentile	9	7	3	3	2	2	0	0
Mean	**6**	**5**	**2**	**2**	**1**	**1**	**0**	**0**
Median	**5**	**4**	**1**	**1**	**0**	**0**	**0**	**0**
25th Percentile	2	1	0	0	0	0	0	0
5th Percentile	0	0	0	0	0	0	0	0
Minimum	0	0	0	0	0	0	0	0

The above statistical summaries only reflect the uncertainty in the LifeSim input parameters and do not include uncertainties for breach parameters or other hydrologic and hydraulic factors.

2.3.2.3 Life Loss on Roads

A potentially important element of the life safety consequences occurs while the PAR is evacuating after receiving an evacuation order. In Beattyville's recent major floods, it was noted that many downtown roads were inundated, which introduces the potential for individuals to lose their lives by coming into contact with flood waters while evacuating. To account for this life loss while evacuating, LifeSim simulates evacuation in vehicles on a road network, making it possible to estimate how much life loss on roads contributes to the total life loss. The estimated mean life loss on roads is summarized in Table 43.

Table 43: Expanded Array Estimated mean breach life loss on roads.

Alternative	Description (NAVD88)		Mean Life Loss on Roads			
			0.2 % AEP	1% AEP	2% AEP	4% AEP
1	Without Project	Day	1	1	0	0
		Night	1	1	0	0
3D	Nonstructural – Elevation 663.0'	Day	1	1	0	0
		Night	1	0	0	0
3C	Nonstructural – Elevation 666.5'	Day	1	0	0	0
		Night	1	0	0	0
3B	Nonstructural – Elevation 669.2'	Day	1	0	0	0
		Night	1	0	0	0
3A	Nonstructural – Elevation 672.2'	Day	1	0	0	0
		Night	1	0	0	0
4	FWEEP Only	Day	1	0	0	0
		Night	1	0	0	0

2.3.2.4 Life Safety Risk

While LifeSim, described in the sections above, produces event-based life loss estimates, those alone are not adequate to describe the annual risk to life safety from riverine flooding, which is reliant on the probability of the modeled events occurring.

The USACE Risk Management Center has developed quantitative risk analysis software (RMC-TotalRisk) to perform risk analysis based on probability of hazard occurrence and the consequences that occur as a result of those user-defined hazards.

2.3.2.4.1 Hazard

To define the hazard and its uncertainty within RMC-TotalRisk, each modeled frequency event was assigned a minimum, most likely, and maximum stage (PERT distribution). In addition to the eight events modeled in HEC-FDA and LifeSim, the 0.001 and 0.0002 AEP events were included to inform the analysis.

Because all structural alternatives had been previously screened from further analysis, only one hydraulic event was needed for this analysis, which was applied to the future without project condition and all nonstructural alternatives.

Table 44: Stage-frequency data used in RMC-TotalRisk

Exceedance Probability	Stage (ft-NAVD88)		
	Minimum	Most Likely	Maximum
0.99	638.77	640.62	642.59
0.5	647.94	649.47	650.96
0.2	651.26	653.28	656.31
0.1	653.38	656.7	663.29
0.04	656.46	663.47	669.7
0.02	660.91	667.77	675.52
0.01	664.34	671.43	681.31
0.002	669.98	680.17	696.66
0.001	672.24	684.09	704.22
0.0002	677.31	693.6	724.37

The uncertainty distribution for the flood hazard is shown in the following figure.

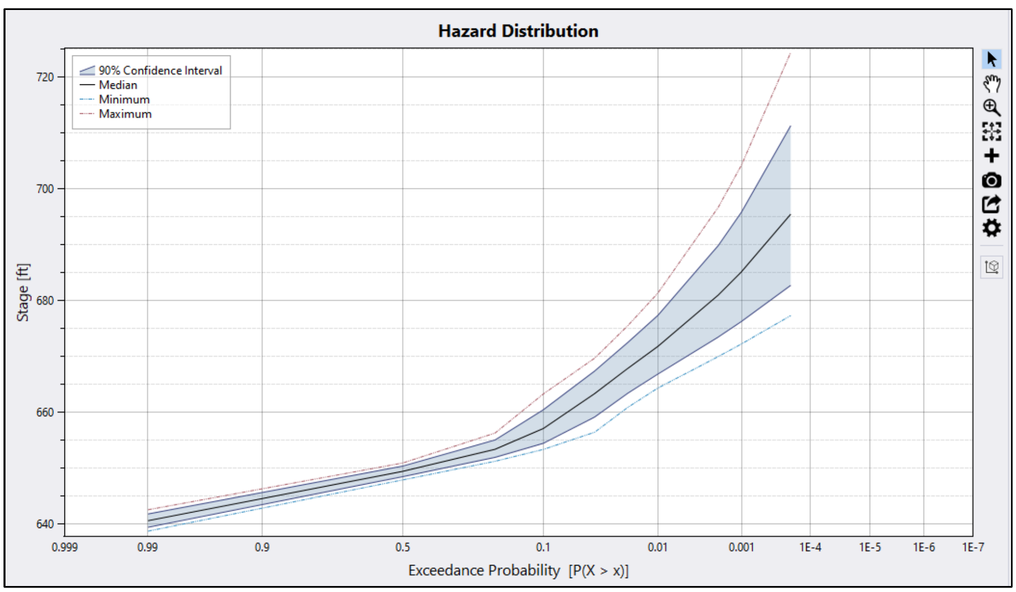

Figure 11: Stage-Frequency Uncertainty Distribution

2.3.2.5 Expected Annual Life Loss

As described in Section 1.5.2.2, daytime and nighttime life loss estimates were developed for a range of flood frequency events for the following scenarios: Future Without Project, Nonstructural to elevation 672.2' NAVD88 + FWEEP, Nonstructural to elevation 669.2' NAVD88 + FWEEP, Nonstructural to elevation 666.5' NAVD88 + FWEEP, Nonstructural to elevation 663.0' NAVD88 + FWEEP, and FWEEP only.

In RMC-TotalRisk, three consequence functions are created for each scenario: Day, Night, and Composite. The daytime exposure scenario rate was assumed to be 45% while the nighttime exposure rate was assumed to be 55%, and the composite curves were created using the day and night scenarios weighted by their respective exposure rates.

Given the likelihood of each modeled event and the expected life loss associated with each event, the result of the RMC-TotalRisk analysis is the total average annual incremental life loss (AALL) for each scenario, shown in Table 45.

Table 45: Expanded Array Expected Annual Life Loss

Alternative	Description (NAVD88)	Expected Annual Life Loss (Lives/Year)	Change in Expected Annual Life Loss	
			Lives/Year	Percent
1	Without Project	0.1349	0	0
3D	Nonstructural – Elevation 663.0’	0.1138	-0.0216	-16%
3C	Nonstructural – Elevation 666.5’	0.0971	-0.0383	-28%
3B	Nonstructural – Elevation 669.2’	0.0941	-0.0413	-31%
3A	Nonstructural – Elevation 672.2’	0.0923	-0.0431	-32%
4	FWEEP Only	0.1252	-0.0093	-7%

In the without project condition, the expected life loss is 0.1349 lives per year – nearly 7 individuals whose lives are expected to be lost due to direct contact with flood waters over the 50-year period of analysis. It should be noted that these figures do not include indirect life loss; that is, life loss that occurs due to other effects of a flood, such as a power outage, exposure to extreme weather conditions, or lack of access to emergency services.

All proposed alternatives reduce the expected annual life loss, several of them by 25-30 percent. However, the cost of the proposed measures must be considered. While USACE does not place a monetary value on human life, the cost per statistical life saved can be a useful measurement to compare the cost-effectiveness of the proposed alternatives.

The procedure to calculate the cost-to-save-a-statistical-life, or CSSL, is described in Appendix P of Engineering Regulation 1110-2-1156. In short, the CSSL is the difference between the annualized cost of a safety remediation measure and the annualized economic benefit of risk reduction to property, divided by the incremental reduction in the annualized risk of life loss brought about by the safety remediation.

Table 46: Expanded Array Cost to Save a Statistical Life

Alternative	Description (NAVD88)	Expected Annual Life Loss (Lives/Year)	Cost to Save a Statistical Life
1	Without Project	0.1349	-
3D	Nonstructural – Elevation 663.0’	0.1138	$33,160,000
3C	Nonstructural – Elevation 666.5’	0.0971	$38,550,000
3B	Nonstructural – Elevation 669.2’	0.0941	$51,770,000
3A	Nonstructural – Elevation 672.2’	0.0923	$58,990,000
4	FWEEP Only	0.1261	$10,230,000

While Alternatives 3A and 3B, Nonstructural to elevation 672.2’ NAVD88 and 669.2’ NAVD88, respectively, contribute the largest reductions to life safety risk at Beattyville, they are the costliest per life saved. Among the proposed alternatives, Alternative 4, FWEEP Only, has the lowest cost to save a statistical life.

2.3.3 Final Array Alternatives Analysis

The life safety analysis of the final array of alternatives is described below. Note that, like the flood damage analysis, some minor changes to the base structure inventory occurred between the analysis of the expanded array and the final array so the without project conditions/no-action alternatives between the two arrays can be expected to contain some discrepancies.

Also note that the alternatives 5B and 5C were not modeled as the additional dry and wet floodproofing was not expected to provide significant enough changes to life safety risk to warrant further analysis. It can be assumed for purposes of this analysis that the life safety outcomes for 5B and 5C are equivalent to those for 5A shown below.

2.3.3.1 Population at Risk

As described in the life safety analysis of the expanded array, population at risk (PAR) is defined as the number of people within a project area that would be subject to inundation during a flood hazard event. The estimated number of inundated structures and PAR are summarized in Table 47 and Table 48, respectively.

Table 47: Final Array Estimated number of inundated structures

Alternative	Description	Structures Inundated			
		0.2 % AEP	1% AEP	2% AEP	4% AEP
1	Without Project	123	120	117	79
4	Flood Warning and Evacuation Emergency Plan	123	120	117	79
5A	FWEEP + Floodway Acquisition + Recreation Features	110	107	104	69
5B	5A + Essential Structures	110	107	104	69
5C (TSP)	5B + Historic Structures	110	107	104	69

Table 48: Final Array Estimated mean population at risk

Alternative	Description		Population at Risk			
			0.2 % AEP	1% AEP	2% AEP	4% AEP
1	Without Project	Day	333	327	358	170
		Night	361	356	309	134
4	Flood Warning and Evacuation Emergency Plan	Day	313	306	347	161
		Night	377	372	321	142
5A	FWEEP + Floodway Acquisition + Recreation Features	Day	288	281	321	141
		Night	351	346	296	123
5B	5A + Essential Structures	Day	288	281	321	141
		Night	351	346	296	123
5C (TSP)	5B + Historic Structures	Day	288	281	321	141
		Night	351	346	296	123

2.3.3.2 Direct Life Loss

Estimates of direct life loss were generated using LifeSim for the 4%, 2%, 1%, and 0.2% AEP inundation scenarios, for both with- and without-project. The more frequent scenarios were not modeled because structures in Beattyville are not expected to incur inundation in those cases.

As in the analysis of the expanded array, 5,000 iterations were performed for each scenario. The estimated direct life loss by scenario is summarized in the following tables.

Table 49. Estimated direct life loss for Future Without Project

	0.2% AEP		1% AEP		2% AEP		4% AEP	
Statistic	**Day**	**Night**	**Day**	**Night**	**Day**	**Night**	**Day**	**Night**
Maximum	38	36	21	20	12	11	6	4
95th Percentile	19	20	8	9	5	4	1	1
75th Percentile	11	11	4	4	2	2	0	0
Mean	7	8	3	3	1	1	0	0
Median	6	6	2	2	1	1	0	0
25th Percentile	2	3	0	1	0	0	0	0
5th Percentile	0	0	0	0	0	0	0	0
Minimum	0	0	0	0	0	0	0	0

Table 50. Estimated direct life loss for Alt. 4: FWEEP Only

	0.2% AEP		1% AEP		2% AEP		4% AEP	
Statistic	**Day**	**Night**	**Day**	**Night**	**Day**	**Night**	**Day**	**Night**
Maximum	34	47	23	21	15	10	4	4
95th Percentile	17	20	8	8	4	4	1	1
75th Percentile	10	11	4	4	2	2	0	0
Mean	6	8	2	3	1	1	0	0
Median	5	7	2	2	1	0	0	0
25th Percentile	2	3	0	0	0	0	0	0
5th Percentile	0	0	0	0	0	0	0	0
Minimum	0	0	0	0	0	0	0	0

Table 51. Estimated direct life loss for Alt. 5A*

	0.2% AEP		1% AEP		2% AEP		4% AEP	
Statistic	**Day**	**Night**	**Day**	**Night**	**Day**	**Night**	**Day**	**Night**
Maximum	32	32	15	14	9	11	4	4
95th Percentile	14	16	6	6	4	3	1	1
75th Percentile	7	9	2	3	2	1	0	0
Mean	5	6	1	2	1	1	0	0
Median	4	5	1	1	0	0	0	0
25th Percentile	1	2	0	0	0	0	0	0
5th Percentile	0	0	0	0	0	0	0	0
Minimum	0	0	0	0	0	0	0	0

**Note that these results are also applicable to Alternatives 5B, and 5C (TSP).*

The above statistical summaries only reflect the uncertainty in the LifeSim input parameters and do not include uncertainties for breach parameters or other hydrologic and hydraulic factors.

2.3.3.3 Life Loss on Roads

A potentially important element of the life safety consequences occurs while the PAR is evacuating after receiving an evacuation order. In Beattyville's recent major floods, it was noted that many downtown roads were inundated, which introduces the potential for individuals to lose their lives by coming into contact with flood waters while evacuating. To account for this life loss while evacuating, LifeSim simulates evacuation in vehicles on a road network, making it possible to estimate how much life loss on roads contributes to the total life loss. The estimated mean life loss on roads is summarized in Table 52.

Table 52: Final Array Estimated mean breach life loss on roads.

Alternative	Description		Mean Life Loss on Roads			
			0.2 % AEP	1% AEP	2% AEP	4% AEP
1	Without Project	Day	1	0	0	0
		Night	1	0	0	0
4	Flood Warning and Evacuation Emergency Plan	Day	0	0	0	0
		Night	1	0	0	0
5A	FWEEP + Floodway Acquisition + Recreation Features	Day	0	0	0	0
		Night	1	0	0	0
5B	5A + Essential Structures	Day	0	0	0	0
		Night	1	0	0	0
5C (TSP)	5B + Historic Structures	Day	0	0	0	0
		Night	1	0	0	0

2.3.3.4 Life Safety Risk

The hazard inputs for RMC-TotalRisk are the same described in Section 1.5.2.4.

2.3.3.5 Expected Annual Life Loss

Given the likelihood of each modeled event and the expected life loss associated with each event, the result of the RMC-TotalRisk analysis is the total expected average incremental life loss (EALL) for each scenario, shown in Table 53.

Table 53: Final Array Expected Annual Life Loss

Alternative	Description	Expected Annual Life Loss (Lives/Year)	Change in Expected Annual Life Loss	
			Lives/Year	Percent
1	Without Project	0.1349	0	0
3A	Nonstructural – Elevation 672.2’	0.0923	-0.0431	-32%
4	Flood Warning and Evacuation Emergency Plan	0.1252	-0.01	-7%
5A	FWEEP + Floodway Acquisition + Recreation Features	0.0949	-0.04	-30%
5B	5A + Essential Structures	0.0949	-0.04	-30%
5C (TSP)	5B + Historic Structures	0.0949	-0.04	-30%

In the without project condition, the expected life loss is 0.1349 lives per year – nearly 7 individuals whose lives are expected to be lost due to direct contact with flood waters over the 50-year period of analysis. It should be noted that these figures do not include indirect life loss; that is, life loss that occurs due to other effects of a flood, such as a power outage, exposure to extreme weather conditions, or lack of access to emergency services.

Both proposed alternatives reduce the expected annual life loss; however, the cost of the proposed measures must be considered. While USACE does not place a monetary value on human life, the cost per statistical life saved can be a useful measurement to compare the cost-effectiveness of the proposed alternatives.

The procedure to calculate the cost-to-save-a-statistical-life, or CSSL, is described in Appendix P of Engineering Regulation 1110-2-1156. In short, the CSSL is the difference between the annualized cost of a safety remediation measure and the annualized economic benefit of risk reduction to property, divided by the incremental reduction in the annualized risk of life loss brought about by the safety remediation.

Table 54: Final Array Cost to Save a Statistical Life

Alternative	Description	Expected Annual Life Loss (Lives/Year)	Cost to Save a Statistical Life
1	Without Project	0.1349	-
3A	Nonstructural – Elevation 672.2’	0.0923	$58,990,000
4	Flood Warning and Evacuation Emergency Plan	0.1252	$10,195,000
5A	FWEEP + Floodway Acquisition + Recreation Features	0.0949	$11,563,000
5B	5A + Essential Structures	0.0949	$11,563,000
5C (TSP)	5B + Historic Structures	0.0949	$11,563,000

3 RECOMMENDED PLAN BENEFITS ANALYSIS

The recommended plan is 5C from the final array, which includes the FWEEP, floodway acquisitions, and nonstructural flood risk management measures applied to essential and historic structures in the study area. The team's understanding of the recommended plan and estimation of benefits were refined as outlined in the following sections. Assumptions that differ from the alternatives analysis will be noted.

3.1 UPDATED ASSUMPTIONS AND INPUTS

The following assumptions and modeling inputs were modified from the alternatives analysis.

3.1.1 Impact Areas

Initially, the study area was divided into seven impact areas. By the time of the alternatives comparison, these areas had been condensed into three, based on hydraulic characteristics. Further refinement of the structure inventory led to it being even more geographically concentrated than it was initially, thus any hydraulic differences would be negligible.

Therefore, the entire study area is treated as one impact area.

3.1.2 Hazard

The hydraulic characteristics of the "Beattyville" impact area are elucidated in the following tables.

Table 55: Future Without Project Condition Water Surface Profiles

Impact Area	Station	Stage by Annual Exceedance Probability							
		0.99	0.5	0.2	0.1	0.04	0.02	0.01	0.002
Beattyville	Kentucky River Reach 1 - 257.5189	640.15	649.32	653.55	655.73	664.88	669.86	672.38	678.8
[1] *Mean modeled river stages in feet NAVD88*									

The without project condition performance statistics help inform the risk of a flood event at a specific flood frequency. The target stage is the stage typically associated with the start of significant damage for the without project condition. The long-term risk is the probability that flooding occurs in a period of 10, 30F, or 50 years, and the assurance probability is the chance of containing the specific exceedance probability event within the target stage should that event occur. Table 5 following table displays these statistics by impact area for the without project condition.

Table 56: Without Project Condition Long Term Risk and Assurance

Impact Area	Threshold Value	Annual Exceedance Probability		Long Term Exceedance Probability			Assurance of Threshold				
		Mean	Median	10 Years	30 Years	50 Years	0.1	0.04	0.02	0.01	0.004
Beattyville	662.37	0.050	0.049	0.404	0.789	0.925	0.990	0.250	0.030	0.020	0.000

3.1.3 Structure Inventory

The final structure inventory was refined and the structures themselves were reevaluated using photos and data gathered from site visits during the Feasibility and Design phase. Structures, content, and vehicle values were updated to represent fiscal year (FY) 2025 price levels (FY25).

The updated distribution of structures across the project area is shown in Figure 12.

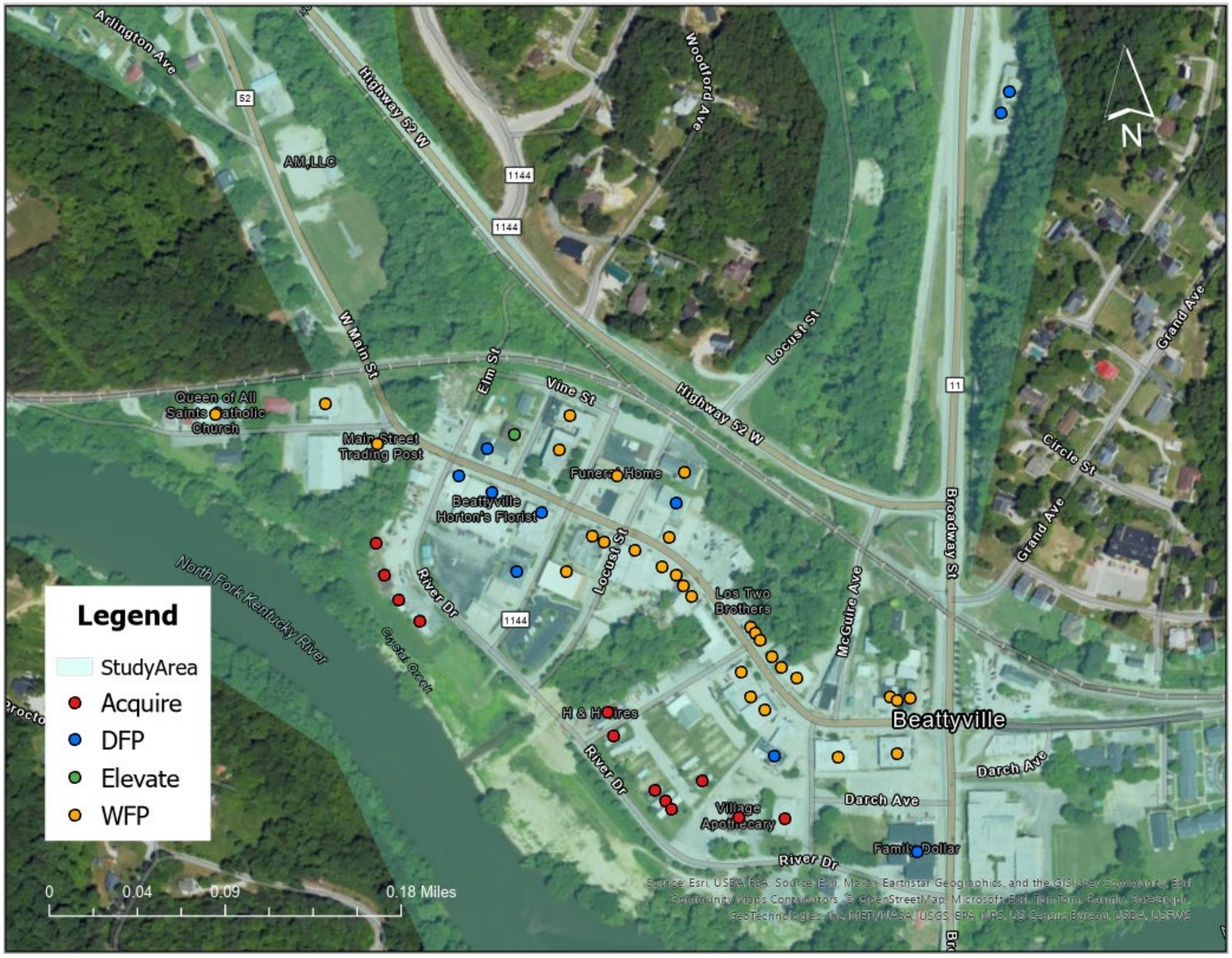

Figure 12: Final Structure Inventory

Table 57: Estimated Value of Structures in Project Area

Damage Category	Number of Structures	Estimated Total Structure Value (dollars)
Residential	8	369,000
Commercial	37	7,391,000
Public	8	2,801,000
Total	**53**	**10,562,000**
Values are in 2025 price levels		

3.2 ESTIMATION OF FLOOD RISK MANAGEMENT BENEFITS

The recommended plan, Alternative 5C, which included the FWEEP, removal of structures from the regulatory floodway, and nonstructural flood risk management measures for essential and historic structures, was evaluated to ascertain the mean expected annual damages compared to the damages that would be incurred in a without project scenario. Results are shown in Table 58.

Table 58. Mean Expected Annual Damages by Damage Category

Alternative	Description	Commercial	Residential	Public	Total Damage
1	Without Project	$358,634	$18,691	$87,705	$465,030
5C	Recommended Plan	$228,311	$1,059	$54,855	$284,225
Values are presented in FY25 price levels and were annualized over a period of 50 years using the FY25 discount rate (3.0%).					

As discussed previously in Section 3.1.1, the entire study area was treated as one impact area in this iteration of economic analysis. As such, the above values in Table 58 also represent the damages by impact area.

The following table displays total expected annual damage (with uncertainty) for the with- and without-project conditions.

Table 59: Total Expected Annual Damage by Alternative (with Uncertainty)

Alternative	Description	Expected Annual Damage (Mean)	Expected Annual Damage (25th to 75th percentile)		
		Mean	Q1	Median	Q3
1	Without Project	465,030	295,473	435,142	603,964
5C	Recommended Plan	284,225	168,634	260,849	374,216
Values are presented in FY25 price levels and were annualized over a period of 50 years using the FY25 discount rate (3.0%).					

Table 60 displays the estimated damages at each flood frequency event by damage category. Note there are no expected damages occurring prior to the 0.04 AEP (or 25-year) event.

Table 60: Estimated Damages by Damage Category and Event

		Frequency Event							
Alternative	**Damage Category**	**0.99**	**0.5**	**0.2**	**0.1**	**0.04**	**0.02**	**0.01**	**0.002**
1 – Without Project	Commercial	-	-	-	-	2,110,155	8,322,923	10,158,354	13,293,064
	Residential	-	-	-	-	33,360	551,246	682,972	749,597
	Public	-	-	-	-	256,054	2,086,299	2,798,782	3,271,876
	Total	-	-	-	-	2,399,568	10,960,469	13,640,108	17,314,537
5C – Recommended Plan	Commercial	-	-	-	-	1,003,789	5,391,071	7,366,964	11,277,061
	Residential	-	-	-	-	0	0	27,495	125,038
	Public	-	-	-	-	87,340	1,295,849	1,738,662	2,698,799
	Total	-	-	-	-	1,091,129	6,686,920	9,133,121	14,100,898
Values are presented in FY24 price levels and were annualized over a period of 50 years using the FY25 discount rate (3.0%).									

The damages reduced, or expected annual benefits, are shown below in Table 61.

Table 61: Damages and Benefits by Alternative

Alternative	Description	Average Annual Equivalent Damage (Mean)			Average Annual Equivalent Damage Reduced (25th to 75th percentile)		
		Total Without Project	Total With Project	Damage Reduced	Q1	Median	Q3
5C	Recommended Plan	465,030	284,225	180,911	126,832	174,315	229,733
Values are presented in FY24 price levels and were annualized over a period of 50 years using the FY25 discount rate (3.0%).							

3.2.1 Nonstructural Measures Incremental Analysis

As noted previously in this appendix, the following assumptions were made for the application of nonstructural measures:

1. Dry floodproofing measures would be applied to a height of three feet above the finished first floor elevation.
2. Wet floodproofing measures would be applied to a height of eight feet above the finished first floor elevation.
3. Structures being raised in place, or elevated, would be assessed individually. An elevation design height will be determined during feasibility.

To ensure the optimal level of protection was applied, a sensitivity analysis was necessary; however, because of the number of structures receiving nonstructural flood risk management measures, it was not feasible to perform such an analysis for every individual structure. Therefore, a sensitivity analysis was conducted for one structure receiving each of the proposed measures to be used as a proxy.

3.2.1.1 Dry Floodproofing

Because the maximum height of dry floodproofing recommended by USACE's nonstructural committee is three feet, no higher levels were explored, but costs and benefits were estimated for dry floodproofing to one foot and two feet above first floor elevation.

To accomplish this analysis in FDA 2.0, a structure inventory consisting of a single structure – in this case, structure number 18 – was utilized to represent the without project condition. Then that inventory was used to create three new inventories consisting of the same structure, but each with a different occupancy type that would allow the application of different depth-damage curves to account for the differing levels of flood protection. The results of this analysis are shown below.

The measure's total investment cost was amortized over a 50-year period of analysis at the FY25 Federal discount rate of 3.0%. The assumed construction duration for the recommended plan was 4 months.

Table 62: Incremental Analysis – Dry Floodproofing

Beattyville, KY General Investigation Summary of Annual Benefits and Costs FY 2025 Price Levels 3.0% Interest Rate			
Investment Cost	**Dry Floodproofing - 1 foot**	**Dry Floodproofing - 2 foot**	**Dry Floodproofing - 3 foot**
Construction First Cost	555,047	649,964	744,881
Interest During Construction	2,743	3,212	3,682
Total Investment Cost	557,790	653,176	748,563
Annual Costs			
Interest & Amortization	21,679	25,386	29,093
Operation & Maintenance	0	0	0
Total Annual Costs	21,679	25,386	29,093
Annual Benefits			
Flood Risk Management	1,583	2,961	4,141
Total Annual Benefits	1,583	2,961	4,141
Benefit vs. Cost Ratio	**0.07**	**0.12**	**0.14**
Net Benefits	-20,096	-22,426	-24,953
Assumptions			
[1]All operations and maintenance costs are assumed to be			
[2]4 month construction duration			

Note that annual costs (or charges) and benefits shown in this table refer to average annual equivalent (AAE) values.

The decision was made to target three feet of dry-floodproofing as it provided the most protection possible and was simultaneously the most cost effective of the explored options.

3.2.1.2 Wet Floodproofing

An incremental analysis was conducted for five different levels of wet floodproofing protection: 2 feet, 4 feet, 6 feet, 8 feet, and 10 feet.

To accomplish this analysis in FDA 2.0, a structure inventory consisting of a single structure – in this case, structure number 6 – was utilized to represent the without project condition. Then that inventory was used to create five new inventories consisting of the same structure, but each with a different occupancy type that would allow the application of different depth-damage curves to account for the differing levels of flood protection. The results of this analysis are shown below.

The measure's total investment cost was amortized over a 50-year period of analysis at the FY25 Federal discount rate of 3.0%. The assumed construction duration for the recommended plan was 4 months.

Table 63: Incremental Analysis – Wet Floodproofing

Beattyville, KY
General Investigation
Summary of Annual Benefits and Costs
FY 2025 Price Levels
3.0% Interest Rate

Investment Cost	**Wet Floodproofing 2 foot**	**Wet Floodproofing 4 foot**	**Wet Floodproofing 6 foot**	**Wet Floodproofing 8 foot**	**Wet Floodproofing 10 foot**
Construction First Cost	501,924	541,438	580,952	620,467	659,981
Interest During Construction	2,481	2,676	2,871	3,067	3,262
Total Investment Cost	504,405	544,114	583,823	623,534	663,243
Annual Costs					
Interest & Amortization	19,604	21,147	22,691	24,234	25,777
Operation & Maintenance	0	0	0	0	0
Total Annual Charges	19,604	21,147	22,691	24,234	25,777
Annual Benefits					
Flood Risk Management	8,290	9,072	9,606	9,815	10,092
Total Annual Benefits	8,290	9,072	9,606	9,815	10,092
Benefit vs. Cost Ratio	**0.42**	**0.43**	**0.42**	**0.41**	**0.39**
Net Benefits	-11,314	-12,075	-13,085	-14,419	-15,685

Assumptions:
[1]All operation and maintenance costs are assumed to be the responsibility of the structure owner
[2]4 month construction duration

Note that annual costs (or charges) and benefits shown in this table refer to average annual equivalent (AAE) values.

The team ultimately decided to move forward with eight feet of wet floodproofing for the applicable structures. This level provided significant protection and resiliency for the community while avoiding the additional costs that would be encountered when dealing the electrical and duct work that are often found in ceilings.

3.2.1.3 Elevation

An incremental analysis was conducted for three different levels of raise-in-place protection: 2 feet, 4 feet, and 6 feet.

To accomplish this analysis in FDA 2.0, a structure inventory consisting of a single structure – in this case, structure number 33, which happens to be the only structure in the inventory receiving this measure – was utilized to represent the without project condition. Then that inventory was used to create three new inventories consisting of the same structure, but each with a different foundation height to account for the differing levels of flood protection. The results of this analysis are shown below.

The measure's total investment cost was amortized over a 50-year period of analysis at the FY25 Federal discount rate of 3.0%. The assumed construction duration for the recommended plan was 4 months.

Table 64: Incremental Analysis – Elevation

Beattyville, KY General Investigation Summary of Annual Benefits and Costs FY 2025 Price Levels 3.0% Interest Rate			
Investment Cost	**Elevation - 2 foot**	**Elevation - 4 foot**	**Elevation - 6 foot**
Construction First Cost	212,362	271,041	329,719
Interest During Construction	1,050	1,340	1,630
Total Investment Cost	213,412	272,381	331,349
Annual Costs			
Interest & Amortization	8,294	10,586	12,878
Operation & Maintenance	0	0	0
Total Annual Costs	8,294	10,586	12,878
Annual Benefits			
Flood Risk Management	1,025	1,832	2,462
Total Annual Benefits	1,025	1,832	2,462
Benefit vs. Cost Ratio	**0.12**	**0.17**	**0.19**
Net Benefits	-7,269	-8,754	-10,416

Assumptions
[1]All operations and maintenance costs are assumed to be the responsibility of the structure owner.
[2]4 month construction duration

Note that annual costs (or charges) and benefits shown in this table refer to average annual equivalent (AAE) values.

The team decided to elevate the structure by six feet to provide the most cost-effective flood protection. Higher elevations were not pursued because the building's existing foundation is already approximately four feet above ground level. A concept-level analysis determined that, to maintain the aesthetic consistency of the existing steps, the elevation should be limited to six feet. Raising the building beyond this height would result in stairs that could not be accommodated along the front façade, potentially impacting the visual and historical integrity of the structure.

3.3 ESTIMATION OF RECREATION BENEFITS

3.3.1 Recreation

This section updates the original analysis described in Section 2.2.4 with current Unit Day Values, based Economic Guidance Memorandum 25-04, Unit Day Method.

3.3.1.1 Unit Day Value Assessment

The FY25 values for general recreation were used in this final analysis, shown in Table 65.

Table 65: Conversion of UDV Points to Dollar Values (FY25)

Point Values	General Recreation Values	General Fishing and Hunting Values	Specialized Fishing and Hunting Values	Specialized Recreation Values other than Fishing and Hunting
0	$5.17	$7.44	$36.22	$21.02
10	$6.14	$8.41	$37.19	$22.31
20	$6.79	$9.05	$37.84	$23.93
30	$7.76	$10.02	$38.81	$25.87
40	$9.70	$11.00	$39.78	$27.49
50	$11.00	$11.97	$43.66	$31.05
60	$11.97	$13.26	$47.54	$34.28
70	$12.61	$13.91	$50.45	$41.39
80	$13.91	$14.88	$54.33	$48.18
90	$14.88	$15.20	$58.21	$54.98
100	$15.52	$15.52	$61.44	$61.44

Using these updated values, the value provided by the project site per user per day in the with- and without-project conditions are shown in Table 66.

Table 66: Recreation benefit provided per user per day

Future Without Project	Future Without Project	Alternative 5C - Recommended Plan
Recreation Experience	3	15
Availability of Opportunity	1	12
Carrying Capacity	3	8
Accessibility	3	12
Environmental Quality	1	10
Total Recreation Points	11	57
Value	$11.68	$6.21

3.3.1.2 Visitation Estimate
Visitation estimates were not adjusted from the prior analysis. A full description of the visitation assumptions can be found in Section 2.2.4.2, but in short, the PDT assumed annual visitation of 55,000 in the with-project condition and 5,000 in the without project condition.

3.3.1.3 Recreation Benefits
The estimated benefits provided by the addition of recreation features to the site at Beattyville are shown in below.

Table 67: Unit Day Value estimate for Future With Project

Recreation Input Variables	With Project	Without Project
Annual Visitors	55,000	5,000
Unit Day Value	$11.68	$6.21
Annual Recreation Benefits	$642,345	$31,025

Thus, the benefits provided to the nation by the alternatives including the proposed recreation features total $611,320 annually.

3.4 BENEFIT-COST ANALYSIS

3.4.1 Cost Calculations
The summation of project first costs and interest during construction provides the total investment cost for the plan. To annualize charges, each impact area's total investment cost was amortized over a 50-year period of analysis at the FY25 Federal discount rate of 3.0%. The assumed construction duration for the recommended plan was 9.75 years, or 117 months.

First costs consist of construction, real estate, preconstruction, engineering, and design (PED), and construction management. The costs shown below are detailed in the Cost Engineering appendix and in the Total Project Cost Summary dated 16 April 2025.

Note that the project first cost for the recommended plan is presented at the FY25 price level; however, the cost certification shows the project first cost at the FY26 price level in preparation for submittal of the project for authorization in FY26.

Table 68: Recommended Plan Project First Costs

Alternative	Description	PED,	Construction Management	Construction Cost	Real Estate Cost	Total Cost
5C	Recommended Plan	3,731,000	1,598,000	25,363,000	2,226,000	32,918,000
	Values are presented in FY25 price levels.					

3.4.2 National Economic Development Results

The estimated construction duration of the recommended plan is just under 10 years, during which the implementation of each increment would be staggered based on its relative priority, established during the course of the feasibility study.

The estimated implementation schedule is as follows:

- Phase 1 (FWEEP): Nov. 2026 – Feb. 2028
- Phase 2 (Floodplain Acquisition with Recreation and Environmental Restoration): May 2027 – July 2029
- Phase 3 (Essential Structures – Dry/Wet Floodproof): June 2028 – Dec. 2032
- Phase 4 (Historic Structures – Dry/Wet Floodproof, Raise in Place): May 2029 – Sep. 2036

Despite the fact that construction activities are expected to continue over the course of 117 months, Phase 3 and Phase 4 do not have positive net benefits, so the PDT found it appropriate to consider the end of Phase 2 as the point at which benefits begin to accrue. Therefore, the period of analysis is 2030-2080.

The summary of annual benefits and costs for the Recommended Plan is presented in Table 69.

Table 69: Recommended Plan Summary of Annual Benefits and Costs

Beattyville, KY
General Investigation
Summary of Annual Benefits and Costs
FY 2025 Price Levels
3.0% Interest Rate

	5C: Recommended Plan
Project Cost	
Project First Cost	32,918,000
Interest During Construction	5,233,951
Total	38,151,951
Average Annual Equivalent Costs	
Project Implementation	1,482,794
Operation & Maintenance	12,000
Total	1,494,794
Average Annual Equivalent Benefits	
Flood Risk Management	180,805
Recreation	611,320
Total	792,125
Benefit vs. Cost Ratio	**0.53**
Net Benefits	-702,669

Assumptions
[1]117 month construction duration
[2]50-year period of analysis; Base year is 2030
[3]Required maintenance is not expected to exceed $12,000 annually

The executive branch uses as a principal performance metric for a project's inclusion in its budget request the project's benefit-cost ratio (BCR) calculated with a 7% discount rate (i.e., ratio of the present value of benefits to the present value of costs discounted at 7%). For most water resource projects, which have concentrated up-front costs and benefits accruing over decades, the 7% discount rate results in a lower BCR than the BCR that was calculated in the planning process using lower water planning discount rates. The use of a 7% discount rate for executive branch budgeting for the Corps is consistent with general guidance from the Office of Management and Budget (OMB) for discounting federal programs: this guidance is elaborated in Circular A-94. Since 1992, OMB has recommended a 7% discount rate for BCAs of most federal programs. The recommended plan summary of annual benefits and costs using a 7% discount rate is shown in the following table.

Table 70: Recommended Plan Summary of Annual Benefits and Costs with 7% Discount Rate

Beattyville, KY **General Investigation** **Summary of Annual Benefits and Costs** FY 2025 Price Levels 7.0% Interest Rate	
	5C: Recommended Plan
Project Cost	
Project First Cost	32,918,000
Interest During Construction	13,696,929
Total	46,614,929
Average Annual Equivalent Costs	
Project Implementation	3,377,711
Operation & Maintenance	12,000
Total	3,389,711
Average Annual Equivalent Benefits	
Flood Risk Management	180,805
Recreation	611,320
Total	792,125
Benefit vs. Cost Ratio	**0.23**
Net Benefits	-2,597,586

Assumptions
[1]117 month construction duration
[2]50-year period of analysis; Base year is 2030
[3]Required maintenance is not expected to exceed $12,000 annually

3.5 Long-term Project Performance

Because the measures implemented for this project are all nonstructural, the likelihood that floodwaters will reach the structures within the study area in the with project condition is the same as in the without project condition. However, to gauge some level of project performance, the target elevations were analyzed for one structure representing each of the proposed measures: dry floodproofing, wet floodproofing, and elevation. The structures used for this analysis are the same ones that were used in the incremental analysis described in Section 3.2.1.

Flood damages from riverine flooding generally are expected to begin at relatively frequent events, and damages increase significantly as the AEP moves from more frequent to less frequent events.

The performance statistics help inform the risk of a flood event at a specific flood frequency. The target stage in the following table represents the stage to which either floodproofing was applied or to which the first floor was elevated. It should be noted that for the wet-floodproofed structures, it is assumed the contents will still incur damages at the frequencies described in the without project condition analysis.

The long-term risk is the probability that flooding occurs in a period of 10, 30, or 50 years, and the assurance probability is the chance of containing the specific exceedance probability event within the target stage should that event occur.

The conditional probability of design non-exceedance for each of the measures, covering a range of flood frequencies, is provided in the tables below.

Category Definitions:

Target Stage Annual Exceedance Probability: the probability that the river stage will exceed the level of floodproofing or first floor elevation in any given year.

Long-Term Exceedance Probability: the probability that the river stage will exceed the level of floodproofing or first floor elevation in a 10-, 30-, or 50-year period.

Assurance by Events: the probability that a given storm event will result in a river stage that does not exceed the level of floodproofing or first floor elevation.

Table 71: Long-term Project Performance

Scenario	Target Stage	Target Stage Annual Exceedance Probability		Long-Term Exceedance Probability			Assurance of Threshold					
		Mean	Median	10 Years	30 Years	50 Years	0.1	0.04	0.02	0.01	0.004	0.002
Dry Flood Proofing	666.9	0.03	0.03	0.28	0.62	0.80	1.00	0.65	0.31	0.18	0.06	0.02
Wet Floodproofing	674.1	0.01	0.01	0.11	0.29	0.43	1.00	0.95	0.80	0.63	0.37	0.22
Raise-in-Place	672.2	0.02	0.01	0.15	0.38	0.55	1.00	0.90	0.68	0.50	0.25	0.12

The following table shows the annual probability that the stage to which the structure has been floodproofed would be exceeded.

Table 72: Assurance of Annual Exceedance Probability

Scenario	AEP With 90% Assurance	Assurance of AEP					
		0.1	0.04	0.02	0.01	0.004	0.002
Dry Flood Proofing	0.060	1.00	0.65	0.31	0.18	0.06	0.02
Wet Floodproofing	0.029	1.00	0.95	0.80	0.64	0.38	0.23
Raise-in-Place	0.039	1.00	0.90	0.68	0.50	0.25	0.12

3.6 Regional Economic Development Benefits

The Principles and Guidelines (1983) established the Regional Economic Development (RED) account to register changes in the distribution of regional economic activity that result from each alternative plan. In addition to the benefits accounted for within the NED account, the implementation of the Recommended Plan would result in local economic activity which is accounted for within the RED account. These benefits should not be considered as additive to the NED benefits described above but as regional transfers and therefore a net-zero contribution to national economic development.

As described in Section 2.2.7, the USACE Regional Economic System (RECONS) regional economic impact modeling tool was utilized to estimate the regional economic development benefits that would result from construction of the recommended plan at Beattyville.

RECONS incorporates impact area data, as well as multipliers, direct ratios (jobs to sales, income to sales, etc.), and geographic capture rates to estimate jobs, labor income, and other critical impacts to the local, state, and national economy.

In the figure below, the impact areas for regional economic impacts are shown. Lee County is the local impact area, and the state impact area is Kentucky. State impacts include local impacts, and national impacts include both state and local impacts.

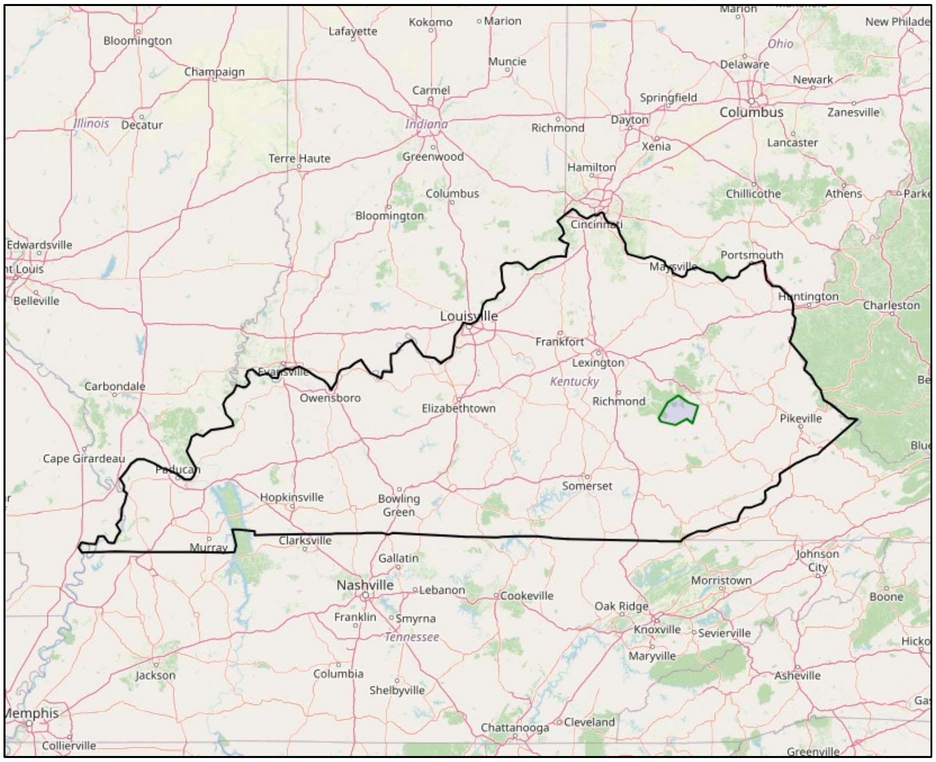

Figure 13: Regional Economic Impact Areas

Streamlined RECONS Definitions:

- Output: Economic output or total industry output is the value of production by industry for a given period. It is also known as gross revenues or sales.
- Labor Income: Labor income represents all forms of employment earnings.
- Jobs (Employment): The work in which one is engaged; an occupation by which a person earns income. Employment includes both part-time and full-time jobs. All jobs are presented in full- time equivalence (FTE).
- Value Added: These are payments made by industry to workers, which also include interest, profits, and indirect business taxes. Value-added is an estimate of the gross regional or state product.

RECONS includes three categories of economic impacts:

- Direct impact is defined as expenditures made by USACE. In the impact area in which a project is located, direct impact represents that proportion of the expenditure that flows to material and service providers in the impact area. For employment and earnings measures, the direct impact represents the jobs associated with the work activity (e.g., onsite construction jobs that are likely to be filled by residents of the region [i.e., after adjustment for in-commuting by workers residing outside the region]).
- Secondary impact includes indirect impact, which includes the backward-linked suppliers for any goods and services used by the directly affected activities, and induced impact, which occurs from household expenditures associated with direct- and indirect-affected

workers spending their income within the impact area. Economic impact measures reported are number of jobs, employment earnings, output, and value added.

- Total impact is equal to the sum of the direct, indirect, and induced effects for output, employment, value added, and labor income.

The Recommended Plan is expected to result in approximately $25,363,000 in construction expenditures in Lee County. These expenditures are expected to occur between 2026 and 2036. Notably, and as highlighted in Table 2 of this appendix, approximately 13% of Beattyville residents are employed by the construction industry.

The construction expenditures of the recommended plan are expected to support approximately 210 jobs and approximately $11,846,000 in value added within Lee County. The following table outlines the impacts at the local, state, and national level resulting from implementing the Recommended Plan.

Table 73: Regional Economic Development Benefits

Area	Local Capture	Output	Jobs*	Labor Income	Value Added
Local – Lee County					
Direct Impact		$14,870,000	170	$8,676,000	$8,383,000
Secondary Impact		$6,254,000	40	$1,854,000	$3,464,000
Total Impact	$14,870,000	$21,124,000	210	$10,529,000	$11,846,000
State – Kentucky					
Direct Impact		$19,031,000	210	$12,532,000	$12,075,000
Secondary Impact		$16,462,000	90	$5,307,000	$8,869,000
Total Impact	$19,031,000	$35,493,000	300	$17,840,000	$20,944,000
US					
Direct Impact		$24,202,000	250	$16,141,000	$15,576,000
Secondary Impact		$44,705,000	200	$14,240,000	$24,375,000
Total Impact	$24,202,000	$68,907,000	450	$30,381,000	$39,951,000
* Jobs are presented in full-time equivalence (FTE)					

4 ABILITY TO PAY

4.1 ESTIMATING THE NON-FEDERAL COST SHARE

Section 103(m) of Public Law 99-662, 33 U.S.C. 2213m (Jan. 26, 1995) requires that all cost-sharing agreements for flood risk management covered by the terms of Section 103(a) or 103(b) be subject to the ability-to-pay test. As a result of the application of the test, some projects will be cost shared by the non-Federal sponsor at a lower level than the standard non-Federal share that would be required under the provisions of Section 103 of PL 99-662, 33 USC 2213.

All ability-to-pay calculations, procedures, and methodologies are presented in ER 1165-2-121, which can be found here:

https://www.publications.usace.army.mil/Portals/76/Publications/EngineerRegulations/ER_1165-2-121.pdf?ver=2013-09-08-233444-150

The non-Federal cost share for the flood risk management scope is equivalent to the benefits-based floor for this study, which is 13.25%. The cost share is determined via the benefits and income tests and the process for calculating each is shown below.

4.1.1 Benefits Test

If the benefit-cost ratio divided by 4 (BCR/4), when expressed as a percentage, is greater than or equal to the standard non-Federal cost share, the project is not eligible for a reduction and would be subject to the standard non-Federal cost share required under the provisions of Section 103 within Public Law 99-662.

This figure (BCR/4, expressed as a percentage) is known as the "Benefits-based floor," shown in Table 74.

Table 74: Ability to Pay – Benefits Test

Plan	Average Annual Benefits	Average Annual Cost	BCR	BCR/4	Benefits-based floor
Recommended Plan	792,125	1,494,794	0.53	0.1325	13.25%

4.1.2 Income Test

Since the calculated BBF is less than the standard level of cost sharing, the amount of the non-Federal share to be applied to the alternatives' costs must be determined by the income test. The income test, as outlined in ER 1165-2-121, determines the fraction of reduction in cost sharing depending on the current economic resources of the state and county in which the project is located.

The first step is to calculate the Eligibility Factor (EF) for the project area according to the following formula (based on EGM 19-04):

EF (Eligibility Factor) = a – b1 (State income index) – b2 (County income index)

Where a = 18.22; b1 = 0.079; b2 = 0.158

It should be noted that a, b1, and b2 are fixed values supplied directly from EGM 19-04.

The state income index and county income index are factors created directly from the Bureau of Economic Analysis's Per Capita Personal Income data, using the three most recent years for which data are available. For the Recommended Plan, this was 2020-2022.

Table 75: Ability to Pay - Eligibility Factor

Plan	State Index	County Index	Eligibility Factor
Recommended Plan	79.61	53.79	3.43

If the EF > 1, the non-Federal share is equal to the Benefits Based Floor, calculated in Section 4.1.1.

4.1.3 Non-Federal Cost Share

Thus, the non-Federal cost share for flood risk management portions of the project is 13.25% of the estimated cost, as shown in Table 76. Note that the ability to pay adjustment to the non-Federal cost share is only applicable to the flood risk management components of the plan. The non-Federal cost share for construction of recreation facilities remains 50%.

Table 76: Non-Federal Cost Share

Plan	Benefits Based Floor (NFS Cost Share %)
Recommended Plan (FRM components only)	13.25%