Neuse River Basin Flood Risk Management Integrated Feasibility Study and Environmental Assessment

Appendix B. Economics

US Army Corps
of Engineers

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1.0. INTRODUCTION

The Neuse River Basin is a U.S. Army Corps of Engineers (USACE) feasibility study focused on evaluating potential flood risk management (FRM) alternatives to reduce flood and life safety risks in the Neuse River Basin. The State of North Carolina Department of Environmental Quality is the non-federal sponsor for the study. This study was authorized by the House Committee on Transportation and Infrastructure Resolution adopted July 23, 1997, and was funded under the 2019 Additional Supplemental Appropriations for Disaster Relief. Additional information regarding the study can be found in the main report and report appendices.

1.1. Purpose and Overview

The purpose of the economic appendix is to present the socioeconomic analysis completed to identify a recommended plan for a federal project for the study. The analysis follows the framework and methodology as directed by the USACE Planning Guidance Notebook (ER 1105-2-100) dated 22 April 2000 and well as the guidance listed in Section 1.4 below. The economic appendix includes the following:

- A description of the framework of the economic analysis, including the major assumptions, data, methodologies, and analytical tools used.
- A discussion of relevant background information including demographic, social, economic, and housing data for the study area.
- A description of the flood risk analysis completed, in terms of probability and consequence of flooding, for the without-project and with-project conditions for the study area. The FRM analysis evaluates flood damages in the study area on an equivalent annualized basis and calculates project performance by simulating a large number of possible flood events, taking into account all pertinent economic and engineering data including risk and uncertainty factors.

1.2. Location

The Neuse River Basin covers approximately 6,200 square miles in North Carolina, with an upstream boundary just northwest of Raleigh, and extending 248 miles southeast where the river has a confluence with the Pamlico Sound. The mainstem of the Neuse River flows through the entire basin, with several tributaries along the mainstem also contributing to flood events.

1.3. Historical Background

The study area is subject to severe flooding, particularly during the Atlantic hurricane season, which runs from June to November. In recent years, hurricanes caused severe flooding and federally recognized natural disasters were declared. Particularly severe impacts from Hurricane Dorian (2019), Hurricane Florence (2018), Hurricane Matthew (2016), and Hurricane Irene (2011) were witnessed in North Carolina in the past decade.

In 2018, North Carolina reported 42 fatalities caused by Hurricane Florence, and estimated damages totaled $17 billion. Approximately 75,000 structures were flooded in the state and over 5,000 individuals were rescued from flooding.

1.4. Study Guidance

The analysis completed for this study is consistent with current regulations and policies. Pertinent guidance governing economic analysis procedures includes:

- Engineer Regulation (ER) 1165-217, Civil Works Review Policy, 1 May 2021
- Engineer Circular (EC) 1165-2-218 USACE Levee Safety Program, 22 Apr 2021
- Economic Guidance Memorandum (EGM) 01-03, Generic Depth-Damage Relationships, 4 Dec 2000
- Economic Guidance Memorandum (EGM) 04-01, Generic Depth-Damage Relationships for Residential Structures with Basements, 10 Oct 2003
- Economic Guidance Memorandum (EGM) 09-04, Generic Depth-Damage Relationships for Vehicles, 22 Jun 2009
- Engineer Manual (EM) 1110-2-1619, Risk-Based Analysis for Flood Damage Reduction Studies, 1 Aug 1996
- Engineer Regulation (ER) 1105-2-100, Planning Guidance Notebook, 22 Apr 2000
- Engineer Regulation (ER) 1105-2-101, Risk Assessment for Flood Risk Management Studies, 17 Jul 2017
- Engineer Regulation (ER) 1110-2-1156, Safety of Dams – Policy and Procedures, 31 Mar 2014
- Engineer Regulation (ER) 1165-2-26, Implementation of Executive Order 11988 on Flood Plain Management, 30 Mar 84
- Institute for Water Resources (IWR) Report 96-R-12, Analysis of Nonresidential Content Value and Depth-Damage Data for Flood Damage Reduction Studies, May 1996
- Planning Bulletin (PB) 2019-04, Incorporating Life Safety into Flood and Coastal Storm Risk Management Studies
- Secretary of the Army (Civil Works) (SACW) POLICY DIRECTIVE – Comprehensive Documentation of Benefits in Decision Document, 5 Jan 2021
- Water Resources Development Act (WRDA) of 1990, Sec. 308 Flood Plain Management, 28 Nov 1990

1.5. The System of Accounts

Per the 5 January 2021 SACW POLICY DIRECTIVE – Comprehensive Documentation of Benefits in Decision Document, all USACE planning study project delivery teams (PDTs) must evaluate and provide a complete accounting, consideration, and documentation of the total benefits of alternative plans across all benefit categories. Total benefits involve a summation of monetized and/or quantified benefits, along with a complete accounting of qualitative benefits, for project alternatives across national and regional economic, environmental, and social benefit categories.

In computing total benefits of a project alternative, it is imperative that any benefits reflected in more than one category are only counted once. The level of detail will vary based on study type and the decision-context for the specific problems identified, recognizing that not all benefits can be monetized, and some cannot be cost-effectively quantified. Even if non-monetary measures are used, these benefits and impacts must be accounted for in the most substantive way possible.

Each study must include, at a minimum, the following plans in the final array of alternatives for evaluation:

1) The “No Action” alternative.
2) A plan that maximizes net total benefits across all benefit categories.
3) A plan that maximizes net benefits consistent with the study purpose.

4) For flood-risk management studies, a nonstructural plan, which includes modified floodplain management practices, elevation, relocation, buyout/acquisition, dry flood proofing, and wet flood proofing.
5) A locally preferred plan, if requested by a non-federal partner, if not one of the aforementioned plans.

1.5.1. National Economic Development (NED)

Economic costs and benefits associated with an alternative are evaluated in terms of their impacts on national wealth, without regard to where in the United States the impacts may occur. National Economic Development (NED) benefits must result directly from a project and must represent net increases in the economic value of goods and services to the national economy, not simply to a region or locality. Using a 50-year period of analysis, and the current federal discount rate, expected annual damages (EAD) or damages reduced (i.e., benefits) are calculated.

NED costs represent the costs of diverting resources from other uses in implementing the project, as well as the costs of uncompensated economic losses resulting from detrimental effects of the project. NED annual benefits, the benefit-cost ratio, and the net NED annual benefits are calculated during the evaluation process. Net benefits represent the amount by which the annual NED benefits exceed annual NED costs, thereby defining the plan’s contribution to the nation’s economic output. A benefit-cost ratio of 1.0 or greater must be demonstrated for Federal interest. The plan with the highest net benefits is considered the recommended NED plan, assuming technical feasibility, environmental soundness, and acceptability.

1.5.2. Regional Economic Development (RED)

Studies must quantify the regional economic impacts on local and regional income, employment, and other measures of the regional economy from the construction of and operation of a project such as changes in property or land value, to the extent practicable for each alternative. Where impacts are anticipated to be the same across all alternatives or not play a significant role in the evaluation of alternatives and selection of a recommended plan, a qualitative assessment may suffice.

1.5.3. Other Social Effects (OSE)

Relevant factors must be described and analyzed in the most substantive manner possible, whether quantitative or qualitative. The analysis may present the same factor from multiple points of view. The analysis must also account for who benefits as well as who is adversely affected because of each alternative.

Flood and coastal storm risk management reports must include an assessment of potential mortality (life loss) for the future without project condition, as well as estimated changes in potential for and magnitude of mortality (life risk) for all alternatives in the final array. Where the change is anticipated to be the same across all alternatives or not play a significant role in the evaluation and selection of a recommended plan, a qualitative risk assessment will suffice.

The residual risk to life safety must be determined for the recommended plan and when changes in estimated life loss play a significant role in decision-making.

1.5.4. Environmental Quality (EQ)

For each alternative plan, positive and negative benefits to the environment must be analyzed consistent with current ecosystem restoration or environmental compliance guidance. The benefit assessment can be quantitative or qualitative and, if appropriate, monetized. The analysis must distinguish between national and regional benefits while ensuring benefits are not accounted for more than once.

2.0. STUDY AREA

The study area, shown in Figure 1 below, is located in eastern North Carolina and includes the entire Neuse River Basin, which commences northwest of Raleigh and continues toward the Pamlico Sound, where it ends southeast of New Bern. The study area intersects more than 400 census tracts, 23 counties, and covers approximately 6,200 square miles of land.

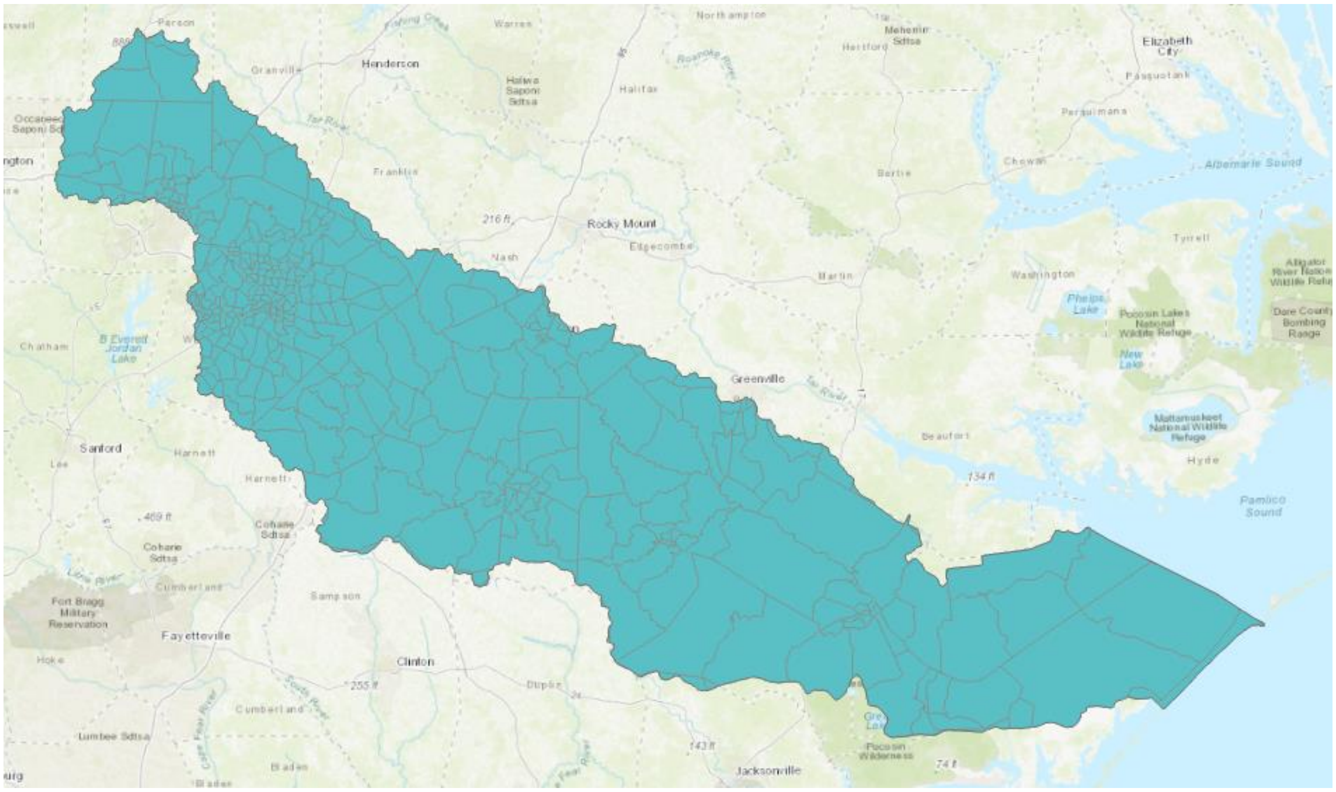

Figure 1. Neuse River Basin Study Area Census Tracts

2.1. Land Use

The study area includes agricultural, national forest, and built out (residential, commercial, and public/government) land use. The 2019 National Land Cover Database, depicted in Figure 2, shows higher intensity development in and around Raleigh, and near major urban areas throughout the basin. Land use was taken into consideration when evaluating where to focus the analysis for the study. Population centers at high risk of flooding were identified as an initial way to narrow the study area.

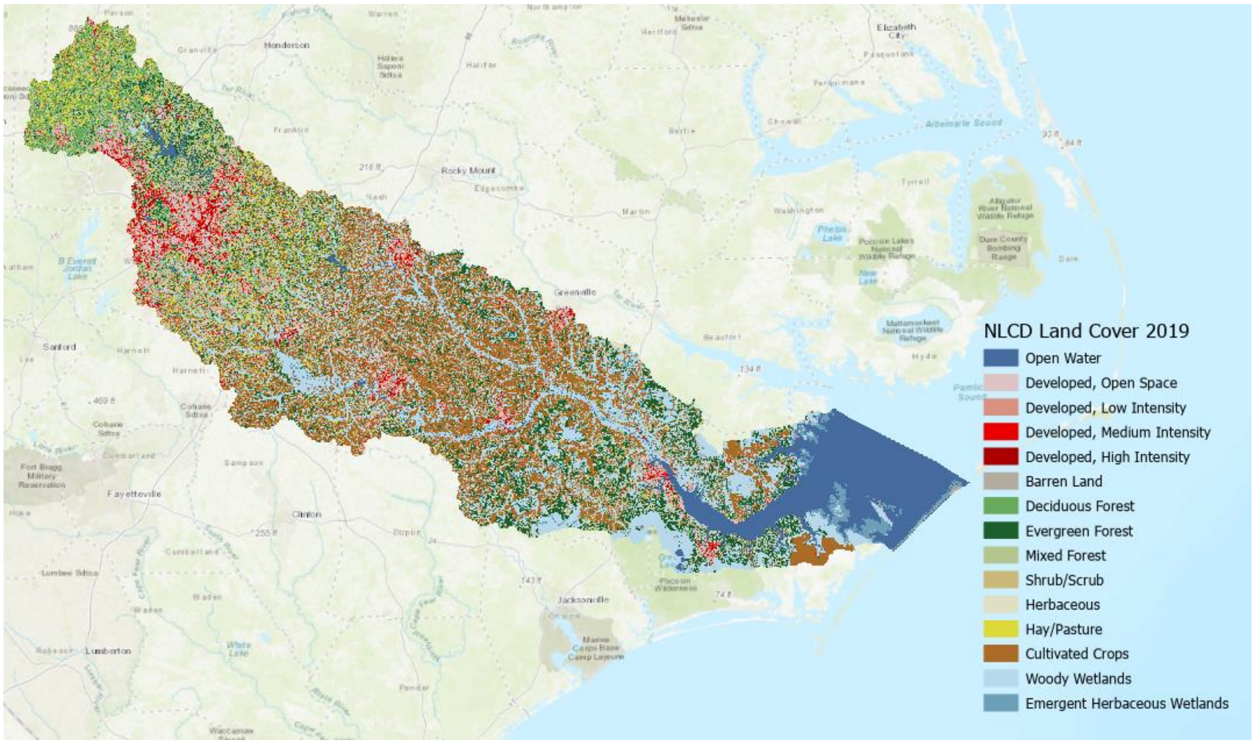

Figure 2. Study Area Land Use

2.2. Population and Socioeconomics

The total estimated population count in the Neuse River Basin is approximately 2.2 million as of 2019. The following figures display the distribution of the population by census tract, and other socioeconomic and demographic factors that impact the population at risk in the study area. Demographic data for the following maps was taken from the American Community Survey (ACS) 2015-2019 5-year estimates available on census.gov, unless otherwise indicated.

Figure 3 displays population count by census tract. More densely populated census tracts include those near Raleigh, while the lower end of the basin contains less densely populated tracts.

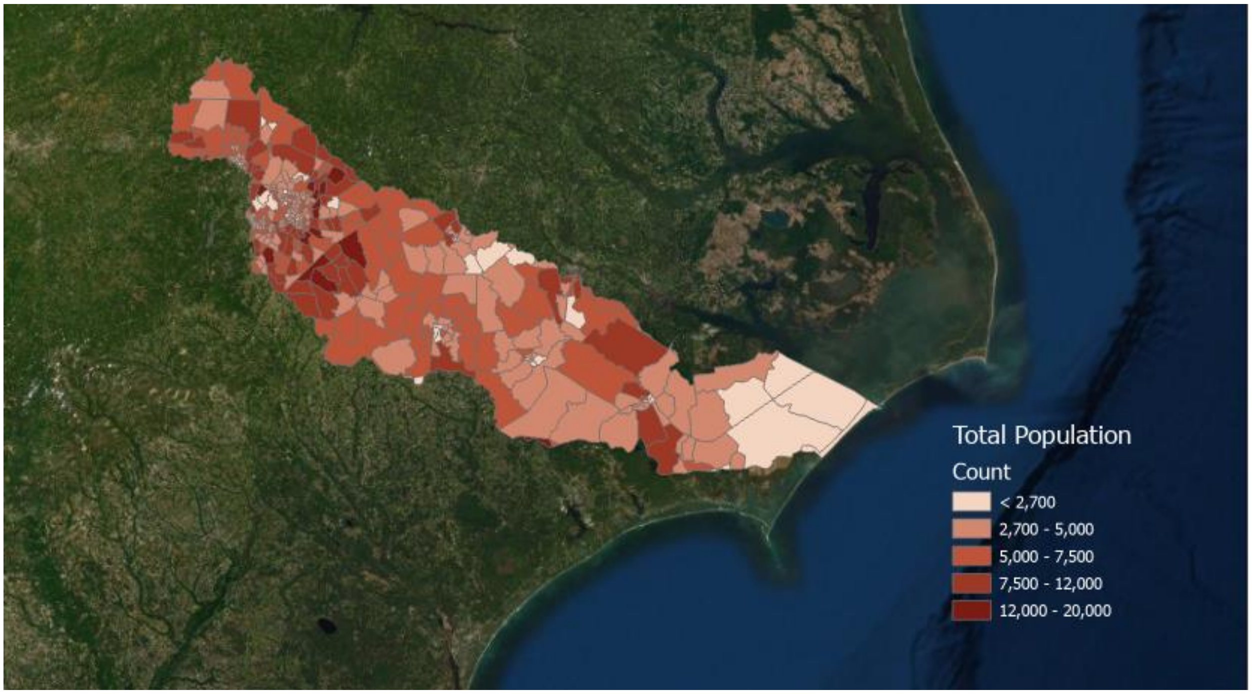

Figure 3. Population Count by Census Tract, ACS 2019 5-year Estimates

Figure 4 displays median household income in 2015 inflation-adjusted dollars overlaid by average household size, by census tract. The average median household income by tract is $58,000 annually, while the lowest is $10,300 and the highest is $165,300. Census tracts with the highest median income are concentrated near Raleigh and other census tracts in Wake County. Lower income households are located in Craven, Wilson, Johnston, Nash, Pitt, and Greene counties.

The average household size is 3 individuals, but there doesn't appear to be a strong directional correlation between household income and household size. Smaller households tend to be near the confluence of the Neuse with the Atlantic Ocean.

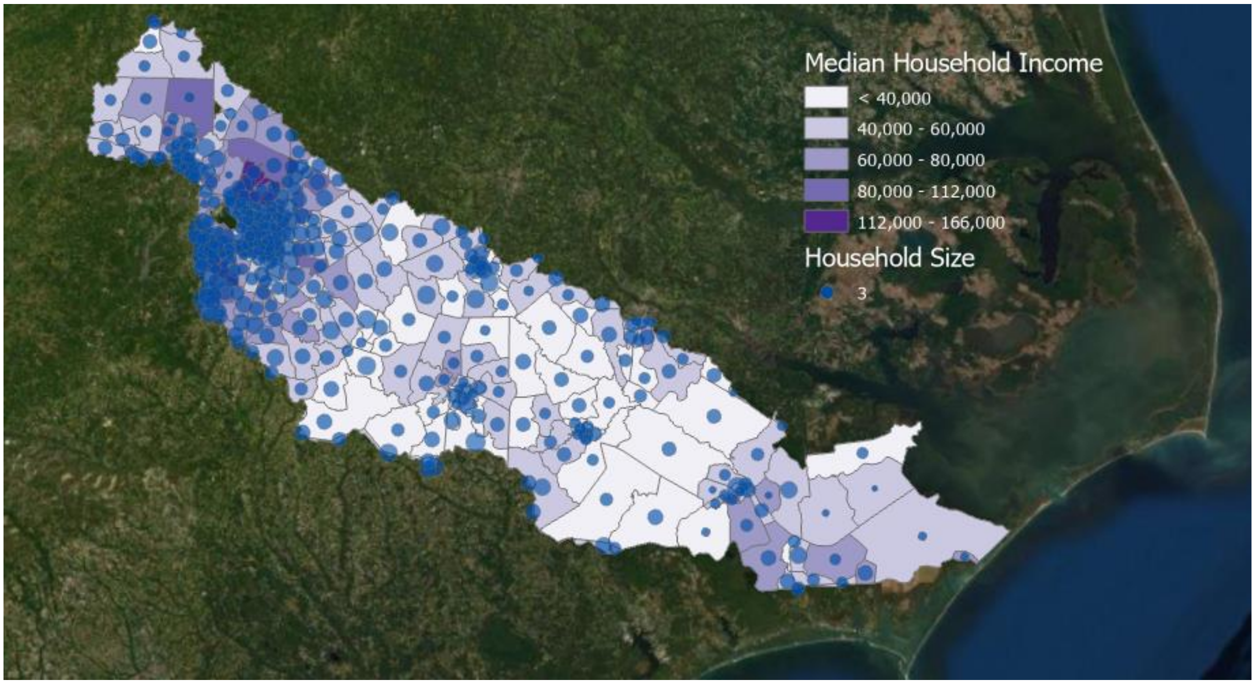

Figure 4. Median Household Income in 2015 Inflation Adjusted Dollars vs Household Size

Figure 5 shows the non-white population count by census tract. Census tracts located in Wake County near Raleigh have the highest non-White populations. These census tracts are also more densely populated than tracts in the lower part of the basin.

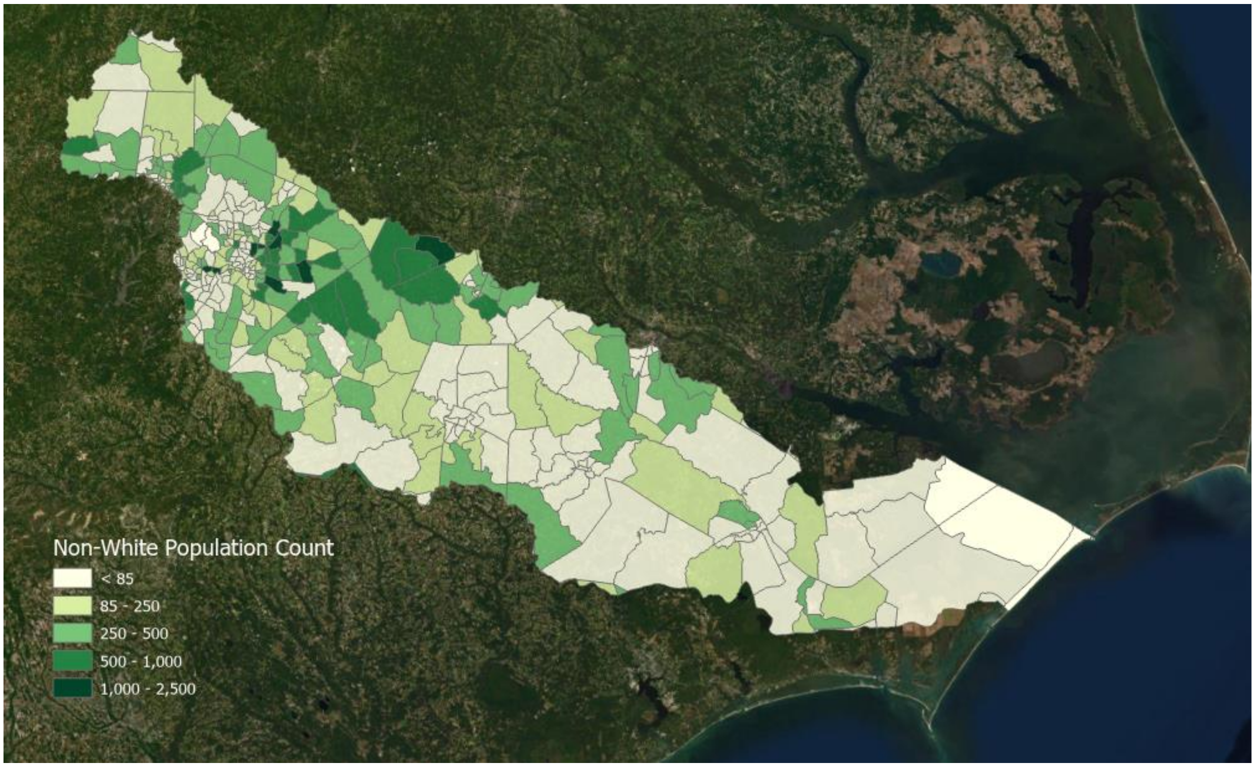

Figure 5. Non-White Population Count by Census Tract, ACS 2019 5-year Estimates

Figure 6 shows the percent of the population that is older than 65 and may be more vulnerable in event of a flood than younger individuals who often can more easily evacuate. The darkest green color shows census tracts where 25-50 percent of the population is older than 65. These tracts are located mainly in the lower part of the basin, with a few tracts in the upper basin above Raleigh.

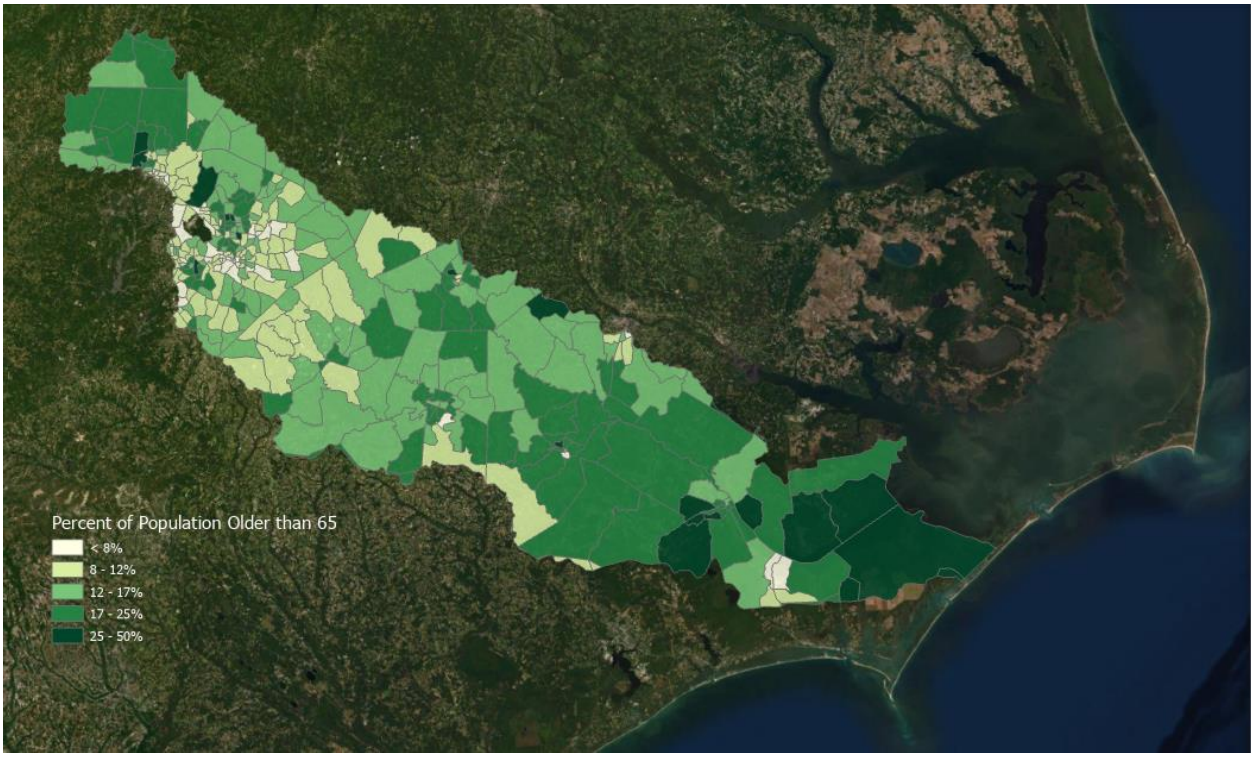

Figure 6. Percent of Population Age 65 or Older, ACS 2019 5-year Estimates

Figure 7 displays the percent of the population in each census tract under the poverty line, which was $24,250 for a household of four in 2015. The basin wide average poverty rate is 16.5 percent, which is higher than the 2015 national average of 13.5 percent. The highest tract level poverty rate occurs near Kinston, in Census Tract 103, where 71 percent of the population was under the poverty line in 2015. Seven census tracts have poverty rates below one percent and are all located near North or Northwest Raleigh.

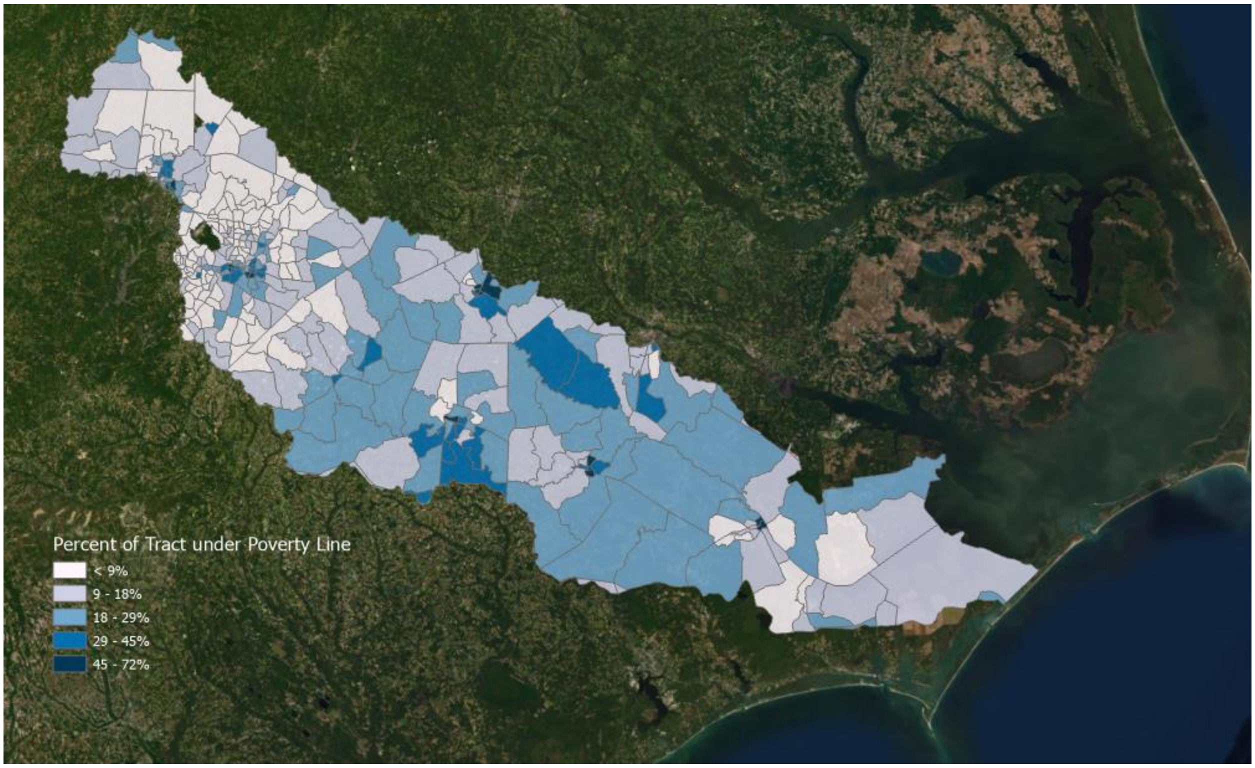

Figure 7. Percent of Population under Poverty Line by Census Tract, 2015 ACS 5-year Estimates

The following tables display demographic data taken from the ACS 5-year estimates (2015-2019). Table 1 displays population data from 2010 and 2020 for North Carolina and the U.S. The growth rate for the study area in the past decade was similar to that of the entire U.S.

Table 1. Study Area and Comparison Area Population Trends

Geography	2010	2020	Percent Change 2010-2020
North Carolina	9,535,486	10,439,388	9%
U.S.	308,745,538	331,449,281	7%

Source: census.gov/quickfacts

Table 2 shows the distribution of race and income in North Carolina and the U.S. North Carolina has a larger percent of African American people than the U.S., on average, and a lower percent of Hispanic, Latino, or Asian people. The age distribution is roughly equal to that of the entire U.S.

Table 2. Selected Population Characteristics

Demographic	North Carolina	U.S.
Population	10,439,388	331,449,281
% 65 and above	16.7	16.5
% 18 and under	21.9	22.3
Two or more races, %	2.3	2.8
Hispanic or Latino (of any race) %	9.8	18.5
White alone %	70.6	76.3
Black or African American alone %	22.2	13.4
American Indian and Alaska Native alone%	1.6	1.3
Asian %	3.2	5.9

Source: census.gov/quickfacts

Table 3 displays household demographics for North Carolina and the U.S. The median value of owner-occupied housing is lower than that of the national average, as is the percent households that speak a language other than English at home. Other demographic traits are similar to the national average.

Table 3. Household Demographics

Demographic	North Carolina	U.S.
Total Housing Units, 2019	4,747,943	139,684,244
% Owner Occupied	65	64
Median Value of Owner-occupied housing	172,500	217,500
Median gross rent	907	1,062
Average household size	2.52	2.62
Language other than English spoken at home (%)	11.80	21.60
Bachelor’s degree or higher, percent of persons age 25+	31.30	32.10

Source: census.gov/quickfacts

Table 4 displays income demographics for North Carolina and the U.S. North Carolina’s unemployment rate is similar to that of the national average, while the per capita and median household income are lower than the national average. The poverty rate is approximately 1.5 percentage points above the average U.S. rate.

Table 4. Income Demographics 2019

Geography	Unemployment Rate 2019	Per Capita Income, last 12 months	Median Household Income 2019 dollars	Percent of Individuals Living Below Poverty
North Carolina	3.50%	30,783	54,602	12.9
U.S.	3.60%	34,103	62,843	11.4

Source: census.gov/quickfacts

3.0. NED Methodology

This section provides an overview of the economic analysis used to evaluate the flood risk management alternatives developed to identify the national economic development (NED) plan, along with the models and tools used to compute NED economic benefits.

3.1. Framework of Economic Analysis

3.1.1. Price Level, Period of Analysis, and Discount Rate

Values listed in this analysis are based on fiscal year (FY) 2022 price levels. Annualized benefits and costs were computed using a 50-year period of analysis and the FY 2022 federal discount rate of 2.25 percent. Annualized values are presented in thousands of dollars unless otherwise noted.

3.1.2. Economic Analysis Tool: HEC-FDA Risk Analysis Program

The economic analysis uses the Hydrologic Engineering Center Flood Damage Analysis (HEC-FDA) program to compute damages. Economic damages serve as a basis for computing net economic benefits, and the benefit-cost ratio (BCR). HEC-FDA is a USACE certified risk-based program and is standard for economic computations for flood risk management studies. HEC-FDA integrates engineering data (hydrologic, hydraulic, and geotechnical when applicable) and economic data (structure/content inventory and depth-percent damage curves) to model the potential flood risk for the without project condition and study alternatives. HEC-FDA version 1.4.3 is used in this analysis.

ER 1105-2-101 requires incorporating risk and uncertainty in calculating damage estimates for flood events. This is best represented by a range of possible damage values and their likelihood of occurring, or a probability distribution. HEC-FDA uses Monte Carlo simulation to obtain a random sample of the contributing relationships and computes stage-damage functions, exceedance probability discharge curves, and conditional stage-discharge relationships to generate expected annual damage (EAD) values. EAD estimates capture the mean of the probability distribution of annual damage and are the basis for calculating equivalent annual damages and benefits. Uncertainty is incorporated into EAD estimates using Monte Carlo simulation: each iteration of a simulation randomly samples the uncertainty distributions, and the resulting values are used to transform the flow and stage distributions to a damage distribution. The area under the curve of the distribution is integrated to compute EAD. Thousands of iterations of this process are repeated to infer the EAD distribution and estimate EAD as the probability weighted average of all possible peak annual damages, where damage is a continuous random variable.[1] This process is depicted in Figure 8.

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[1] This process is described in more detail in the HEC-FDA User's Manual Version 1.4.1 available at http://www.hec.usace.army.mil/software/hec-fda/documentation/CPD-72_V1.4.1.pdf and the HEC-FDA update notes Version 1.4.3 available at https://www.hec.usace.army.mil/software/hec-fda/documentation/HEC-FDA_ReleaseNotes_Jun2021.pdf.

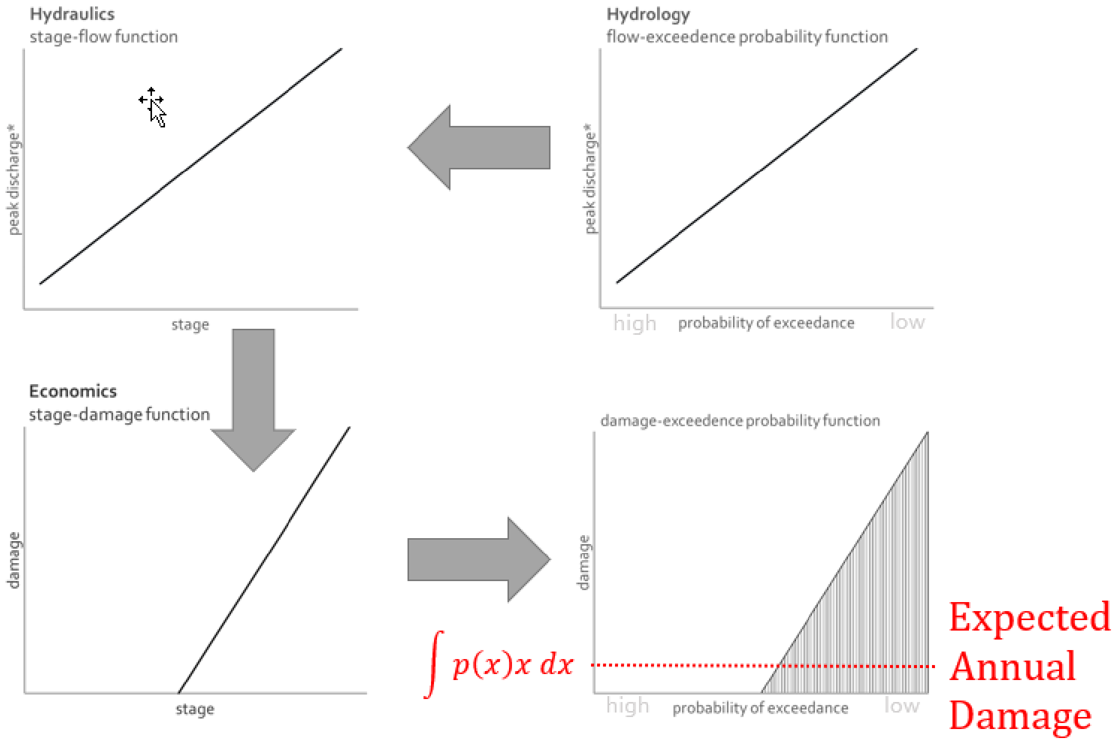

Figure 8. EAD Computation Process

To compute EAD values, HEC-FDA requires the following data:

1. **Structure Inventory Data –** This includes a structure identification number, a use category (industrial, commercial, single-family residence, etc.), stream location identified by cross sectional or grid data, first floor elevation, and depreciated structure and content values. This data was compiled using ArcGIS Pro 2.9, Spyder 5.2.1, and Microsoft Excel, and imported into HEC-FDA.

2. **Hydrologic and Hydraulic Data** – This data includes water surface profiles, exceedance probability discharge relationships, stage/discharge relationships, and levee fragility curves. Water surface profiles were developed in Hydrologic Engineering Center River Analysis System (HEC-RAS), processed in ArcGIS Pro and Excel to combine with the structure inventory, and then imported into the HEC-FDA program.

   A river station from the HEC-RAS model was selected to represent the discharge and stage for each reach. These representative stations are referred to as reach index points throughout this appendix. Structures in each reach were assigned a water surface profile associated with the corresponding reach index point in FDA.

3. **Depth/Damage Functions for Structures and Structure Contents –** Depth-damage functions are used to calculate the percent damage a structure will incur at a specific water elevation in a flood event. Depth-damage functions and associated standard errors for residential structures and their contents were developed by the Institute for Water Resources (IWR) and published in *Economic Guidance Memorandum 04-01: Generic Depth-Damage Relationships for Residential Structures with Basements, October 2003.* The depth-damage functions and standard error estimates are based upon previous

damages that occurred during flood events in the United States. Depth-damage functions for non-residential structures were obtained from the URS Group's expert elicitation report *Solicitation of Expert Opinion Depth-Damage Function Calculations for the Benefit-Cost Analysis Tool, October 2008.*

4. **Risk and Uncertainty Parameters –** Uncertainty parameters discussed in Section 3.2 of this report were also entered into HEC-FDA.

Discharge-exceedance probability, stage-discharge, and damage-stage functions derived at a damage reach index location are used to compute the damage-exceedance probability function. Monte Carlo simulation is a computationally efficient method of obtaining the damage-exceedance probability function due to uncertainty in input parameters. This numerical integration process requires all these relationships, and risk and uncertainty parameters to be input into HEC-FDA. Expected annual damage values are obtained from the cumulative distribution function produced in successive iterations of the Monte Carlo process.

3.1.3. Primary Sources of Uncertainty

Uncertainties are accounted for in the HEC-RAS model (see Appendix A, H&H Engineering), and in the HEC-FDA portion of the analysis. The primary sources of uncertainty present in the calculation of economic damages include storm water discharge, water surface elevations, levee performance, structure elevations, structure and structure content values, and depth-damage relationships. These are described in more detail below.

1. **Levels of Storm Water Discharge –** The amount of rainfall from storm events with equal probabilities can vary by location throughout the watershed. Variability in storm intensity, elapsed time during rainfall, ground permeability, soil, ambient temperature, and other physical factors can also cause variation in the location and timing of rainwater entering the channel. This variation causes uncertainty in the level of storm water discharge at any location along the river.

   In addition to natural variation arising from physical factors, there is uncertainty in the modeling of water discharges for a storm event due to limited historical meteorological and stream gauge data. This data can often be incomplete or limited in sample size (length of record for time-series data). Discharge-probability distributions in this study were computed using the graphical method and were based on a period of record length of 30 years. HEC-FDA calculates 95 percent confidence intervals for storm discharges that are used in economic computations.

2. **Water Surface Elevation –** The shape of the riverbed, water temperature, location and amount of debris, and obstructions in the channel can affect the water surface elevation for a specific location along the river. When the water surface elevation exceeds the top of the levee elevation, water flows onto the floodplain. Thus, uncertainty affects water surface elevations in the floodplain and in the channel. To address this uncertainty, a standard deviation with standard normal distributions were input into HEC-FDA for water surface elevations. A standard deviation of 0.5 feet, held constant at the 0.2 annual exceedance probability (AEP) event was used.

3. **Levee Performance –** There is uncertainty about how an existing levee will perform under certain water surface elevations, how interior water-control facilities will perform,

and the thoroughness of closures or openings in an existing levee. For this analysis, top of bank elevations were used without geotechnical failure functions.

4. **Structure Elevations –** Structure elevation is key in determining the depth of flooding inside of a structure during a flood event. First floor structure elevation is the aggregate of topographical elevation and foundation height. Both elevations are prone to uncertainty. Uncertainty in topographical and foundation height varies by the survey methodology and resolution, and foundation height uncertainty varies by surveying methodology. Statistical uncertainty was determined by referencing the standard deviation estimates contained in EM 1110-1-1619, which presents standard deviation of error estimates for various measurement methods, based on Institute for Water Resources (IWR) research. First floor elevations were derived from LIDAR surveys and were provided by the State of North Carolina's Flood Risk Information System parcel data (available at https://fris.nc.gov/). Structures were assigned standard deviations of error for first floor elevations of 0.60 feet, based on requirements for aerial survey with 5-foot contour data. It is assumed that joint distribution error and corresponding probability distribution functions are normally distributed with a mean error of zero.

5. **Depreciated Structure and Content Replacement Values –** The depreciated replacement values for structures and contents are used to determine economic damages in the floodplain and are a function of structure type, condition, and size. Since surveying every structure in the floodplain was not feasible for this study, uncertainty arises in these values. Field surveys were based on a randomized stratified sample of floodplain structures, and were used to determine structure type, condition, square footage, and foundation height, as outlined in Section 3.2. *Marshall & Swift* multiplier values per square foot and uncertainties for structure condition and corresponding estimates of depreciation were used to calculate the structure and content depreciated replacement costs. Errors for structure value estimates are assumed to be normally distributed with a mean error of zero, and standard deviations range from 10 to 15 percent of mean structure value. Structure content values are estimated as a percentage of the structure value, based on structure type and the depth-damage function.

6. **Depth-Damage Relationships** – Depth-damage functions are used to calculate the percent damage a structure will incur at a specific water elevation in a flood event and is subject to uncertainty. The methodology used to construct depth-damage relationships for non-residential structures was developed by an expert-opinion elicitation process, conducted by URS Group and published in *Solicitation of Expert Opinion Depth-Damage Function Calculations for the Benefit-Cost Analysis Tool, October 2008.* This report provides non-residential depth-damage curves for structure contents by structure type, as well as content-to-structure value ratios and associated standard errors.

   Depth-damage functions and associated standard errors for residential structures and their contents were developed by the Institute for Water Resources (IWR) and published in Economic Guidance Memorandum (EGM) 01-03*: Generic Depth-Damage Relationships.* The depth-damage functions and standard error estimates are based upon previous damages that occurred during flood events in the United States.

   Depth damage functions for other damage categories are described in the discussion of damages by category in the following sections.

3.1.4. Economic Damage Reaches and Index Stations

There are eight reaches along the mainstem of the Neuse River, five reaches in Big Ditch, seven reaches in Crabtree Creek, and seven reaches in Hominy Swamp Creek. Damage reaches were defined in HEC-RAS based on similar hydromorphology, hydraulic characteristics, and economic considerations.

Figure 9 depicts all reaches in the study area. The mainstem reaches extend from just south of Raleigh downstream to the confluence of the Neuse River with the Pamlico Sound. Crabtree Creek reaches extend north of the mainstem Neuse River through Raleigh. Big Ditch reaches are located near Goldsboro and overlap with Mainstem Reach 5 (MS5). It is important to note that the flood source of Big Ditch is different than that of the mainstem Neuse River, which is why it was modeled separately. Hominy Swamp Creek reaches lie near the city of Wilson. Figure 10-Figure 12 depict the tributary reaches in more detail.

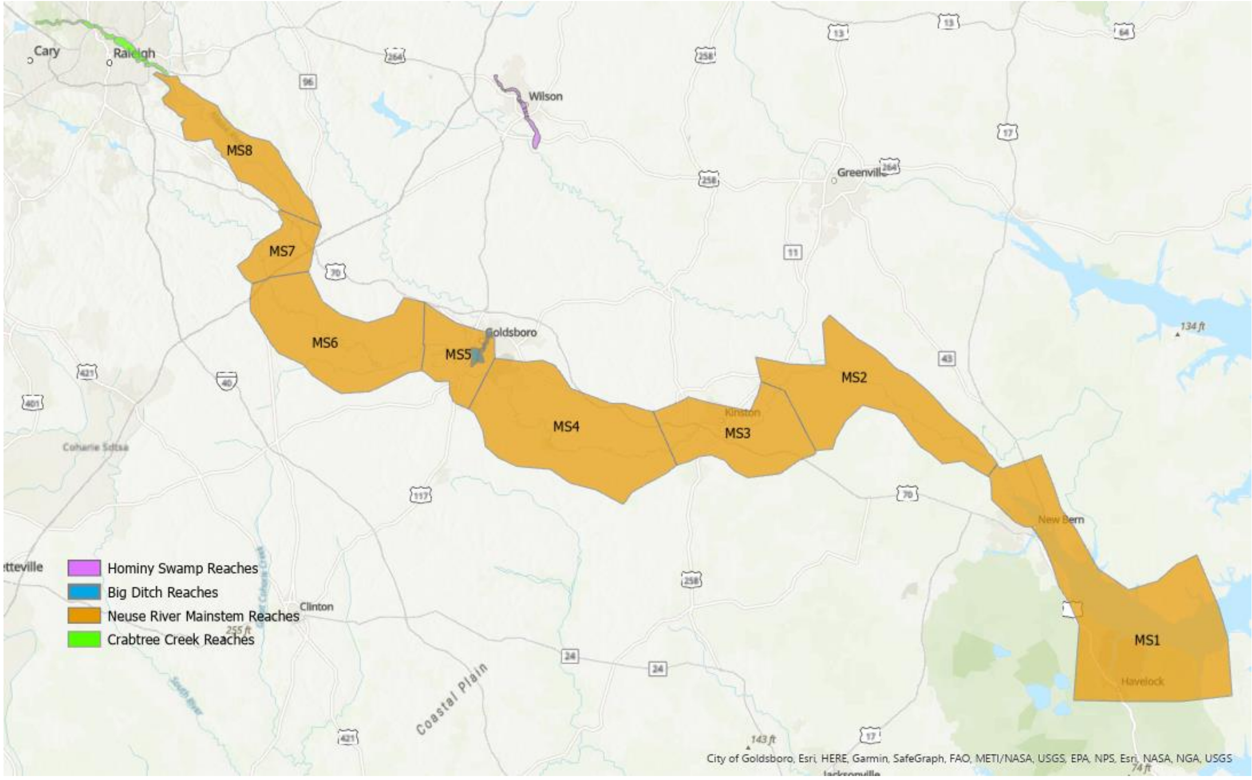

Figure 9. Study Area Reaches

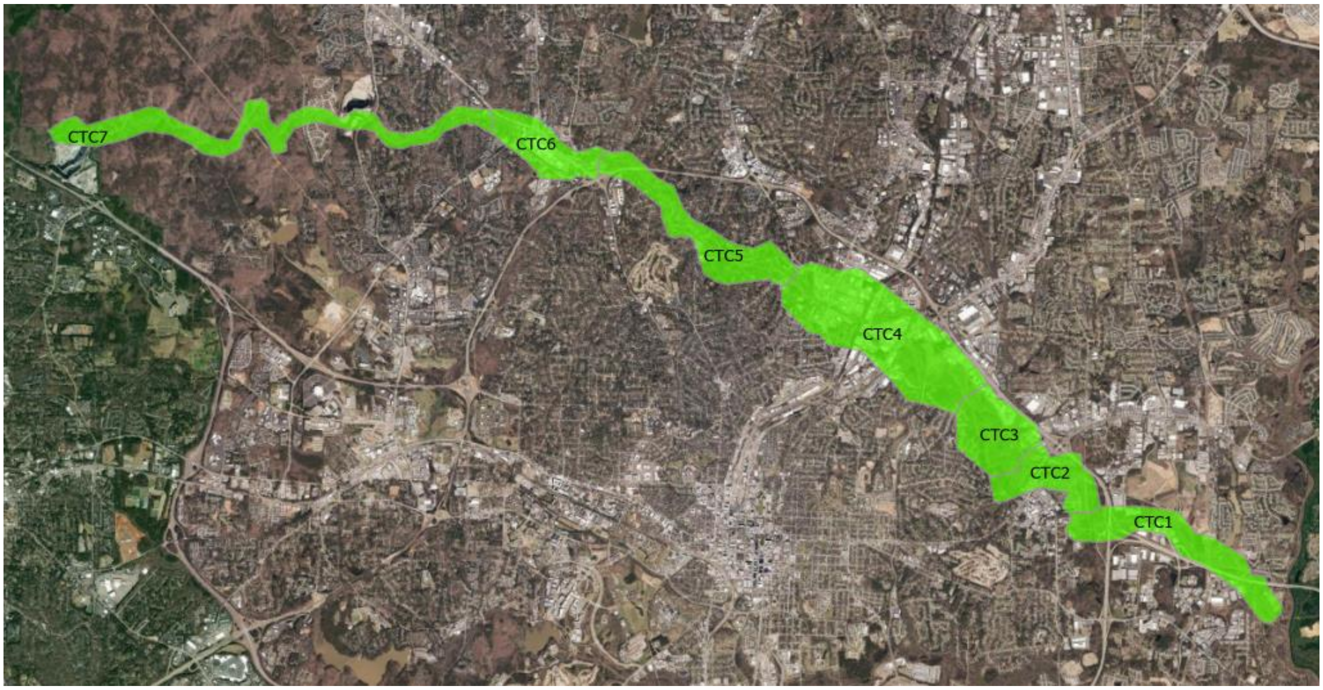

Figure 10. Crabtree Creek Reaches

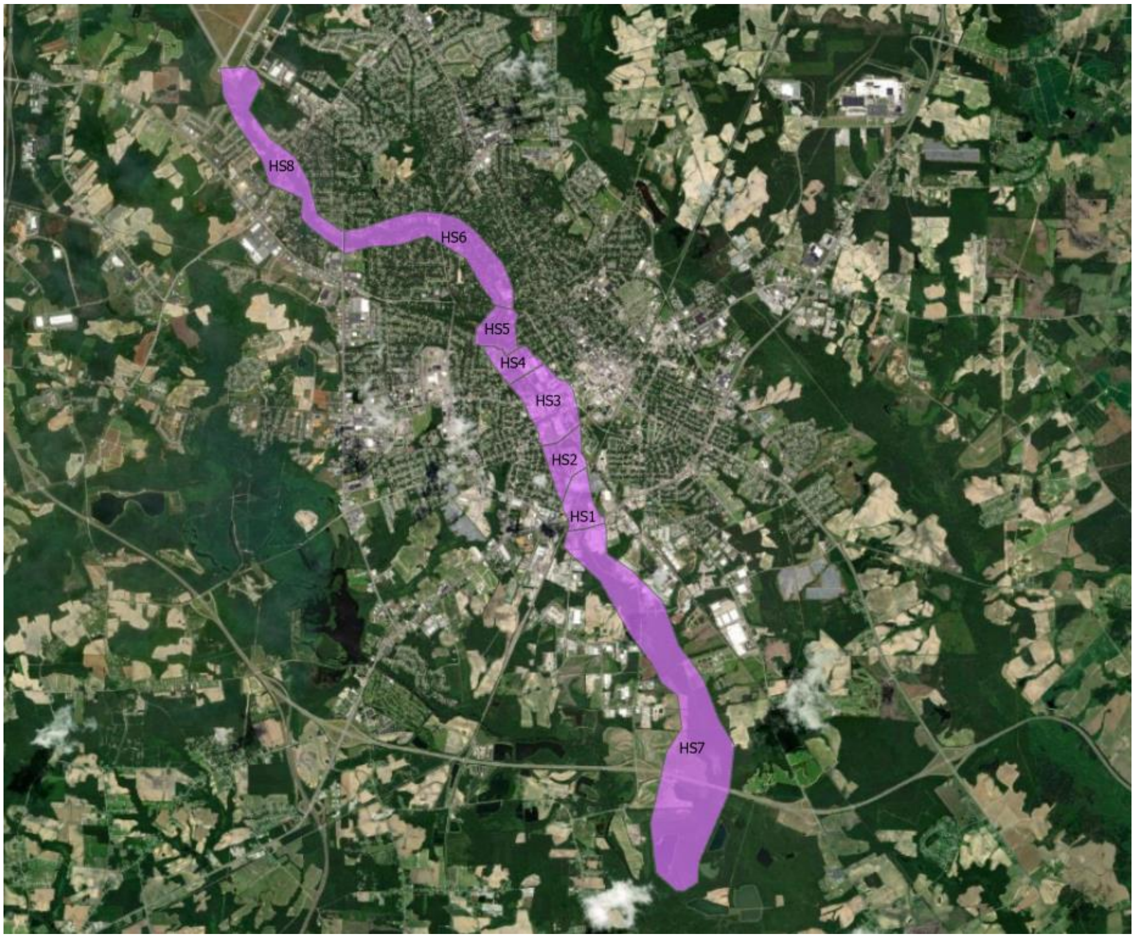

Figure 11. Hominy Swamp Creek Reaches

Figure 12. Big Ditch Reaches

Each reach is associated with an index station, which is used to specify discharge-probability, stage-discharge, and stage-damage functions for each reach. The index station assignments were based on hydrologic parameters, and a close examination of hydraulic conditions specific to each reach. The assigned index location generally represents the water surface elevations occurring in the reach. Table 5. Neuse Mainstem Reach Index Stations-Table 8. Big Ditch Reach Index Stations present reach index and downstream/upstream cross section (DS/US XS) information for all modeled areas.

Table 5. Neuse Mainstem Reach Index Stations

Reach	DS_XS	US_XS	Index Station
MS1	-16.8	14.107	6.87
MS2	14.107	43.213	30.701
MS3	43.213	64.367	54.87
MS4	64.367	99.102	89.755
MS5	99.102	118.152	99.56
MS6	118.152	153.03	140.775
MS7	153.03	161.877	157.412
MS8	161.877	186.491	171.912

Table 6. Crabtree Creek Reach Index Stations

Reach	DS_XS	US_XS	Index Station
CTC1	1112	17176	12657
CTC2	17176	24219	18718
CTC3	24219	30656	30656
CTC4	30656	46296	44283
CTC5	46296	62311	55183
CTC6	62311	70362	65209
CTC7	70362	82898	74754

Table 7. Hominy Swamp Creek Reach Index Stations

Reach	DS_XS	US_XS	Index Station
HS1	23292.02	25803.5	25803.5
HS2	25803.5	27295.57	26919.42
HS3	27295.57	31309.66	30909.7
HS4	31309.66	33087.37	32522.23
HS5	33087.37	35124.69	34437.7
HS6	35124.69	45623.5	36439.75
HS7	2765.41	23292.02	20323.33
HS8	45623.5	58310.43	50077.34

Table 8. Big Ditch Reach Index Stations

Reach	DS_XS	US_XS	Index Station
BD1	1219.655	5960.385	5686.979
BD2	5960.385	9602.607	8928.566
BD3	9602.607	11317.15	10978.88
BD4	11317.15	16036.19	15861.03
BD5	16036.19	20233.13	16774.16

3.2. Data Development

3.2.1. Structure Inventory Development

The structure inventory for the economic analysis was based on data from the North Carolina State FRIS website fris.nc.gov. The data includes parcel footprints with several attributes that are a combination of tax assessor, census, HAZUS, and survey data, and was updated in 2019. The state of North Carolina completed HAZUS damage calculations for the entire Neuse River Basin, which were used to identify high flood risk areas for pre-screening purposes only. A structure inventory was developed using the FRIS building footprints and LiDAR-surveyed first floor elevations.

To develop the structure inventory used in HEC-FDA, the FRIS building footprints were converted to centroids and clipped to the FEMA 0.2 percent AEP boundary plus a 500-foot buffer in ArcGIS Pro. Due to the large size of the basin, the PDT identified nine separable areas in which to focus the study. Structures were clipped to these nine areas in ArcGIS Pro, then stratified by census place and randomly sampled using Python. The structure data was then provided to Real Estate who surveyed the sample and provided occupancy types and Marshall & Swift depreciated replacement costs. Surveyed structure values and occupancy types were used to randomly assign values to the rest of the population by stratified group using Python. Original LiDAR derived first floor elevations from the FRIS data were maintained for each structure.

Section 308 of the Water Resources Development Act (WRDA) of 1990 has been observed in this analysis, and structures built since 1991 in the one percent AEP floodplain are assumed to be in compliance with Section 308 due to the study area's communities' participation in the National Flood Insurance Program (NFIP). Participation was confirmed for structures in Zone A (FEMA 1 percent flood event) using FEMA NFIP reports provided by the State of North Carolina. Tax assessor data in the FRIS dataset was used to determine the age of the structure.

3.2.2. Damage Categories and Structure Occupancy Types

A structure occupancy type in HEC-FDA is a subgroup of damage categories and is the name given to a similar set of structures used to define depth-percent damage functions, first-floor uncertainties, structure value uncertainties, content-to-structure value ratios with uncertainties, and other-to-structure value ratios with uncertainties for each type of structure. A full list of structure occupancy types can be found in Table 11.

3.2.3. First Floor Elevations

First floor structure elevation is the aggregate of terrain and foundation height and is vital in determining when a structure is flooded. First floor elevations for this study were derived from LiDAR surveying and provided by the state of North Carolina. Structures were assigned standard deviations of error for first floor elevations of 0.60 feet, based on requirements in EM 1110-1-1619 for aerial survey with 5-foot contour data.

3.2.4. Structure Valuation

The structure inventory for the feasibility study was developed using North Carolina's FRIS data, and a stratified random sample of structures within the Neuse River Basin. FRIS data included a shapefile of building footprints with attributes from a combination of tax assessor, census, and HAZUS data, and surveys. To narrow the areas of focus for the study, HAZUS damages in the FRIS data were used. However, for the HEC-FDA analysis, no other data attributes from the FRIS data were used besides parcel identification number, XY coordinates, and LiDAR derived first floor elevation. All other attributes were obtained or assigned from the sample of structures surveyed by USACE Real Estate. Structure inventory data was projected into NAD 1983 (2011) State Plane North Carolina FIPS 3200 (US Feet) to maintain consistency with H&H data.

Centroids were calculated from FRIS building footprints in ArcGIS Pro 2.9 and clipped to nine separable areas where the study would be focused, resulting in nearly 44,000 structure centroids. Python 3.7 was used to randomly sample five percent, or 2,200, of these structures, stratifying by census place, which represented each separable area. Sampled structures were subsequently surveyed by USACE Real Estate using both in-person and Google Earth methodology to obtain square footage and Marshall & Swift classifications for structure type, construction quality, and condition. USACE Real Estate provided depreciated replacement costs and occupancy type for surveyed structures, and sample statistics were then randomly applied to all structures in the nine separable areas. Marshall & Swift depreciated replacement values and HEC-FDA damages were calculated in FY (Fiscal Year) 2021 price levels and updated to FY22 price levels.

The final structure inventory was reduced to five areas, based on preliminary damages calculated by the state of North Carolina using HAZUS and hydraulic and hydrologic considerations. The final structure inventory for HEC-FDA modeling included the mainstem Neuse River, Adkins Branch tributary, Big Ditch tributary, Crabtree Creek tributary, and Hominy Swamp Creek. Table 9 below summarizes the structure count and value by damage category and area. Content value derivation is explained in the following section.

Table 9. Structure Inventory Summary by Separable Area

	Structures	Depreciated Structure Value $	Depreciated Content Value $
Adkins Branch			
Residential	153	$17,753,960	$17,753,960
Commercial	37	$42,333,671	$21,374,687
Public	0	$0	$0
Big Ditch			
Residential	274	$53,547,897	$42,642,802
Commercial	74	$67,205,702	$28,226,395
Public	6	$22,099,257	$29,171,019
Crabtree Creek			
Residential	328	$78,943,231	$60,825,815
Commercial	34	$72,529,437	$30,462,364
Public	0	$0	$0
Hominy Swamp Creek			
Residential	200	$40,745,389	$32,096,262
Commercial	51	$52,070,524	$21,869,620
Public	4	$14,371,605	$18,970,519
Mainstem Neuse River			
Residential	11,612	$1,603,553,756	$1,400,276,709
Commercial	2,455	$4,556,456,941	$1,913,711,915
Public	99	$182,784,323	$241,275,306
Total	**15,327**	**$6,804,395,693**	**$3,858,657,373**

It should be noted that Adkins Branch and Big Ditch tributary floodplains overlap the mainstem Neuse River flood extent, and therefore duplicate structures are included in the total count. However, these areas were modeled separately in HEC-FDA to analyze damages from the individual sources of flooding, and no structures were double counted in the alternatives analysis.

Adkins Branch was subsequently screened during the plan formulation process after initial HEC-RAS and HEC-FDA modeling efforts showed very low existing conditions damages.

Table 10 displays uncertainty parameters for structures, which were imported into HEC-FDA with the depth-damage curves.

Table 10. Structure Value Uncertainty

Occupancy Code	Description	Normal Distribution Std Dev (%)	Triangular Distribution Min Error	Triangular Distribution Max Error
SFR1-SFR3	Single Family Residential	17.00		
MFR1-MFR4	Multi-Family Residential	17.00		
C-RET1 – C-RET12	Commercial Retail	11.00		
P-GOV1 – PGOV3	Government owned buildings	13.00		
AUTO	Vehicles		45.00	287.00

3.2.5. Contents Valuation

The generic content depth-damage curves for residential structures provided in Economic Guidance Memorandum (EGM) 01-03, *Generic Depth-Damage Relationships* were used to represent the content depth-damage functions for residential structures in HEC-FDA. These relationships determine content value as a percentage of structure value, based on occupancy type. Content-to-structure value ratios (CSVR) for residential structures are 100 percent, with an error term of zero. CSVR for nonresidential structures were taken from URS Group's *Solicitation of Expert Opinion Depth-Damage Function Calculations for the Benefit-Cost Analysis Tool, October 2008,* and are shown below with uncertainty. Table 11 displays CSVR values and associated uncertainty.

Table 11. Occupancy Types and Content-to-Structure Value Ratios

Occupancy Code	Description	CSVR	Normal Distribution Std Dev %
SFR1-SFR3	Single Family Residential	100.0	0.0
MFR1-MFR4	Multi-Family Residential	14.0	9.0
C-RET1-C-RET12	Commercial	42.0	16.0
P-GOV1-PGOV3	Government Building	132.0	269.0

3.2.6. Depth-Damage Functions: Residential

Depth-damage curves relate the percent of structure and content value that is damaged given the depth of inundation and include uncertainty. As noted above, the depth-damage functions and associated standard deviations developed for EGM 01-03, *Generic Depth-Damage Relationships,* were used for residential structures. Due to the risk of flooding from hurricanes and rivers, high water tables, and mild climate, basements are very uncommon in North Carolina. Additionally, no surveyed structures contained basements and therefore residential depth damage functions used were for structures without basements. Depth-damage functions are shown in Table 12 for one story structures. For multi-story structures, refer to the EGM 01-03.

Table 12. One Story, No Basement Residential Depth-Damage Function

Depth	Mean of Damage	Standard Deviation of Damage
-2	0%	0.0%
-1	2.5%	2.7%
0	13.4%	2.0%
1	23.3%	1.6%
2	32.1%	1.6%
3	40.1%	1.8%
4	47.1%	1.9%
5	53.2%	2.0%
6	58.6%	2.1%
7	63.2%	2.2%
8	67.2%	2.3%
9	70.5%	2.4%
10	73.2%	2.7%
11	75.4%	3.0%
12	77.2%	3.3%
13	78.5%	3.7%
14	79.5%	4.1%
15	80.2%	4.5%
16	80.7%	4.9%

3.2.7. Depth-Damage Functions: Nonresidential

The depth-damage functions used for nonresidential structures and contents are based on the data presented in the 2008 URS Group draft report *Solicitation of Expert Opinion Depth-Damage Function Calculations for the Benefit-Cost Analysis Tool*. Twenty-one core nonresidential structure types were evaluated by a panel of experts from across the United States using historical flood damage data. The resulting data from the panel included nationally relevant depth-damage functions for use in estimating the value of damages from flooding to commercial, industrial, and public structures nationwide. For nonresidential structures, depth-damage function uncertainties are expressed as a triangular distribution.

3.2.8. Other Damage Categories

In addition to damages to structures and their contents, various other damages may occur in a flood event, including cleanup costs, other public assistance, and damages to vehicles. This section explains these categories in more detail and justifies them as flood damage reduction categories that are included in the calculation of with-project benefits.

3.2.8.1. Cleanup Costs

ER 1105-2-100 provides for emergency expenses, which include hazardous and toxic waste cleanup, to be included in damage estimates for flood events. Structures that are inundated in a flood event require post-flood cleanup in order to remove floodwater, sediment, debris, mold, mildew, and toxins. These cleanup costs are considered a damage category in the calculation of with-project benefits and can vary based on the depth of flooding. A depth-damage curve is used to estimate the cost incurred for a given level of inundation in a structure. Depth-damage functions for cleanup costs come from USACE Sacramento District's *Technical Report: Content Valuation and Depth Damage Curves for Nonresidential Structures, May 2007*. A structure incurs the maximum cleanup cost when it is inundated with 3 feet or more of water.

Debris cleanup costs were taken from Chapter 6 of the New Orleans Emergency Cost Report, 2012. A general residential maximum cleanup costs value of $8,484 was used only for residential structures in HEC-FDA. Nonresidential structures and emergency response roadway clearing costs were not included.

3.2.8.2. Vehicle Damages

This economic analysis includes vehicle damages for vehicles at residential structures. Historical floods, including Hurricane Florence, inundated vehicles with mud and water and caused many automobile owners to file with their insurance companies as the hurricane caused total losses of vehicles. In just the first week after Hurricane Florence, State Farm Insurance received 2,400 automobile claims related to the storm in North Carolina.[2]

Automobile damages are calculated as a function of the number of vehicles per residence, estimated average value per vehicle, and the depth of flooding above the ground elevation. Damages to autos in commercial, industrial, and public parking lots are not included in the analysis.

To obtain the vehicle replacement amount, the average number of available vehicles per household in North Carolina was taken from the 2019 American Community Survey 1-year estimates available at census.gov. A weight was then calculated based on the percent of households with zero through five cars. The weighted average of total cars per household was calculated to be 1.18. Average vehicle cost was calculated based on the average cost of vehicles posted on Auto Trader, where used vehicles are posted for sale. A histogram of the sample was calculated and the value at the 50th percentile of $26,158 was used. Multiplied by the number of vehicles per household, the vehicle replacement cost for vehicles at residences used in the analysis is $30,871. In accordance with EGM 09-04 Table 5, it is assumed that 50 percent of the vehicles will be removed prior to the flood event occurring, due to an estimated warning time of six hours or less. This resulted in a final per household vehicle value of $15,435. This value was used in HEC-FDA to calculate vehicle damages.

Depth-damage functions and associated standard deviations for vehicle damages were taken from EGM 09-04, *Generic Depth-Damage Relationships for Vehicles*. The depth damages for pickups was used as this is the most representative vehicle type in the study area. The maximum damage value of $15,435 per household was only incurred when flooding reached 9 feet in depth.

3.2.8.3. Other Emergency Costs

Other emergency costs incurred in flood events come from FEMA's Individuals and Households Program (IHP) and include the following: Public Assistance (PA) to aid in public debris removal, emergency protective measures, and to repair roads, bridges, water facilities, public buildings, utilities, and public parks and recreation facilities; and Other Needs Assistance (ONA), which includes aid to replace essential household items, and moving, storage, medical, dental, and funeral expenses caused by the flood. Housing assistance is not included in the analysis.

For emergency costs in this analysis, actual PA and ONA claims data for the state of North Carolina after Hurricane Florence was gathered from FEMA's website and used to calculate

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[2] https://www.npr.org/2018/09/26/651517127/florence-floodwaters-total-thousands-of-cars-stranding-locals

maximum emergency cost values.[3] PA per household was calculated by taking the total sum of public assistance and dividing it by the number of Individual Assistance Applications approved. As of May 2021, nearly $359 billion in public assistance grants had been obligated and 34,713 individual assistance applications had been approved for IHP. This resulted in a PA per household amount of $10,352. Other needs assistance from this storm event totaled $23 million as of May 2021 and is based on 14,251 approved claims. Therefore, average ONA per household was calculated to be $1,667. This was added to the PA per household amount for a maximum emergency cost amount of $12,019.

Emergency costs are also assigned a depth-damage function that associates a specific depth of flooding to a percentage of the emergency costs in HEC-FDA. Fifty percent of the total value of emergency costs are incurred when water surface elevations are greater than 0.5 feet, while water surface elevations of one foot or greater incur 100 percent of the emergency cost value. This assumes that households must incur a depth of flooding greater than zero to be eligible to file a claim. Thus, structures which are inundated one foot or more above the first-floor elevation would incur public and other needs assistance related costs reflected in the FEMA claims data.

3.3. Damage Analysis Modeling

Damages modeled in HEC-FDA are the basis for calculating net National Economic Development (NED) benefits. The structure inventory (including values, elevations and depth-damage functions, and uncertainty parameters) for the study area were input into HEC-FDA along with sets of water surface profiles for damage computations. Damages in the analysis consist of physical inundation damages to commercial, industrial, residential, and public structures as well as respective contents and vehicles.

3.3.1. Model Hydraulic and Hydrologic Inputs

Water surface profiles were developed in HEC-RAS for the future without (FWOP) and future with-project (FWP) conditions. These included profiles for the 0.5, 0.2, 0.1, 0.04, 0.02, 0.01, 0.005, and 0.002 AEP events. Water surface profiles were developed and evaluated in HEC-FDA for five separable areas: Adkins Branch, Big Ditch, Crabtree Creek, Hominy Swamp Creek, and mainstem Neuse River. After the initial FWOP conditions were developed for Adkins Branch, it was determined that damages were not sufficient to continue modeling this area. Therefore, only FWP conditions were developed in HEC-RAS for Big Ditch, Crabtree Creek, Hominy Swamp Creek, and mainstem Neuse River.

Cross sections and associated river stations from the HEC-RAS model were spatially joined to structure inventory data using ArcGIS Pro 2.9. Each river station was associated with a specific discharge and stage for the AEP frequencies listed above in the water surface profile. Therefore, each structure was assigned the water surface profile associated with the nearest cross section.

Geotechnical functions were not developed for the FDA models since there are no reaches with a potential levee failure.

3.3.2. Exceedance Probability-Discharge Functions

Exceedance probability-discharge functions are generated from the water surface profiles for each condition, reach, and analysis year. For this study, the graphical method was used to generate probability-discharge functions. Uncertainty was computed using an Equivalent Record

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[3] FEMA data retrieved from https://www.fema.gov/disaster/4393, on May 20, 2021.

Length (N) of 25-year gage record for all project conditions. The “Less Simple” method of Order Statistics was used to approximate uncertainty with a standard normal distribution. Since HEC-FDA 1.4.3 was used, 173 points were included in the standard probabilities for graphical probability functions.

3.3.3. Stage-Discharge Functions

A stage-discharge function is the relationship between the discharge at a river cross section and the water surface elevation produced by that discharge. Stage-discharge functions were retrieved from the water surface profiles for each condition, reach, and analysis year. The probability density function defining uncertainty for the stage-discharge relationship was specified by a normal distribution with a standard deviation of 0.5 feet, becoming constant at the 0.2 AEP profile.

4.0. WITHOUT-PROJECT ANALYSIS AND RESULTS

4.1. Future Without-Project Condition

This section describes the analysis of damages that are expected to occur in the absence of a Federal project to address flood risks in the study area. These damages include damages to structure and structure contents, and other damages, which include vehicle damages, and cleanup and emergency costs associated with flooding. Without project flooding also impacts Other Social Effects, which includes loss of life, and is quantified in this section.

Hydraulic modeling resulted in insignificant differences between projected impervious area changes between an existing and future condition within the Neuse River mainstem and other tributary models. As a result, existing conditions frequency simulation results were assumed to be representative of FWOP conditions, as described in Appendix A of this report.

HEC-FDA software was used to calculate economic damages for this study. Expected annual flood damages are the basis for calculating with-project benefits and are crucial to the evaluation of the project. Expected annual damages are equal to the mean of all possible values of damage that are derived through Monte Carlo sampling of discharge-exceedance probability relationships, stage-discharge relationships, and stage-damage relationships and their uncertainties. This section presents expected annual damages, and as the result of time-dependent variance in hydrologic, hydraulic, and economic data, the values presented are estimates only. Uncertainty parameters for the exceedance-probability relationship and stage-discharge relationship were developed by H&H engineers as detailed in Section 3.3.

Future without and future with-project conditions were developed in HEC-RAS and modeled in HEC-FDA for three separable areas: Crabtree Creek, Hominy Swamp Creek, and mainstem Neuse River. Future without project conditions were developed for Big Ditch (no future with-project structural alternative was modeled for Big Ditch).

4.2. Flooding Characteristics

The without-project analysis and results are based predominantly on estimates of the flooding extent, the depth of flooding, and the property that may be damaged from flooding within a particular area. Flood extents for the 0.002 AEP event for each of the four separable areas are shown below. As previously mentioned, the flood source for Big Ditch is separate from that of the mainstem Neuse River, which is why the overlapping area was modeled separately.

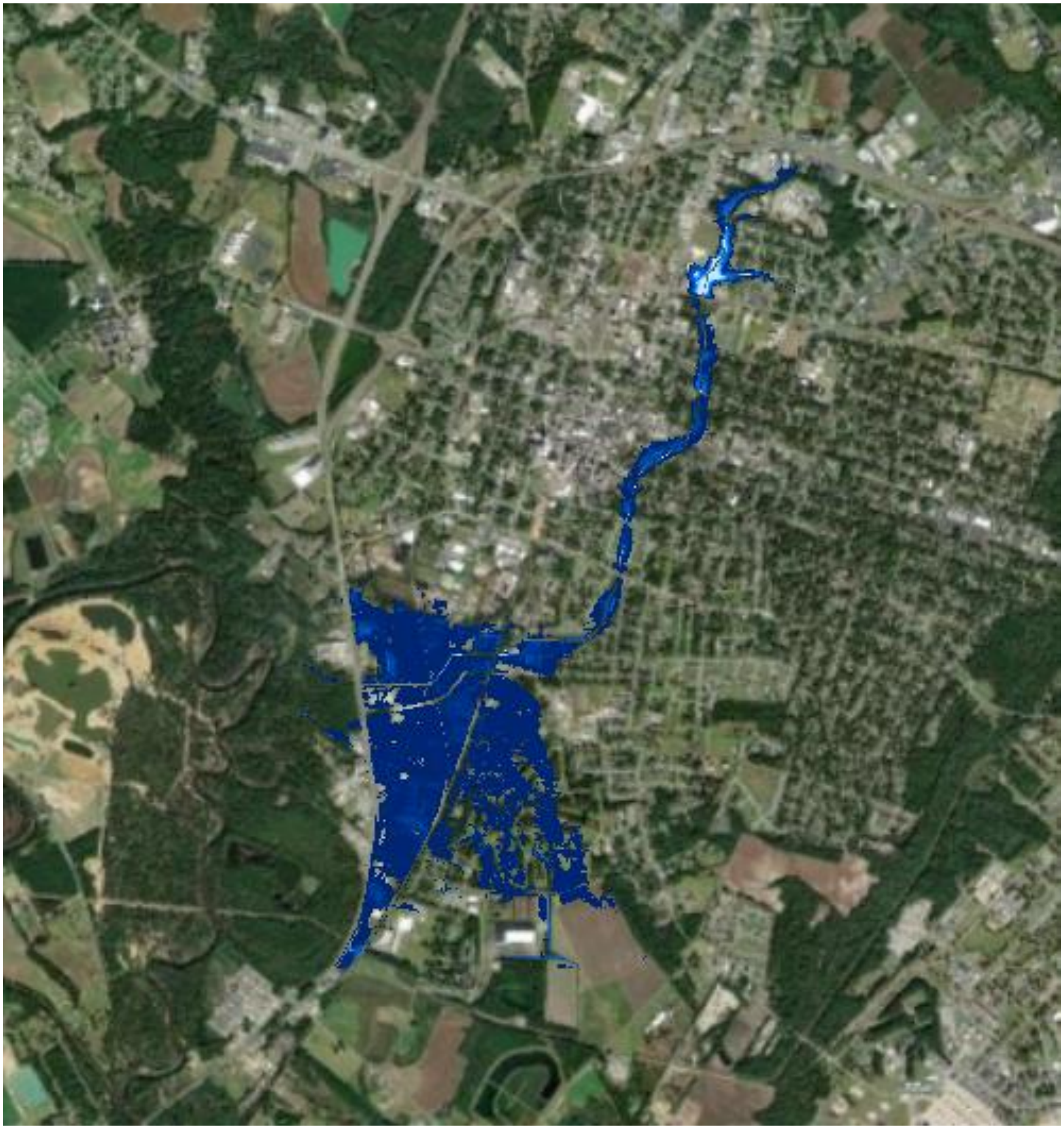

Figure 13. Big Ditch 0.002 AEP Flood Extent

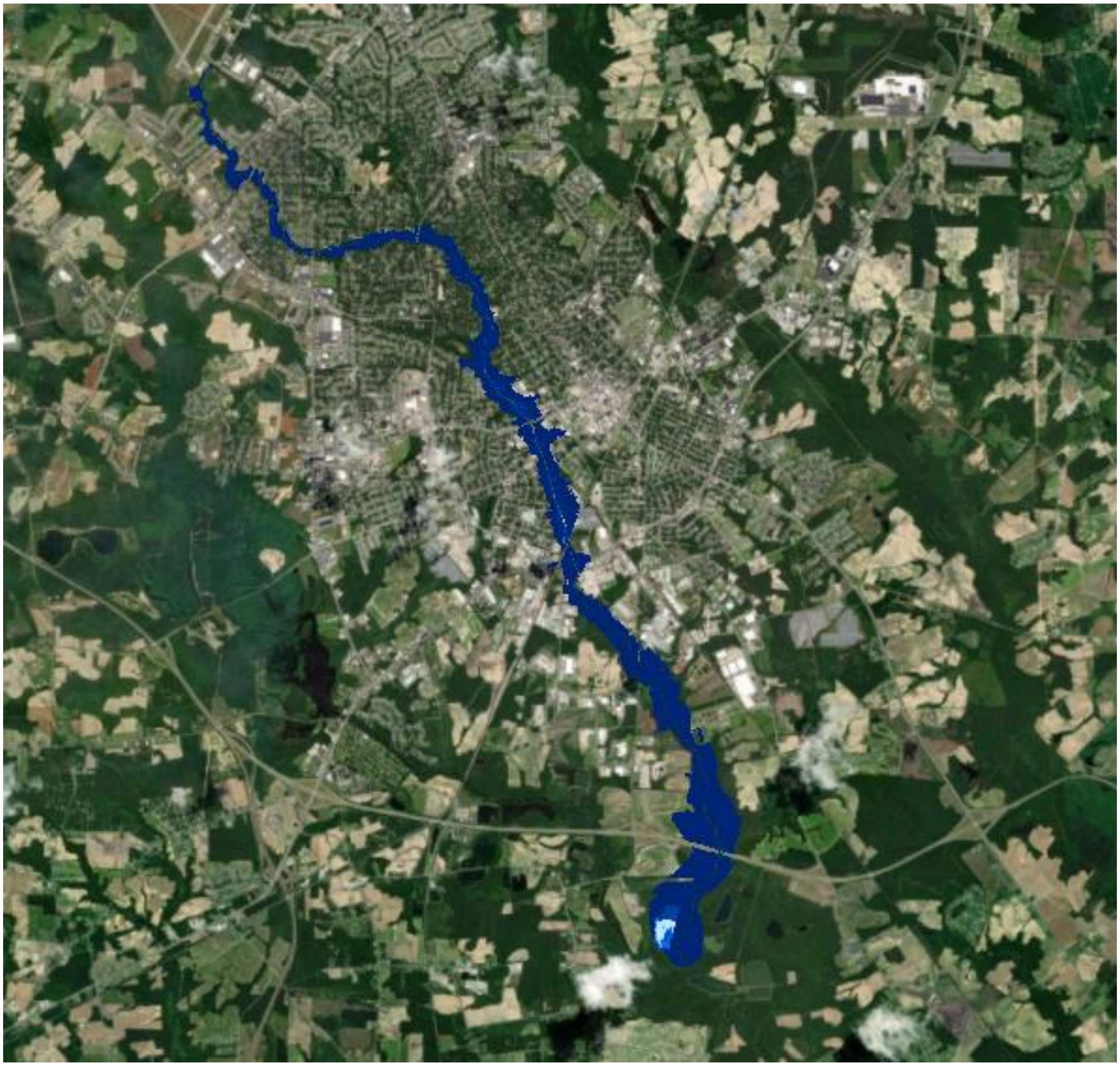

Figure 14. Hominy Swamp Creek 0.002 AEP Flood Extent

Figure 15. Crabtree Creek 0.002 AEP Flood Extent

Figure 16. Mainstem Neuse 0.002 AEP Flood Extent

4.3. Flood Risk: Probability and Consequences

4.3.1. Expected Annual Damages

Expected annual damages (EAD) describe the consequences of flooding on an annual basis considering a full range of flood events. Future without-project EAD are shown in Table 13-Table 25 by reach and damage category for each separable area.

Table 12 and Table 14 display the without-project EAD for Hominy Swamp Creek. Residential, commercial, and public structures account for $823,000 in EAD, while other damages account for $186,000 annually. Total without-project EAD for Hominy Swamp Creek are just over $1 million.

Table 13. Hominy Swamp Creek Without-Project EAD (Structures)

Reach	Residential	Commercial	Public	Total
HS1	64	62	0	126
HS2	49	26	18	93
HS3	124	135	0	259
HS4	70	57	0	127
HS5	71	58	0	129
HS6	34	33	0	67
HS7	10	12	0	22
HS8	0	0	0	0
Total	**422**	**383**	**18**	**823**

Note: values in $000s, FY22 price level

Table 14. Hominy Swamp Creek Without-Project EAD (Other)

Reach	Auto	Clean-Up	Emergency	Total
HS1	8	3	5	16
HS2	14	5	6	25
HS3	38	8	18	64
HS4	12	4	6	22
HS5	27	7	13	47
HS6	6	2	4	12
HS7	0	0	0	0
HS8	0	0	0	0
Total	**105**	**29**	**52**	**186**

Note: values in $000s, FY22 price level

Table 15 displays the number of damaged structures and expected damages by Hominy Swamp Creek flood event. The 10 percent AEP event results in an expected $1.8 million in damages and approximately 61 impacted structures. The 0.2 percent AEP event results in an expected $32 million in damages and impacts approximately 555 structures.

Table 15. Hominy Swamp Creek Structure Damages and Count by AEP Event

Reach	10% AEP Structures	10% AEP Damages	2% AEP Structures	2% AEP Damages	1% AEP Structures	1% AEP Damages	0.2% AEP Structures	0.2% AEP Damages
HS1	11	$430	17	$957	24	$1,219	38	$2,147
HS2	2	$1	30	$380	72	$1,667	162	$8,267
HS3	29	$965	51	$2,713	66	$3,085	115	$5,573
HS4	9	$89	48	$1,739	55	$2,295	69	$6,010
HS5	4	$147	16	$335	32	$575	66	$6,358
HS6	6	$125	21	$350	37	$1,099	75	$2,899
HS7	0	$0	5	$187	5	$358	30	$744
HS8	0	$0	0	$0	0	$0	0	$0
Total	**61**	**$1,757**	**188**	**$6,662**	**291**	**$10,297**	**555**	**$31,997**

Note: values in $000s; FY22 price level

Table 16 and Table 17 display the without-project EAD for Crabtree Creek. Residential, commercial, and public structures account for $868,000 in EAD, while other damages account for $141,000 annually. Total without-project EAD for Crabtree Creek are just over $1 million.

Table 16. Crabtree Creek Without-Project EAD (Structures)

Reach	Residential	Commercial	Public	Total
CTC1	0	0	0	0
CTC2	22	4	0	26
CTC3	3	29	0	32
CTC4	249	326	0	575
CTC5	50	48	0	99
CTC6	29	99	0	128
CTC7	9	0	0	9
Total	**362**	**507**	**0**	**868**

Note: values in $000s; FY22 price level

Table 17. Crabtree Creek Without-Project EAD (Other)

Reach	Auto	Clean-Up	Emergency	Total
CTC1	0	0	0	0
CTC2	2	2	2	5
CTC3	17	5	13	35
CTC4	29	12	32	72
CTC5	5	2	6	14
CTC6	5	2	4	11
CTC7	2	1	2	5
Total	**59**	**24**	**58**	**141**

Note: values in $000s; FY22 price level

Table 18 displays the number of damaged structures and expected damages by Crabtree Creek flood event. The 10 percent AEP event results in an expected $726,000 in damages and approximately 55 impacted structures. The 0.2 percent AEP event results in an expected $43 million in damages and impacts approximately 451 structures.

Table 18. Crabtree Creek Structure Damages and Count by AEP Event

Reach	10% AEP Structures	10% AEP Damages	2% AEP Structures	2% AEP Damages	1% AEP Structures	1% AEP Damages	0.2% AEP Structures	0.2% AEP Damages
CTC1	0	$0	0	$0	0	$0	0	$0
CTC2	0	$0	8	$313	17	$616	28	$1,510
CTC3	4	$68	4	$77	4	$78	14	$882
CTC4	42	$542	175	$6,353	225	$11,929	284	$23,971
CTC5	4	$52	44	$1,085	48	$2,264	64	$4,819
CTC6	1	$9	23	$412	42	$902	53	$11,759
CTC7	4	$55	4	$104	4	$114	8	$201
Total	**55**	**$726**	**258**	**$8,344**	**340**	**$15,904**	**451**	**$43,142**

Note: values in $000s; FY22 price level

Table 19 and Table 20 display the without-project EAD for Big Ditch. Residential, commercial, and public structures account for $3 million in EAD, while other damages account for $69,000 annually. Total expected annual damages for Big Ditch are just over $3 million.

Table 19. Big Ditch Without-Project EAD (Structures)

Reach	Residential	Commercial	Public	Total
BD1	187	108	1,283	1,577
BD2	59	38	0	97
BD3	41	26	1,274	1,342
BD4	0	0	0	0
BD5	0	0	0	0
Total	**287**	**172**	**2,557**	**3,017**

Notes: values in $000s; FY22 price level

Table 20. Big Ditch Without-Project EAD (Other)

Reach	Auto	Clean-Up	Emergency	Total
BD1	11	9	24	43
BD2	1	1	3	6
BD3	5	6	10	20
BD4	0	0	0	0
BD5	0	0	0	0
Total	**17**	**16**	**36**	**69**

Notes: values in $000s; FY22 price level

Table 21 displays the number of damaged structures and expected damages by Big Ditch flood event. The 10 percent AEP event results in an expected $13 million in damages and approximately 294 impacted structures. The 0.2 percent AEP event results in an expected $23.7 million in damages and impacts approximately 500 structures.

Table 21. Big Ditch Structure Damages and Count by AEP Event

Reach	10% AEP Structures	10% AEP Damages	2% AEP Structures	2% AEP Damages	1% AEP Structures	1% AEP Damages	0.2% AEP Structures	0.2% AEP Damages
BD1	53	$2,800	86	$3,908	99	$4,403	123	$6,002
BD2	17	$63	49	$299	61	$501	106	$1,584
BD3	14	$2,119	18	$3,251	18	$3,675	35	$4,536
BD4	208	$8,320	209	$8,632	209	$8,753	209	$8,977
BD5	2	$11	10	$113	11	$197	27	$2,602
Total	**294**	**$13,314**	**372**	**$16,203**	**398**	**$17,530**	**500**	**$23,701**

Note: values in $000s; FY22 price level

Table 22 and Table 23 display the without-project EAD for the mainstem Neuse River. Residential, commercial, and public structures account for $32 million in EAD, while other damages account for $6 million annually. Total expected annual damages for the mainstem are just over $38 million.

Table 22. Mainstem Neuse River Without-Project EAD (Structures)

Reach	Residential	Commercial	Public	Total
MS1	5,181	7,311	120	12,612
MS2	526	1,471	11	2,008
MS3	1,420	2,074	125	3,619
MS4	1,088	936	701	2,725
MS5	1,775	4,572	2,775	9,122
MS6	588	673	322	1,584
MS7	181	248	0	429
MS8	20	7	23	51
Total	**10,780**	**17,292**	**4,078**	**32,150**

Notes: values in $000s; FY22 price level

Table 23. Mainstem Neuse River Without-Project EAD (Other)

Reach	Auto	Clean-Up	Emergency	Total
MS1	1,508	366	856	2,729
MS2	157	37	83	277
MS3	494	113	233	840
MS4	365	84	178	627
MS5	587	132	265	984
MS6	250	58	123	431
MS7	76	17	33	126
MS8	9	2	5	16
Total	**3,445**	**809**	**1,776**	**6,030**

Notes: values in $000s; FY22 price level

Table 24 displays the number of damaged structures and expected damages by mainstem Neuse River flood event. The 10 percent AEP event results in an expected $32.9 million in damages and approximately 1,485 impacted structures. The 0.2 percent AEP event results in nearly $2 billion in expected damages and impacts approximately 32,638 structures. While the other models focus on a smaller tributary of the Neuse River, the mainstem spans nearly the entire

Neuse River Basin, which is evidenced by the higher number of impacted structures and consequences.

Table 24. Mainstem Neuse River Structure Damages and Count by AEP Event

Reach	10% AEP Structures	10% AEP Damages	2% AEP Structures	2% AEP Damages	1% AEP Structures	1% AEP Damages	0.2% AEP Structures	0.2% AEP Damages
MS1	573	$3,287	6,494	$158,636	9,692	$306,134	15,763	$746,224
MS2	31	$407	377	$7,361	753	$17,733	2,250	$211,686
MS3	197	$3,617	1,031	$39,664	1,726	$71,777	3,848	$187,984
MS4	165	$1,878	894	$25,954	1,475	$48,077	3,460	$142,985
MS5	395	$22,276	1,458	$87,004	2,236	$153,162	5,302	$465,489
MS6	102	$1,230	373	$13,127	524	$24,168	1,058	$55,662
MS7	18	$141	142	$2,572	259	$8,224	802	$40,381
MS8	4	$62	10	$161	15	$319	155	$5,307
Total	**1,485**	**$32,898**	**10,779**	**$334,479**	**16,680**	**$629,594**	**32,638**	**$1,855,718**

Note: values in $000s; FY22 price level

Table 25 shows aggregate future without-project damages by separable area. Total without-project damages exceed $43 million. Damages to structures and contents account for $37 million of that, while other damage categories account for approximately $6 million.

Table 25. Neuse River Basin Without Project EAD

Stream	Structure & Content Damages	Other Damages	Total Damages
Hominy Swamp Creek	$823	$186	$1,009
Crabtree Creek	$868	$141	$1,009
Big Ditch	$3,017	$69	$3,086
Mainstem Neuse River	$32,150	$6,030	$38,180
Total	**$36,858**	**$6,426**	**$43,284**

Notes: values in $000s; FY22 price level

4.3.2. FWOP Project Performance by Reach

Without project performance statistics help inform the risk of a flood event for a specific frequency. Three components are indicators of project performance: the annual exceedance probability (AEP) is the likelihood flooding occurs in any given year; the long-term exceedance probability (LTEP) is the probability that flooding occurs in a period of 10, 30, or 50 years; and the assurance, also called conditional non-exceedance probability (CNP) is the probability that flooding doesn’t occur, conditional on a flood event of 0.02, 0.01 and 0.002 frequency occurring.

AEP represents the probability of any event equaling or exceeding a specified stage in any given year. With levees present, the stage would be the top of levee or effective top of levee as specified by the geotechnical fragility curves. For this study, top of bank elevation is used. For non-leveed reaches, the target stage is determined by the exceedance of a percentage of the mean damage associated with a specified event. The default criteria of five percent of the total damage for the 0.01 AEP event was used for this study. Table 26-Table 29 below display the project performance statistics by reach for each separable area under the without project condition.

Table 26 shows high probability of flooding in any given year in reaches HS1, HS3, HS5, and HS6. The probability that banks are overtopped in 30 or 50 years is nearly 100 percent in all reaches. Correspondingly, assurance is low in all reaches. HS8 has the highest probability that no flooding occurs, given a 0.02, 0.01, or 0.002 AEP event occurs.

Table 26. Hominy Swamp Creek Without-Project Performance

Reach	Expected AEP	LTEP 10 Years	LTEP 30 Years	LTEP 50 Years	CNP 2%	CNP 1%	CNP 0.2%
HS1	0.98	1.00	1.00	1.00	0.00	0.00	0.00
HS2	0.40	0.99	1.00	1.00	0.00	0.00	0.00
HS3	0.79	1.00	1.00	1.00	0.00	0.00	0.00
HS4	0.41	1.00	1.00	1.00	0.00	0.00	0.00
HS5	0.90	1.00	1.00	1.00	0.00	0.00	0.00
HS6	1.00	1.00	1.00	1.00	0.00	0.00	0.00
HS7	0.27	0.96	1.00	1.00	0.03	0.03	0.01
HS8	0.13	0.74	0.98	1.00	0.14	0.10	0.02

Table 27 shows high probability of flooding in any given year in reaches CTC1, CTC3, CTC4, and CTC5. The probability that banks are overtopped in 10, 30, or 50 years is nearly 100 percent in all reaches. Correspondingly, assurance is low in all reaches.

Table 27. Crabtree Creek Without-Project Performance

Reach	Expected AEP	LTEP 10 Years	LTEP 30 Years	LTEP 50 Years	CNP 2%	CNP 1%	CNP 0.2%
CTC1	1.00	1.00	1.00	1.00	0.00	0.00	0.00
CTC2	0.76	1.00	1.00	1.00	0.00	0.00	0.00
CTC3	1.00	1.00	1.00	1.00	0.00	0.00	0.00
CTC4	1.00	1.00	1.00	1.00	0.00	0.00	0.00
CTC5	0.92	1.00	1.00	1.00	0.00	0.00	0.00
CTC6	0.34	0.98	1.00	1.00	0.00	0.00	0.00
CTC7	0.28	0.96	1.00	1.00	0.00	0.00	0.00

Table 28 shows high probability of flooding in any given year in reaches BD2, and BD3. The probability that banks are overtopped in 10, 30, or 50 years is nearly 100 percent in BD2 and BD3. Assurance is also low in these reaches. There is low long-term risk and high probability that no flooding occurs given the listed frequency events in reaches BD4 and BD5.

Table 28. Big Ditch Without-Project Performance

Reach	Expected AEP	LTEP 10 Years	LTEP 30 Years	LTEP 50 Years	CNP 2%	CNP 1%	CNP 0.2%
BD1	0.37	0.99	1.00	1.00	0.08	0.06	0.02
BD2	0.99	1.00	1.00	1.00	0.00	0.00	0.00
BD3	0.76	1.00	1.00	1.00	0.00	0.00	0.00
BD4	0.00	0.00	0.00	0.01	1.00	1.00	1.00
BD5	0.00	0.00	0.00	0.01	1.00	1.00	1.00

Table 29 shows high probability of flooding in any given year in reaches MS2, MS3, and MS6. The probability that banks are overtopped in 30 or 50 years is high in all reaches. The probability that no flooding occurs given the listed frequency events is near zero in all reaches except MS5 for the 0.02 and 0.01 AEP events.

Table 29. Mainstem Neuse River Without-Project Performance

Reach	Expected AEP	LTEP 10 Years	LTEP 30 Years	LTEP 50 Years	CNP 2%	CNP 1%	CNP 0.2%
MS1	0.51	1.00	1.00	1.00	0.00	0.00	0.00
MS2	1.00	1.00	1.00	1.00	0.00	0.00	0.00
MS3	1.00	1.00	1.00	1.00	0.00	0.00	0.00
MS4	0.11	0.69	0.97	1.00	0.07	0.06	0.02
MS5	0.07	0.50	0.88	0.97	0.18	0.16	0.04
MS6	1.00	1.00	1.00	1.00	0.00	0.00	0.00
MS7	0.62	1.00	1.00	1.00	0.00	0.00	0.00
MS8	0.22	0.91	1.00	1.00	0.02	0.02	0.01

5.0. WITH-PROJECT ALTERNATIVES ANALYSIS

5.1. With-Project Analysis Overview

To evaluate each alternative plan, alternatives were modeled in HEC-FDA for each separable area, for each plan. The difference between the without-project condition EAD and the with-project EAD for each alternative represents the damages reduced or benefits for the plan. Damages calculated in HEC-FDA are based on physical inundation reduction to homes, businesses, public facilities, and the associated damages reduced to automobiles, cleanup, and emergency costs.

Initially, structural alternatives were modeled in HEC-FDA for the Hominy Swamp Creek, Crabtree Creek, and mainstem Neuse River. The decision to model structural alternatives was based on preliminary hydrologic research and damages that had been calculated by the State of North Carolina using HAZUS. Once these structural measures had been modeled, all of them resulted in a benefit-cost ratio (BCR) below 0.3, and subsequently none of the structural measures were included in the final array. These measures are detailed in Section 5.2.3. Thus, although the final array of alternatives is nonstructural, it should be noted that extensive modeling was undertaken to evaluate structural alternatives until it was evident these plans were not viable. Additionally, combinations of structural and nonstructural measures were evaluated, and none were economically viable.

5.2. Description of Final Array of Alternatives

This section describes the final array of alternatives. The without-project condition, or the no-action plan, is Alternative 1. This alternative is the scenario that would most likely occur in the absence of a federal plan. The no-action plan would likely result in repeated flooding in an area where hurricanes and extreme tropical storms bring heavy rainfall each year. Under the no-action plan, structures would continue to be inundated as outlined in Section 4.0.

5.2.1. Alternative 2

Alternative 2 is a nonstructural plan that evaluated elevating and wet/dry floodproofing structures in specific floodplains in each of the four separable areas: Hominy Swamp Creek, Crabtree Creek, Big Ditch, and the mainstem Neuse River. Structures in each of these four areas were aggregated by reach and by AEP event to determine the best nonstructural plan. Costs of different floodproofing measures were compared to damages reduced by elevating or floodproofing structures to determine the most appropriate floodproofing method, and a measure was recommended that maximized net benefit for each structure. Without-project damages were compared to elevating/floodproofing structures to the 100-year flood elevation plus 2 feet. This was based on local National Flood Insurance Program (NFIP) guidelines that dictate what the State of North Carolina would implement. An optimization analysis that examines additional flood elevation levels will be conducted prior to the ADM.

With-project (floodproofed/elevated) first floor elevations were then adjusted in HEC-FDA to compute with-project damages. Damages were used to calculate net benefits for the 10-, 4-, 2- and 1-percent AEP events and aggregated by flood event and reach to determine the most economically viable combination in each of the four separable areas. In the HEC-FDA models, these computations are labeled as four separate alternatives (NS10, NS25, NS50, and NS100) for each separable area. To ensure no double counting, overlapping structures in Big Ditch and the mainstem Neuse River were included only in the mainstem model, since flood depths were greater from mainstem-source flooding. The flood event was chosen based on which of the four events maximized net benefits in each separable area. Reaches with net benefits less than zero were not included in the alternative plan.

Elevating a structure includes elevated the existing building from its original foundation to the design flood elevation (DFE). This measure is recommended for residential buildings, with or without basements. To calculate the necessary amount each building should be elevated, the elevation of the first floor was subtracted from the 100-year flood elevation plus two feet. In North Carolina, it is required that the first floor be elevated at least two feet above the 100-year flood elevation to be in compliance with local and state codes.

Wet floodproofing is a nonstructural technique that is applicable as either a standalone measure or as a measure combined with other measures such as elevation. Application of wet floodproofing techniques may require a variance from local floodplain management regulations (see FEMA Technical Bulletin 7-93). As a standalone measure, floodwaters are allowed to enter a structure, thereby requiring that all construction materials be water resistant, and all utilities must be elevated above the design flood elevation. Flood vents are installed in the walls to allow floodwaters into the building and equalize the hydrostatic forces. It is required that there be a minimum of two vents with a minimum one square inch of flood vent area for each square foot of the wet floodproofing area, as specified in 44 CFR Section 60.3(c)(5). All utilities, such as heating, lighting, electrical panels and outlets must be elevated above the design flood elevation or be located inside flood resistant closures.

Dry floodproofing of commercial and other non-residential buildings involves applying a water-resistant sealant around the building to prevent flood water from entering. The sealant layer is then protected with a brick veneer or similar material. Closure panels are used at building openings and backflow prevention devices are installed on sanitary sewer lines. A sump pump and drain system should be installed as part of the measure. Masonry or concrete commercial building can generally be dry floodproofed up to design depth of four feet (USACE, 1988). A structural analysis of the wall strength is required if it is desired to achieve higher protection. Buildings constructed of poured concrete, concrete masonry, or brick are most suitable for dry floodproofing.

Alternative 2 includes elevating 419 structures, wet-floodproofing 222 structures, and dry-floodproofing 127 structures. This summary is shown in the Table 30.

Table 30. Alternative 2 Nonstructural Measure Summary

Measure	AEP Event	Elevated Structures	Floodvent Structures	Dry Floodproofed Structures	Total Structures
HS-NS1	0.10	14	0	6	20
CTC-NS6	0.02	38	10	11	59
BD-NS1	0.01	2	4	3	9
MS-NS2	0.02	365	208	107	680
Total		419	222	127	768

Reaches included in Alternative 2 in Hominy Swamp Creek (HS-NS1) include HS1, HS3, HS5, and HS6. In Crabtree Creek (CTC-NS6), reaches included with nonstructural measures include CTC3, CTC4, and CTC7. In Big Ditch, the only reach included in BD-NS1 is BD3. Along the mainstem Neuse River, reaches included in Alternative 2 (MS-NS2) include MS5 and MS6.

5.2.2. Alternative 3

Alternative 3 is a buyout/acquisition plan that includes buying out 164 structures in certain polygon areas in the following reaches: MS3, MS5, and HS1-HS7. Structures included in these polygon areas are limited to those damaged by the 10 percent AEP event. A summary is provided in Table 31.

Table 31. Alternative 3 Measure Summary

Buyout Polygon Area	Reach	Structure Count 0.10 AEP Event
Kinston NS-1	MS3	61
Goldsboro NS-4	MS5, BD1, BD2	67
Wilson NS-1	HS1-HS7	36
Total		**164**

To formulate this alternative, polygon areas were drawn throughout the Neuse River Basin that were in the 0.2 percent AEP floodplain and contained significant clusters of structures that appeared to be incurring damages. Then, HAZUS damages were used to calculate preliminary EAD and eliminate areas that did not incur sufficient damages to cover partial costs (demolition cost estimates were used). The remaining areas included three polygons located in Kinston (Mainstem), Goldsboro (Mainstem), and Wilson (Hominy Swamp Creek). Additionally, HAZUS damages were used to calculate preliminary aggregate EAD for each census tract in the basin. Damage estimates for census tracts were compared to partial costs (demolition costs were used) across 188 census tracts. Only one census tract, in Seven Springs, had damages that were higher than demolition costs. This tract was added to the buyout polygon areas but was later removed due to state buyouts in this area.

Once damages were modeled in HEC-FDA, damages for the identified areas for the 10 percent AEP and 1 percent AEP flood events were evaluated with full costs for buyout and acquisition. Structures damaged by the 10 percent AEP event in these areas were kept in the final array as this maximized net NED benefits.

Buyout and acquisition costs consist of buying the structure and the associated land. The building is either demolished or is sold to others and relocated to a location external to the floodplain. Land acquisition can be in the form of fee title or permanent easement with fee title. After acquisition, the land must be maintained as open space through deed restriction that prohibits any type of development that can sustain flood damages or restrict flood flows. Land acquired as part of a nonstructural project can be converted to a new use such as ecosystem restoration and/or recreation that is consistent with open space restrictions, such as trails, shoreline access, and interpretive markers. Homeowners are relocated to comparable housing, outside of the flood extent.

5.2.3. Screened Structural Measures

Structural measures were screened in three of the separable areas due to lack of economic viability (negative net NED benefits and a benefit-cost ratio below 0.3) and/or environmental feasibility. These are detailed below.

5.2.3.1. Hominy Swamp Creek

Channel modifications were considered along Hominy Swamp Creek by widening the channel using a series of excavated bench cuts. The eleven excavated channel benches along 3.2 miles of the stream would function as floodplains that created a natural alluvial channel process. Later the number of bench cuts was reduced to nine due to environmental considerations and utility locations. Ultimately, the measure was screened with a BCR of 0.29 and net NED benefits that were negative $700,000. This measure is modeled as Hominy Alternative 1 in the HEC-FDA and LifeSim models.

5.2.3.2. Crabtree Creek

Channel modifications were considered along Crabtree Creek by widening the channel. The highly urbanized Crabtree Creek corridor constrained the magnitude of channel templates that could be applied without negatively impacting nearby structures; channel bench segments were separated by bridge structures that crossed over the main channel of Crabtree Creek. For more detail on hydraulic conditions of this measure, refer to the Appendix A, H&H Engineering. The FWOP and FWP conditions for three versions of the channel widening were modeled in HEC-RAS and HEC-FDA. Minimal reductions in water surface elevations were evident for the more frequent events and were limited for the larger flood events. Additionally, the floodplain of this stream is narrow and doesn’t have a wide overbank extent, limiting the initial without-project damages. For Alternative 4 in the Crabtree Creek model, net NED benefits were negative $2.6 million and the BCR was 0.13. Crabtree Creek Alternative 4 was also modeled in LifeSim, and results are presented in Section 6.

5.2.3.3. Mainstem Neuse River

Along the mainstem Neuse River, channel modifications along approximately eleven miles of the river that included bench cuts in the vicinity of Kinston were considered. The large footprint of this measure caused concern for environmental feasibility, and there would be significant operations and maintenance required for this measure. The future without and future with project conditions were modeled in HEC-RAS and HEC-FDA. While the measure was effective at reducing water surface elevations for more frequent events, it was unable to provide significant reductions in flood elevations for more severe events. A preliminary TPCS was obtained from cost engineering, and the BCR was 0.07 with net benefits of negative $6 million. This measure is modeled as Mainstem Alternative 1 in the HEC-FDA and LifeSim models.

5.3. With-Project Annual Benefit Summaries

This section displays the with-project benefits for the final array of alternatives. With-project benefits for both Alternatives 2 and Alternative 3 assume 100 percent participation. A sensitivity analysis will be conducted to evaluate participation rates prior to the ADM. Note that with-project benefits were aggregated by structure outside of HEC-FDA, in order to capture the benefit from floodproofing/elevating or buying out the structure. Therefore, benefits aren’t aggregated by damage category, as they normally are when modeling structural alternatives in HEC-FDA.

5.3.1. Alternative 2

Benefits are displayed for the reaches that are included in the final array. Other AEP events are shown for comparison only. As previously mentioned, all combinations of reaches and the four

AEP events shown were analyzed and the reach and AEP event combination that maximized net benefits was selected for inclusion in the final array.

In Hominy Swamp Creek, the 0.10 AEP event maximized net benefits and is included in the final array. Total average annual benefits for Hominy Swamp Creek are approximately $458,000.

Table 32. Hominy Swamp Creek Average Annual Benefits

Reach	0.10 AEP	0.04 AEP	0.02 AEP	0.01 AEP
HS1	113	113	114	114
HS2	0	0	0	0
HS3	238	242	248	249
HS4	0	0	0	0
HS5	81	88	89	93
HS6	27	31	47	49
HS7	0	0	0	0
HS8	0	0	0	0
Total	**458**	**473**	**498**	**505**

Note: values in $000s; FY22 price level

Total average annual benefits in Crabtree Creek for the 0.02 AEP event are $428,000. Average annual benefits for the 0.01 AEP are only $7,000 higher than the 0.02 AEP, while costs are significantly higher. The additional benefit from choosing the 0.01 AEP event doesn't outweigh the additional cost for including more structures.

Table 33. Crabtree Creek Average Annual Benefits

Reach	0.10 AEP	0.04 AEP	0.02 AEP	0.01 AEP
CTC1	0	0	0	0
CTC2	0	0	0	0
CTC3	42	42	42	42
CTC4	149	205	376	395
CTC5	0	0	0	0
CTC6	0	0	0	0
CTC7	10	10	10	10
Total	**201**	**257**	**428**	**448**

Note: values in $000s; FY22 price level

Table 33 displays average annual benefits for Big Ditch. Structures in Reach BD3 are included up to the 0.01 AEP event. As noted, there is little change in benefits between the 0.10 and 0.01 AEP events.

Table 34. Big Ditch Average Annual Benefits

Reach	0.10 AEP	0.04 AEP	0.02 AEP	0.01 AEP
BD1	0	0	0	0
BD2	0	0	0	0
BD3	1,007	1,007	1,008	1,008

BD4	0	0	0	0
BD5	0	0	0	0
Total	**1,007**	**1,007**	**1,008**	**1,008**

Note: values in $000s; FY22 price level

Total average annual benefits for the Mainstem Reaches 5 and 6 for the 0.02 AEP event are approximately $5.2 million. Similar to Crabtree Creek, the additional benefits of including structures in the 0.01 AEP event don't outweigh the additional costs.

Table 35. Mainstem Neuse River Average Annual Benefits

Reach	0.10 AEP	0.04 AEP	0.02 AEP	0.01 AEP
MS1	0	0	0	0
MS2	0	0	0	0
MS3	0	0	0	0
MS4	0	0	0	0
MS5	2,418	3,660	5,266	5,639
MS6	65	79	87	92
MS7	0	0	0	0
MS8	0	0	0	0
Total	**2,483**	**3,739**	**5,353**	**5,732**

Note: values in $000s; FY22 price level

Total average annual benefits for Alternative 2 are approximately $7 million.

Table 36. Alternative 2 Total Average Annual Benefits

Area	Average Annual Benefits
Hominy Swamp Creek	458
Crabtree Creek	428
Big Ditch	1,008
Mainstem	5,353
Total	7,248

Note: values in $000s; FY22 price level

5.3.2. Alternative 3

The table below displays total average annual benefits for the buyout and acquisition alternative. Potential buyout areas were delineated prior to HEC-RAS/FDA models being completed, and therefore cover multiple modeling reaches. Associated reaches for the buyout areas are displayed below.

Table 37. Alternative 3 Average Annual Benefits

Area	Average Annual Benefits	Reaches
Hominy Swamp Creek (HS-NS4)	504	HS1-HS7
Big Ditch (BD-NS2)	9	BD1, BD2
Mainstem (MS-NS3)	3,180	MS3, MS5
Total	**3,693**	

Note: values in $000s; FY22 price level

Total average annual benefits for Alternative 3 are approximately $3.7 million. These benefits include the damages reduced by removing the structures in the buyout areas indicated.

5.4. With-Project Residual Damages

This section displays with-project residual damages for Alternatives 2 and 3. Residual damages are the damages that still occur with the alternative plan in place and is the difference between without-project damages and with-project benefits. Table 37 shows residual expected annual damages for Alternatives 2 and 3.

Table 38. Residual Expected Annual Damages

Area	Alternative 2 Residual Damages	Alternative 3 Residual Damages
Hominy Swamp Creek	550	505
Crabtree Creek	581	1,009
Big Ditch	2,077	3,077
Mainstem	33,017	35,000
Total	36,225	39,591

Note: values in $000s; FY22 price level

Residual damages for Alternative 3 are significantly higher than for Alternative 2. As noted above, Alternative 2 decreases damages for approximately 768 structures, while Alternative 3 decreases damages for just 164 structures. Total residual damages for Alternative 2 are approximately $36 million, while they are nearly $40 million for Alternative 3.

5.5. Range of Benefits

Will compute after optimization/sensitivity analysis prior to ADM.

5.6. Costs

Costs were prepared by cost engineering for each of the screened structural alternatives as detailed in Section 5.2.3. As previously stated, costs for structural alternatives far outweighed the benefits in all the separable areas and structural alternatives were not included in the final array.

Costs for nonstructural elevations and floodproofing were developed by Omaha District Cost Engineering and reviewed by Wilmington District Cost Engineering. A TPCS was prepared by Wilmington District Cost Engineering after a preliminary screening of nonstructural measures was complete. Costs include real estate administration costs, contingency, and interest during construction (IDC). IDC for nonstructural elevations and floodproofing was computed for a three-month period at the current discount rate of 2.25 percent.

Costs for buyouts and acquisitions were prepared by Real Estate and Cost Engineering and include demolition costs, and the market value cost of the structure and land. Contingency and IDC were also included.

All costs are in FY22 price levels and reflect a project life cycle of 50 years at a discount rate of 2.25 percent. Total project first costs for Alternative 2 are approximately $133 million, and average annual costs are $4.5 million. Total project costs for Alternative 3 are approximately $46 million, and average annual costs are roughly $1.5 million.

Table 39. Costs by Alternative

	Alternative 2 Nonstructural Elevations/Floodproofing	Alternative 3 Buyouts/Acquisitions
Construction Cost		
Hominy Swamp Creek	3,629	7,770
Crabtree Creek	8,149	
Big Ditch	769	7,437
Mainstem Neuse River	79,418	30,578
Subtotal Project Firsts Costs	91,966	45,785
Contingency[1]	22,991	
Planning, Engineering, and Design	7,275	
Construction Management	10,500	
Total Project First Costs	132,732	45,785
Interest During Construction	246	127
Total Gross Investment	132,979	45,912
Average Annual Cost	**4,457**	**1,539**

Notes: values in $000s; FY22 price level; FY22 discount rate of 2.25%; 50-year period of analysis

[1] Contingency is included in the construction cost for Alternative 3

5.7. Benefit-Cost Analysis

Economic costs and benefits resulting from a project are evaluated in terms of their impacts on national wealth, without regard to where in the United States the impacts may occur. National Economic Development (NED) benefits must result directly from a project and must represent net increases in the economic value of goods and services to the national economy, not simply to a locality.

NED benefits, the benefit-cost ratio, and the net NED benefits are calculated during the evaluation process. Net benefits represent the amount by which the NED benefits exceed costs, thereby defining the plan’s contribution to the economic output of the nation. The benefit-cost ratio informs the likely economic feasibility of a project. A project is considered feasible if it has positive net benefits and a BCR of 1.0 or greater. Average annual costs and benefits, annual net benefits, and the BCR are presented in following sections for the final array of alternatives.

Table 40 shows that Alternative 2 results in net NED benefits of $2.8 million, while Alternative 3 results in net NED benefits of $2.2 million. Alternative 2 is therefore the plan that maximizes net NED benefits, also known as the NED plan. The majority of these benefits come from measures along the Mainstem, where there are a larger number of impacted structures. Alternative 2 decreases damages for a larger number of structures at a significantly lower cost per structure, which is why annual benefits for this alternative are higher.

Table 40. Net Benefit Comparison

Category	Alternative 2	Alternative 3
Annual Benefits	7,248	3,693
Hominy Swamp Creek	457	504
Crabtree Creek	429	
Big Ditch	1,008	9
Mainstem Neuse River	5,354	3,180
Annual Costs	4,457	1,539
Net Annual Benefits	**2,791**	**2,155**

Notes: values in $000s; FY22 price level; FY22 discount rate of 2.25%; 50-year period of analysis

Table 41 displays average annual costs and benefits and the benefit-cost ratio (BCR). The BCR is 1.63 for Alternative 2 at the current discount rate of 2.25 percent and is 2.4 for Alternative 3 at the same discount rate.

Table 41. Benefit Cost Analysis

	Alternative 2	Alternative 3
Annual Cost	4,457	1,539
Annual Benefits	7,248	3,693
Net Annual Benefits	2,791	2,155
Benefit to Cost Ratio	1.63	2.40

Notes: values in $000s; FY22 price level; FY22 discount rate of 2.25%; 50-year period of analysis

5.7.1. Benefit and Cost Distributions

Will include when sensitivity analysis/range of benefits is completed with H&H updates prior to ADM.

6.0. OTHER SOCIAL EFFECTS

Other Social Effects (OSE) are one of the four primary accounts listed in Appendix D of ER 1105-2-101. In addition, per *Policy Directive – Comprehensive Documentation of Benefits in Decision Document* issued 5 January 2021, flood risk management studies must include a life safety study objective and the decision document should describe Other Social Effects.

6.1. Life Safety

In accordance with ER 1105-2-101, life loss qualifies as an OSE (Other Social Effects) category. A life safety analysis includes the estimation of the population at risk and associated statistical parameters for life loss. For this analysis, life loss was calculated using LifeSim 2.0 for the future without project (FWOP) condition and future with project (FWP) condition for structural measures only in four separable areas: Hominy Swamp Creek, Crabtree Creek, Big Ditch, and mainstem Neuse River. This software uses Monte Carlo simulation to estimate the number of individuals at risk of life loss by probabilistic event for nighttime and daytime populations. Life loss was calculated for each frequency event used in the HEC-FDA model.

The results of the FWOP and FWP conditions were compared to estimate residual life loss after the project is implemented, and to assess life safety risk during flood events at various flood frequencies. The inclusion of structural measures could transform risk or transfer risk to other areas within the basin. The LifeSim results across each of the flood frequency events captures how the construction of various structural measures would alter life safety risk within the basin. Inputs, assumptions, modeling results, and average annual life loss calculations are detailed in subsequent sections. The numbering of alternatives in the Life Safety section follows the structural alternative numbering in the FDA and RAS models and is summarized in the following table.

Table 42. LifeSim Structural Alternatives Modeled

Separable Area	Structural Alternatives Modeled	
Hominy Swamp Creek	FWOP	Hominy Swamp Alternative 1
Crabtree Creek	FWOP	Crabtree Creek Alternative 4
Big Ditch	FWOP	N/A
Mainstem Neuse River	FWOP	Neuse Mainstem Alternative 1

6.1.1. Data Sources and Input Parameters

Each of the four LifeSim models utilize the same structure inventory inputs and uncertainty parameters in LifeSim. The details of the data sources and inputs are discussed below.

6.1.1.1. Structure Inventory

Structure inventories for each of the four models were developed from the USACE National Structure Inventory (NSI) 2.0 from 2019. The inventories are developed using building footprints, parcel data, FEMA Hazards US (HAZUS) data, and census data, among other sources. The inventories were calibrated in high-risk areas using aerial imagery and available flood inundation data. Population estimates per structure are based primarily on the 2010 Census data and then indexed using 2017 county growth estimates.

Structure placement and structures attributes in the LifeSim models will not exactly match the structure placement and structures attributes used in the HEC-FDA modeling. The number of structures inundated by event and by alternative will vary between the HEC-FDA models and the LifeSim models. NSI 2.0 was utilized due to the quality of the population data, which is one of the key elements of the life safety analysis.

6.1.1.2. LifeSim Uncertainty Parameters

LifeSim follows a timeline of events beginning with the identification of the hazard (e.g., overbank flow starts) and ending with the public taking protective action (also known as mobilization). The warning and response timeline in LifeSim follows events that would occur during a flooding emergency. The timeline is shown below in Figure 17; the real-world actions are shown in blue, and the corresponding LifeSim model parameters are shown below in white.

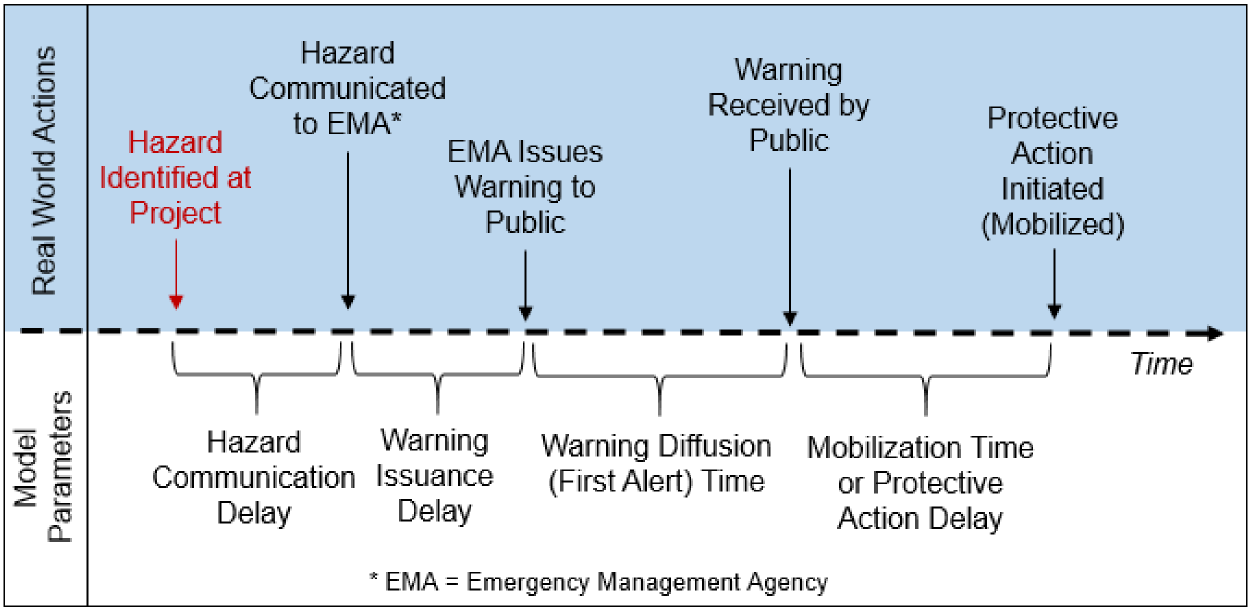

Figure 17. LifeSim Warning and Response Timeline

The definitions of the LifeSim uncertainty parameters are below:

- Imminent Hazard Identification Time: The time at which a potential hazard is about to occur or is actively occurring and local emergency officials should be alerted so they can begin the warning and evacuation process. This parameter is often referred to as the warning time.
- Hazard Communication Delay: The time it takes to contact local emergency officials to alert them of the hazard.
- Warning Issuance Delay: The time it takes the local emergency officials to issue a warning/evacuation order, which includes the time it takes to craft a warning message and/or get approval from other authorities to send out the warning message to the public.
- Warning Diffusion Time: The time it takes to disseminate a public to the warning using various communication channels (e.g., reverse 911, route alerting, social media).
- Protective Action Initiation Delay: The time it takes the public to evacuate once they have received a warning.

The Imminent Hazard Identification Time (i.e., warning time) is set to a uniform distribution of -24 to 0 hours relative to when overbank flow begins. This warning time captures the majority of the warning scenarios the Mapping, Modeling and Consequences Mandatory Center of Expertise (MMC-MCX) uses for dam and levee safety analyses and estimates potential life loss across a wide range of warning times. MMC-MCX levee analyses include a minimal warning scenario with an Imminent Hazard Identification Time upper bound of 30 minutes after the start of the hazard. This was not deemed necessary due to the wide range of uncertainty captured in the other timing parameters in LifeSim. Additionally, the team determined it is unlikely that the potential hazard would not be identified until after overbank flow started. The Hazard Communication Delay was set to a uniform distribution of 0.1 to 0.5 hours, which is the standard time used by the MMC-MCX for all consequence modeling.

The uncertainty parameters in LifeSim, including Warning Issuance Delay, the Warning Diffusion curves, and the Protective Action Initiation (PAI) curve, utilize the preset Unknown curves. This LifeSim modeling method follows the MMC-MCX FY22 Standard Operating Procedures for consequence modeling. These curves allow for significant uncertainty regarding how quickly a warning would be disseminated to the public and what percentage of the public would take protective action. More detailed information regarding the preparedness and risk perception could be retrieved by conducting an elicitation with local emergency managers, but this information is unlikely to change the recommended plan. Due to the significant amount of uncertainty included in the LifeSim model, 5,000 Monte Carlo iterations were simulated. The uncertainty parameter curves used in all four LifeSim models are displayed in Figure 18-Figure 20 below.

More detailed information regarding the preparedness and risk perception could be retrieved by conducting an expert opinion elicitation with local emergency managers, but this information is unlikely to change the recommended plan. As detailed in the subsequent sections, there is overall low life loss while utilizing high amounts of uncertainty in the LifeSim model. An expert opinion elicitation would most likely further reduce life loss due to smaller uncertainty ranges in each of the parameters shown in the timeline above (Figure 17). Additionally, an elicitation typically results in more optimistic mobilization rates, which is the driver for life loss in the Neuse River Basin.

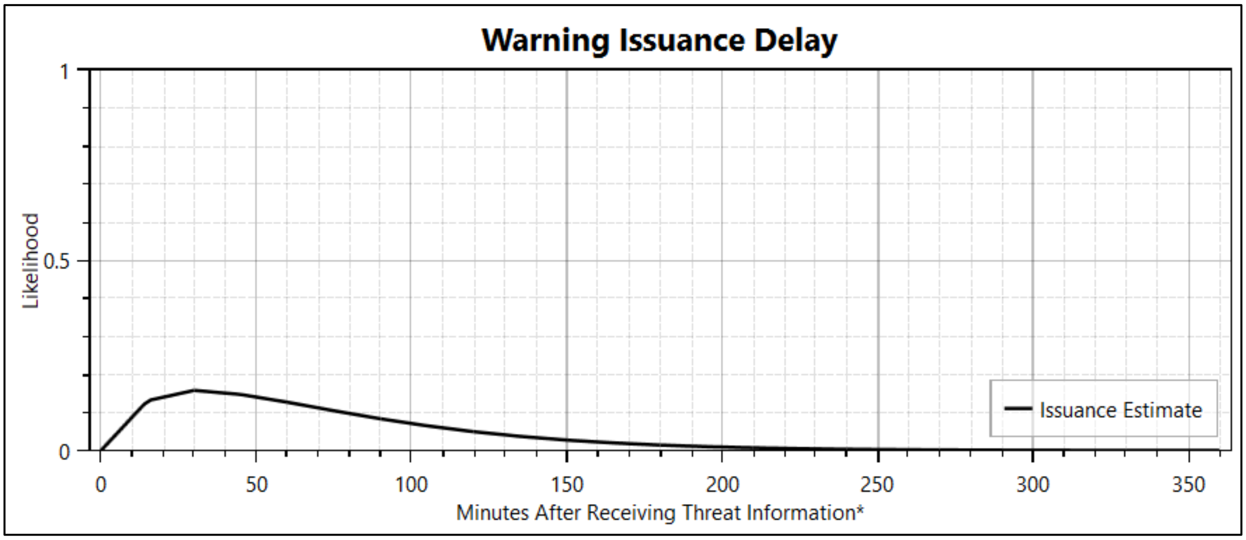

Figure 18. Unknown Warning Issuance Delay Curve

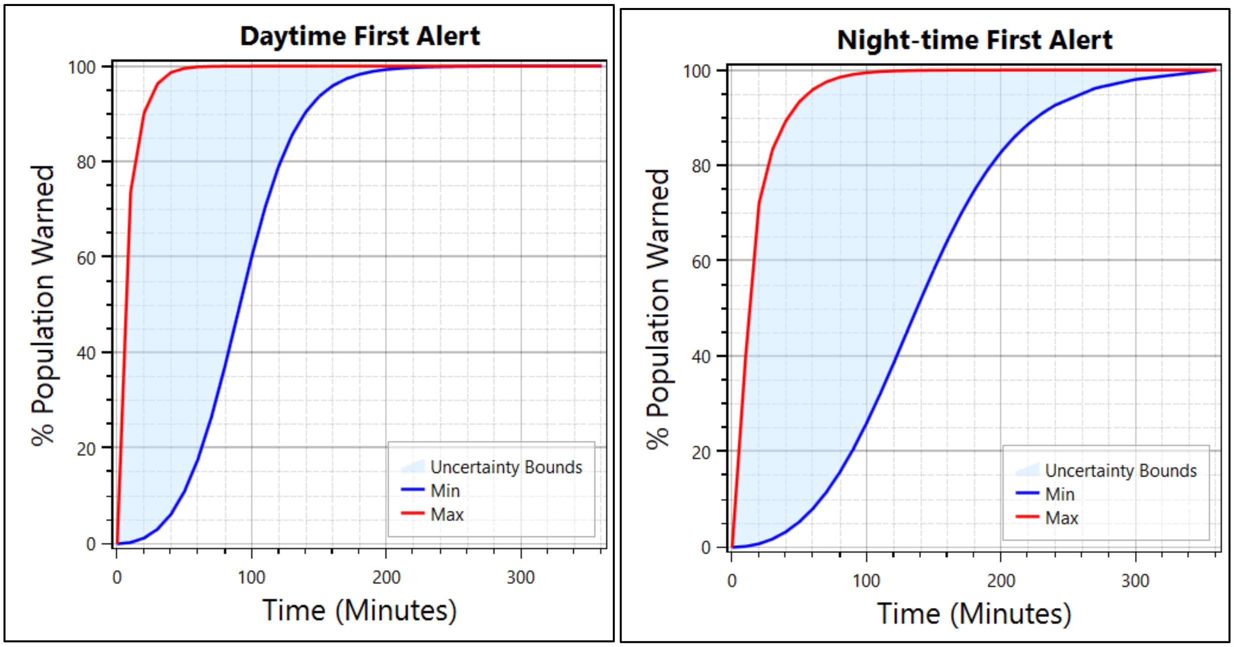

Figure 19. Unknown Warning Diffusion Curve

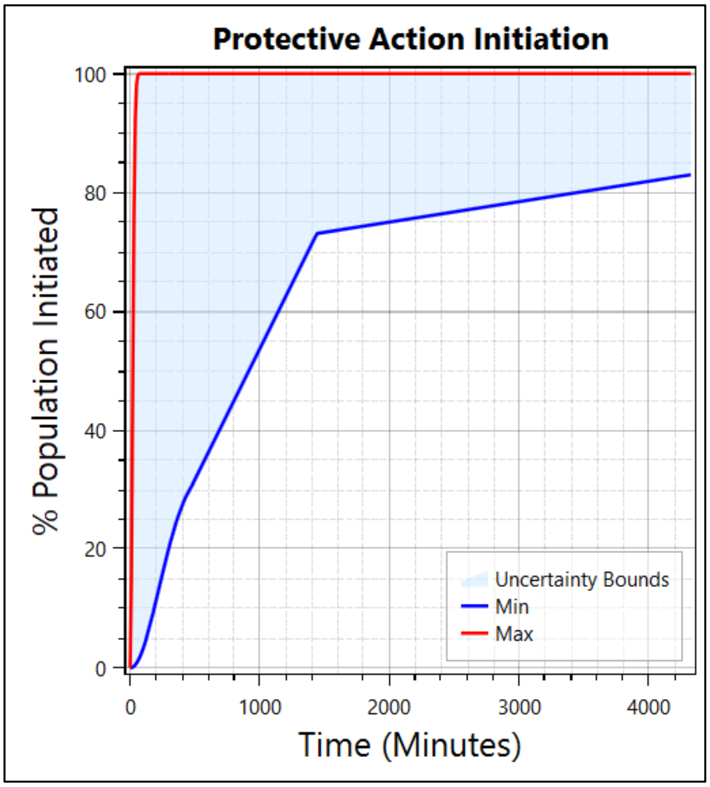

Figure 20. Unknown / Perception: Unknown Warning PAI Curve

6.1.2. Hominy Swamp Creek Life Safety Risk

The Hominy Swamp Creek LifeSim model includes the FWOP hydraulic conditions and FWP hydraulic conditions for Hominy Swamp Alternative 1, which includes a series of benchcuts. The RAS modeling for this area of the Neuse River Basin utilized unsteady flow, allowing for depths, velocities, and arrival times to be generated and imported into LifeSim. The modeling extent is approximately 10 miles, spanning the length of the city of Wilson, NC. Detailed below are the number of structures inundated, Population at Risk (PAR), average loss of life (LOL), average depth on structures, and average velocity on structures.

6.1.2.1. Hominy Swamp Creek FWOP Life Safety Risk

Table 43 below shows the FWOP life safety results for Hominy Swamp Creek. As shown in the table, each event inundates several structures, but the depths and velocities are not significant enough to cause fatalities until the 0.02 AEP. The least frequent event results in significantly higher flood depths (3.5 feet), which causes daytime and nighttime average life loss to increase to 2.3 and 2.7, respectively. Overall, the life safety risk in this area is not significant for the majority of the hydraulic events (i.e., life loss is within the 0.1 to 1 or 0.3 to 3 order of magnitude). The relatively low average life loss is driven by low velocities, low depths, and the relatively small PAR impacted by each event.

Table 43. Hominy Swamp Creek FWOP Life Safety Risk by AEP

Hydraulic Scenario	Structures Inundated	PAR Day	PAR Night	LOL Day	LOL Night	Average Depth (ft)	Average Velocity (ft/s)
0.002 AEP	267	371	375	2.3	2.7	3.5	0.4
0.005 AEP	201	284	285	1.2	1.5	2.9	0.4
0.01 AEP	156	225	227	0.3	0.3	2.4	0.4
0.02 AEP	117	170	171	0.1	0	2.0	0.3
0.04 AEP	69	113	114	0	0	1.9	0.3
0.1 AEP	35	69	70	0	0	1.4	0.2
0.2 AEP	17	12	12	0	0	1.2	0.2
0.5 AEP	3	1	1	0	0	1.0	0.2

Figure 21 below shows the average nighttime life loss for the FWOP 0.002 AEP event. The heat map indicates if life loss was sampled during any of the 5,000 iterations. Green portions of the heat map indicate life loss occurred in that area for a few iterations. Yellow, orange, or red portions of the heat map indicate life loss occurred in that area for several iterations. As shown in the figure, all the sampled life loss is within the city center of Wilson, NC.

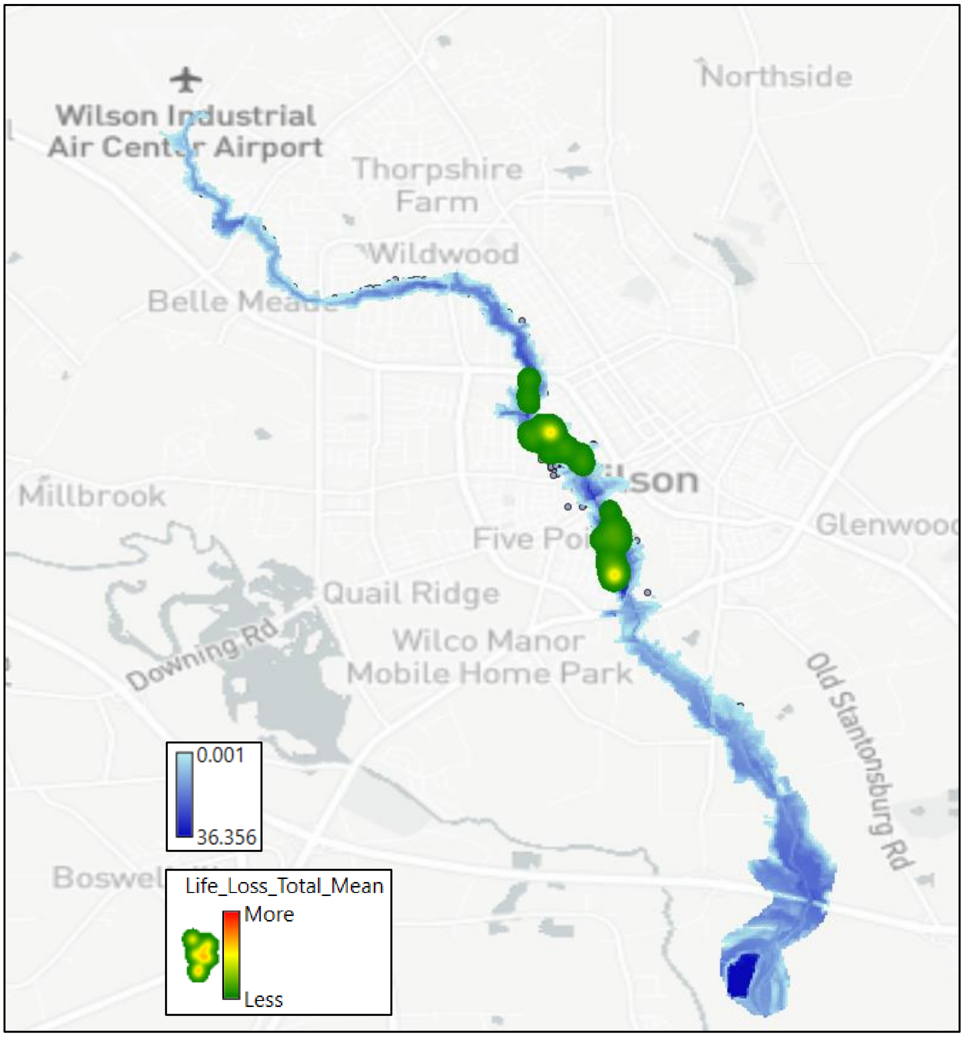

Figure 21. Hominy Swamp Creek FWOP 0.002 AEP Average Night Life Loss Heat Map

6.1.2.2. Hominy Swamp Creek Structural Alternative 1 Life Safety Risk

Table 44 below shows life safety results for Hominy Swamp Creek Structural Alternative 1. Average life loss decreases for the less frequent events, including 0.02 AEP, 0.01 AEP, 0.005 AEP, and 0.002 AEP. This structural alternative inundates less structures, which decreases the PAR. Additionally, depths and velocities decrease when compared to the FWOP. For the 0.002 AEP event, the FWOP's average depths are 3.5 feet with average velocities of 0.4 ft/s; Alternative 1's average depths are 3.2 feet with average velocities of 0.3 ft/s. All scenarios result in either no life loss or relatively low life loss (i.e., within the 0.1 to 1 order of magnitude).

Table 44. Hominy Swamp Creek Alternative 1 Life Safety Risk by AEP

Hydraulic Scenario	Structures Inundated	PAR Day	PAR Night	LOL Day	LOL Night	Average Depth (ft)	Average Velocity (ft/s)
0.002 AEP	247	311	312	0.8	0.8	3.2	0.3
0.005 AEP	175	222	222	0.3	0.3	2.6	0.3
0.01 AEP	121	139	140	0.2	0.1	2.2	0.3
0.02 AEP	79	80	80	0	0	1.9	0.2
0.04 AEP	44	51	52	0	0	1.8	0.3
0.1 AEP	21	16	16	0	0	1.2	0.3
0.2 AEP	7	3	3	0	0	0.9	0.3
0.5 AEP	1	0	0	0	0	0.5	0.7

Figure 22 below shows the average nighttime life loss for Hominy Swamp Creek Structural Alternative 1 0.002 AEP event. The heat map indicates if life loss was sampled within these areas during any of the 5,000 iterations. Green portions of the heat map indicate life loss occurred in that area for a few iterations. Yellow, orange, or red portions of the heat map show life loss occurred in that area for several iterations. As shown in the figure, all of the sampled life loss is within the city center of Wilson, NC. The life loss is more concentrated in the southern portion of Wilson, NC compared to the FWOP.

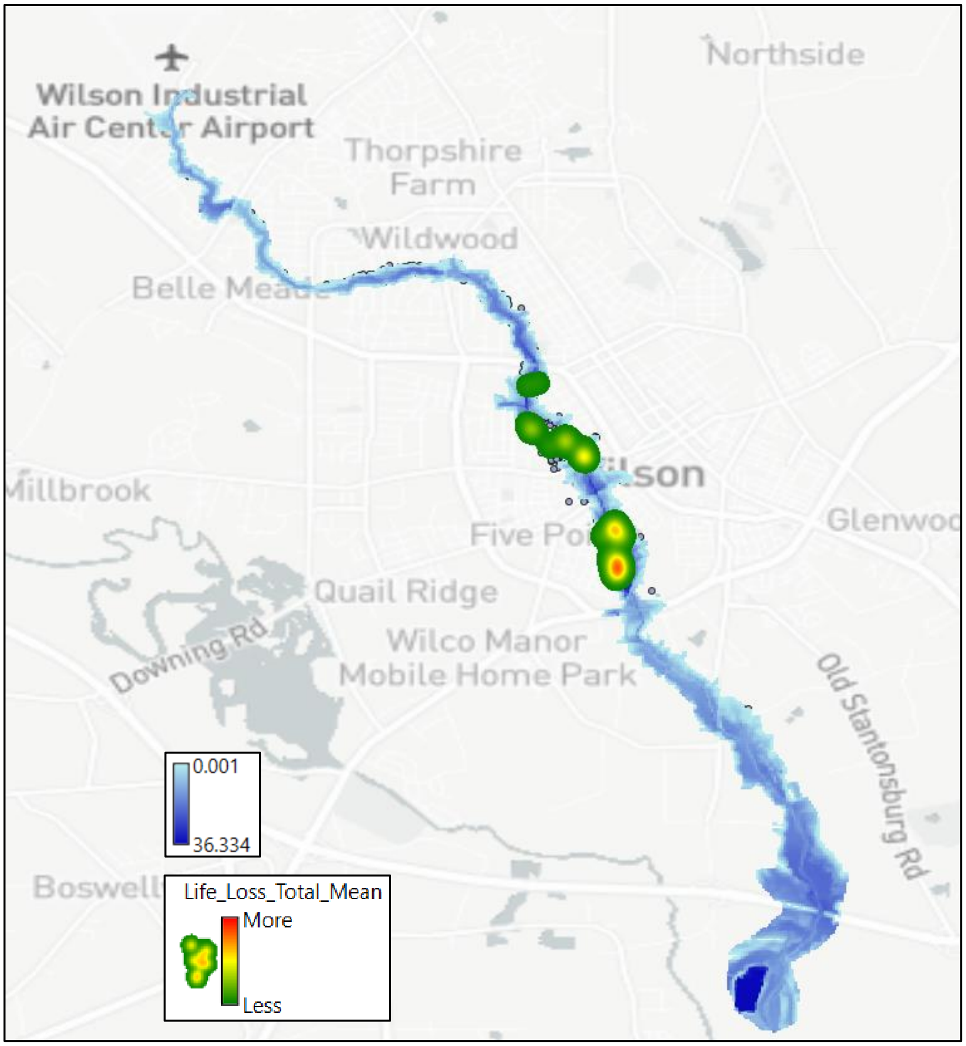

Figure 22. Hominy Swamp Creek Structural Alternative 1 0.002 AEP Average Night Life Loss Heat Map

6.1.2.3. Hominy Swamp Creek Average Annual Life Loss Estimates

Average Annual Life Loss (AALL) for each hydraulic scenario was estimated using a sum of the interval average life loss method for the full range of hydraulic events. Either the daytime or nighttime average life loss value was utilized, whichever value was higher (e.g., Hominy Creek's 0.002 AEP life loss is 2.7 and 2.3 for day and night, respectively; the nighttime life loss of 2.7 was used in the AALL calculation). The calculation for the FWOP is detailed in the table below. All AALL estimates for each modeled area utilized this method.

Table 45. Hominy Swamp Creek FWOP Average Annual Life Loss

Hydraulic Scenario	Probability Interval[1]	Average Life Loss[2]	Interval Average Life Loss[3]	Interval Life Loss Calculation[4]	Summary Expected Life Loss[5]
0.5 AEP		0			
	0.300		0	0	0
0.2 AEP		0			
	0.100		0	0	0
0.1 AEP		0			
	0.060		0.005	0.0003	0.0003
0.04 AEP		0.01			
	0.020		0.04	0.0008	0.0011
0.02 AEP		0.07			
	0.010		0.18	0.0018	0.0029
0.01 AEP		0.29			
	0.005		0.88	0.0044	0.0073
0.005 AEP		1.47			
	0.003		2.075	0.0062	**0.0135**
0.002 AEP		2.68			

[1] Interval probability computed as difference of probabilities between two events
[2] Average life loss by event
[3] Average life loss for the interval
[4] Probability interval*Interval Average Life Loss
[5] Cumulative sum of column F (final sum is the average annual life loss)

The AALL calculation is similar to how HEC-FDA calculates expected annual damages, but the AALL calculation does not include uncertainty. The AALL estimates could be further refined if additional life loss result statistics were utilized in the calculation (e.g., standard deviation, maximum, and minimum). However, the simplified AALL estimates clearly demonstrates if life safety risk is reduced following the implementation of structural measures. The FWOP's AALL is 0.013 lives/year, which is relatively low (i.e., within the order of magnitude of 0.1 to 1 life loss). Alternative 2 reduces the most AALL for Hominy Creek and Alternative 1 reduces a similar amount of AALL.

Table 46. Hominy Swamp Creek Average Annual Life Loss Reduction

Scenario	Average Annual Life Loss	Average Annual Life Loss Reduction
FWOP	0.013	-
Alternative 1	0.005	0.008

6.1.3. Crabtree Creek Life Safety Risk

The Crabtree Creek LifeSim model includes the FWOP hydraulic conditions and FWP hydraulic conditions for Crabtree Creek Structural Alternative 4, which includes channel modifications. The RAS modeling for this area of the Neuse River Basin utilized unsteady flow, allowing for depths, velocities, and arrival times to be generated and imported into LifeSim. The modeling extent is approximately 15 miles and inundates northern Raleigh, NC.

6.1.3.1. Crabtree Creek FWOP Life Safety Risk

Table 47 shows the FWOP life safety results for Crabtree Creek. Detailed below are the number of structures inundated, PAR, average life loss, average depth on structures, and average velocity on structures. The PAR in this area is larger compared to Hominy Swamp Creek and Big Ditch due to the presence of schools, large commercial buildings, and apartment buildings. As shown in the table, the depths and velocities of floodwaters are significant enough to cause fatalities beginning at the 0.005 AEP event, however, average life loss is less than one for both day and night for this event. The 0.002 AEP event results in higher flood depths (4.4 feet), which causes daytime and nighttime average life loss to increase to 5.8 and 5.0, respectively. Overall, the life safety risk in this area is not significant (i.e., within the 0.1 to 1 life loss order of magnitude) for most of the hydraulic events. The average life loss in the 0.002 AEP event is driven by flood depths and the high PAR.

Table 47. Crabtree Creek FWOP Life Safety Risk by AEP

Hydraulic Scenario	Structures Inundated	PAR Day	PAR Night	LOL Day	LOL Night	Average Depth (ft)	Average Velocity (ft/s)
0.002 AEP	492	4,022	3,970	5.8	5.0	4.4	0.3
0.005 AEP	414	3,589	3,537	0.6	0.5	3.4	0.2
0.01 AEP	381	3,051	3,007	0	0	2.1	0.2
0.02 AEP	335	2,868	2,826	0	0	1.0	0.3
0.04 AEP	104	594	587	0	0	1.3	0.3
0.1 AEP	40	118	118	0	0	0.9	0.3
0.2 AEP	9	34	34	0	0	0.3	0.2
0.5 AEP	0	0	0	0	0	N/A	N/A

Figure 23 shows the average nighttime life loss for the 0.002 AEP event. The heat map indicates if life loss was sampled within these areas during any of the 5,000 iterations. Green portions of the heat map indicate life loss occurred in that area in only a few iterations. Yellow, orange, or red portions of the heat map show life loss occurred in that area in several iterations.

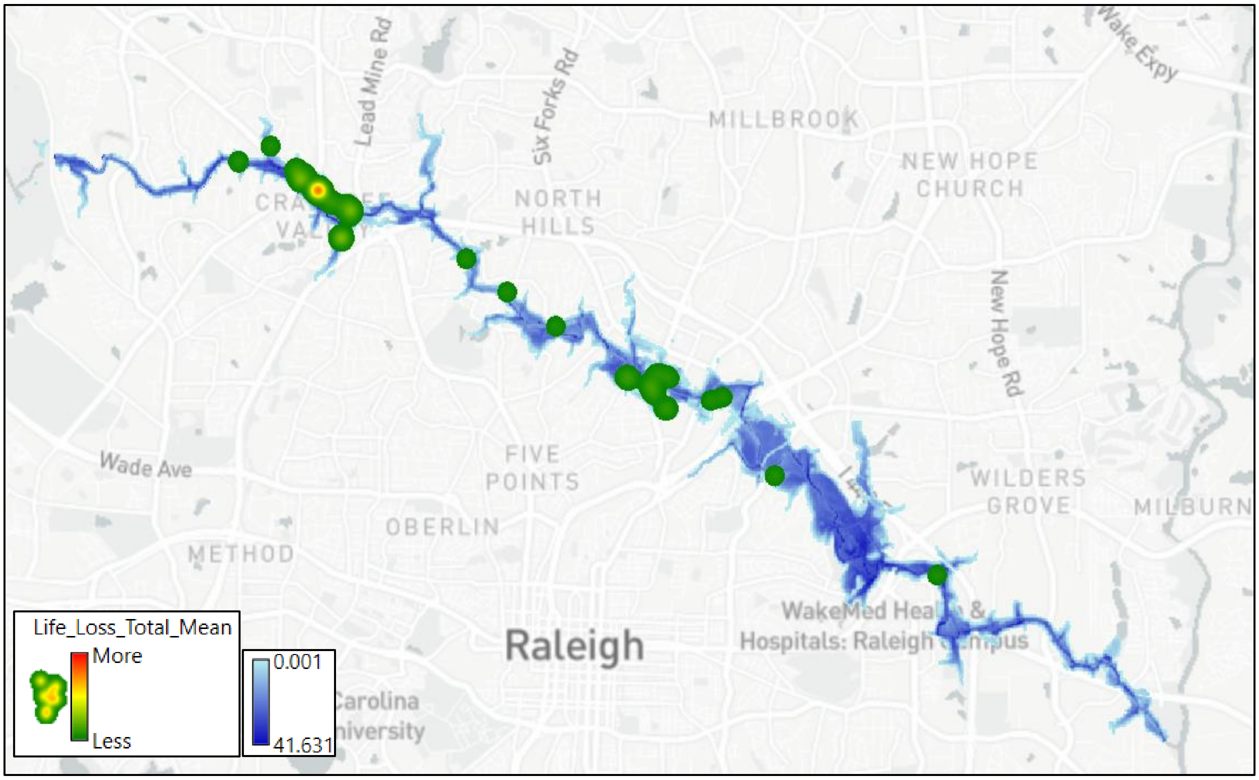

Figure 23. Crabtree Creek FWOP 0.002 AEP Average Night Life Loss Heat Map

6.1.3.2. Crabtree Creek Structural Alternative 4 Life Safety Risk

Table 48 shows Alternative 4's life safety results for Crabtree Creek. Compared to the FWOP, this alternative slightly increases daytime average life loss and slightly decreases nighttime average life loss. Alternative 4 inundates less structures and decreases the average flood depths on structures. The increase in average life loss is due to uncertainty sampling during the LifeSim simulations, specifically in the fatality rates. A few iterations sample a higher fatality rate in structures with large PAR, which inflates the average PAR. Alternative 4 may increase average life loss in Crabtree Creek for the less frequent events.

Table 48. Crabtree Creek Structural Alternative 4 Life Safety Risk by AEP

Hydraulic Scenario	Structures Inundated	PAR Day	PAR Night	LOL Day	LOL Night	Average Depth (ft)	Average Velocity (ft/s)
0.002 AEP	454	3,912	3,860	6.0	4.5	4.1	0.2
0.005 AEP	381	3,019	3,019	0.1	0.1	3.0	0.2
0.01 AEP	344	2,903	2,861	0	0	1.7	0.2
0.02 AEP	118	656	648	0	0	1.5	0.3
0.04 AEP	70	484	478	0	0	0.9	0.3
0.1 AEP	3	5	5	0	0	1.2	0.8
0.2 AEP	1	0	0	0	0	1.3	1.3
0.5 AEP	0	N/A	N/A	N/A	N/A	N/A	N/A

Figure 24 shows the average day life loss for the Structural Alternative 4 0.002 AEP event. The heat map indicates if life loss was sampled within these areas during any of the 5,000 iterations.

Green portions of the heat map indicate life loss occurred in that area for only a few iterations. Yellow, orange, or red portions of the heat map show life loss occurred in that area for several iterations. The life loss heat map demonstrates that Alternative 4's life safety risk is similar to the FWOP's life safety risk

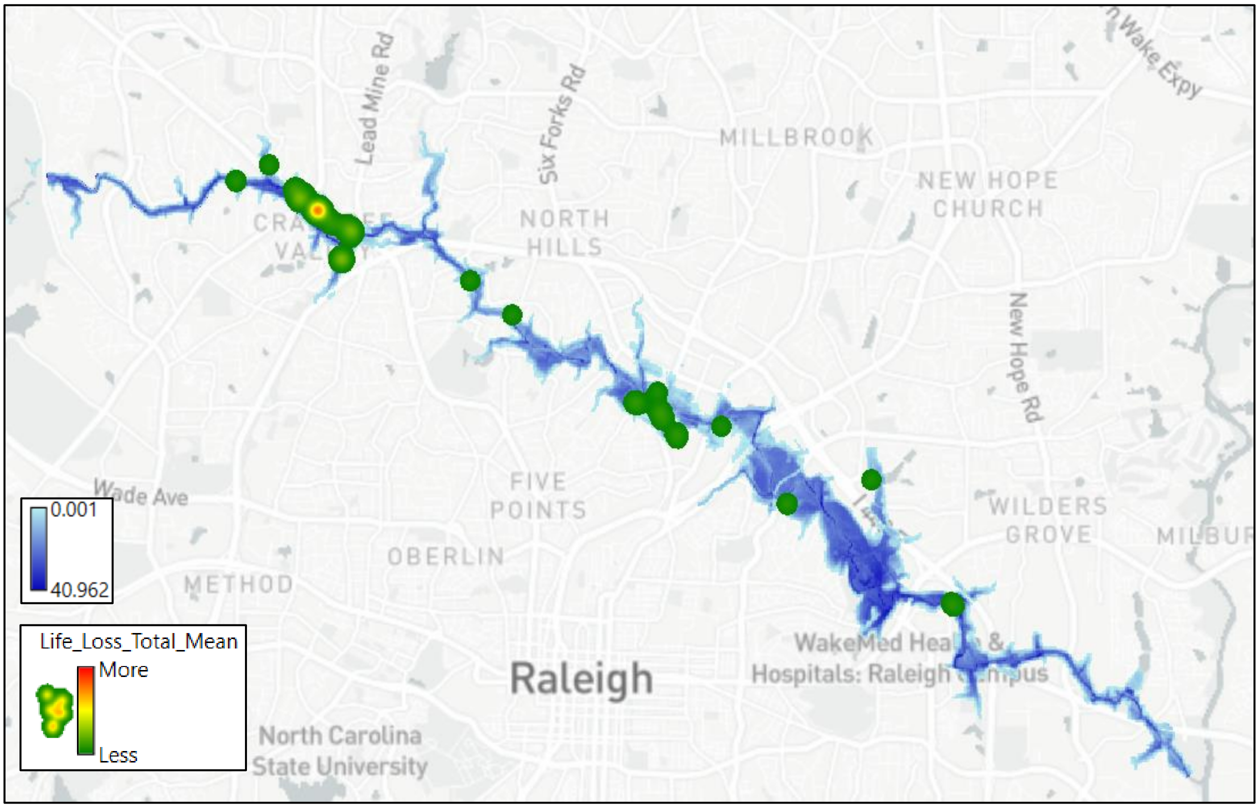

Figure 24. Crabtree Creek Structural Alternative 4 0.002 AEP Average Day Life Loss Heat Map

6.1.3.3. Crabtree Creek Average Annual Life Loss Estimates

Table 45 in the Hominy Creek Life Safety section details the AALL calculation method used to estimate AALL for Crabtree Creek. The AALL calculation is similar to how HEC-FDA calculates expected annual damages, but the AALL calculation does not include uncertainty. The AALL estimates could be further refined if additional life loss result statistics were utilized in the calculation (e.g., standard deviation, maximum, and minimum). However, the simplified AALL estimates clearly demonstrates if life safety risk is reduced following the implementation of structural measures. The FWOP's AALL is 0.012 lives/year, which is relatively low (i.e., within the order of magnitude of 0.1 to 1 life loss). None of the alternatives significantly reduce AALL; Alternative 4 reduces the most AALL, but the reduction is negligible.

Table 49. Crabtree Creek Average Annual Life Loss

Scenario	Average Annual Life Loss	Average Annual Life Loss Reduction
FWOP	0.012	-
Alternative 4	0.011	0.001

6.1.4. Big Ditch Life Safety Risk

The Big Ditch LifeSim model only includes the FWOP hydraulic conditions since no structural measures were considered within this area. The Big Ditch RAS modeling utilized unsteady flow, allowing for depths, velocities, and arrival times to be generated and imported into LifeSim. The modeling extent is less than 1 mile and primarily inundates the southern portion of the city of Goldsboro, NC.

6.1.4.1. Big Ditch FWOP Life Safety Risk

Table 50 shows the FWOP life safety results for Big Ditch. Detailed below are the number of structures inundated, PAR, average life loss, average depth on structures, and average velocity on structures. As shown in the table, each of the events inundate several structures, but the depths and velocities are not significant enough to cause fatalities, on average. The depths and velocities appear higher for the higher frequency events; the more frequent events (e.g., 0.5 AEP) inundate less structures, decreasing the sample size, and skewing the average depths and velocities.

Table 50. Big Ditch FWOP Life Safety Risk by AEP

Hydraulic Scenario	Structures Inundated	PAR Day	PAR Night	LOL Day	LOL Night	Average Depth (ft)	Average Velocity (ft/s)
0.002 AEP	387	616	614	0	0	1.1	0.1
0.005 AEP	335	543	540	0	0	1.1	0.3
0.01 AEP	291	504	501	0	0	1.0	0.3
0.02 AEP	247	433	431	0	0	0.9	0.3
0.04 AEP	172	315	314	0	0	0.9	0.3
0.1 AEP	138	267	266	0	0	1.0	0.3
0.2 AEP	59	75	74	0	0	1.1	0.3
0.5 AEP	32	26	26	0	0	1.2	0.6

Figure 25 displays the average life loss heat map for the FWOP 0.002 AEP event. Two of the 5,000 iterations resulted in life loss for this scenario. The average life loss shown below reflect the average life loss of 0.001 in two structures within the Big Ditch study area. Average life loss across all frequency events in Big Ditch is zero, which is primarily due to low flood depths and low velocities.

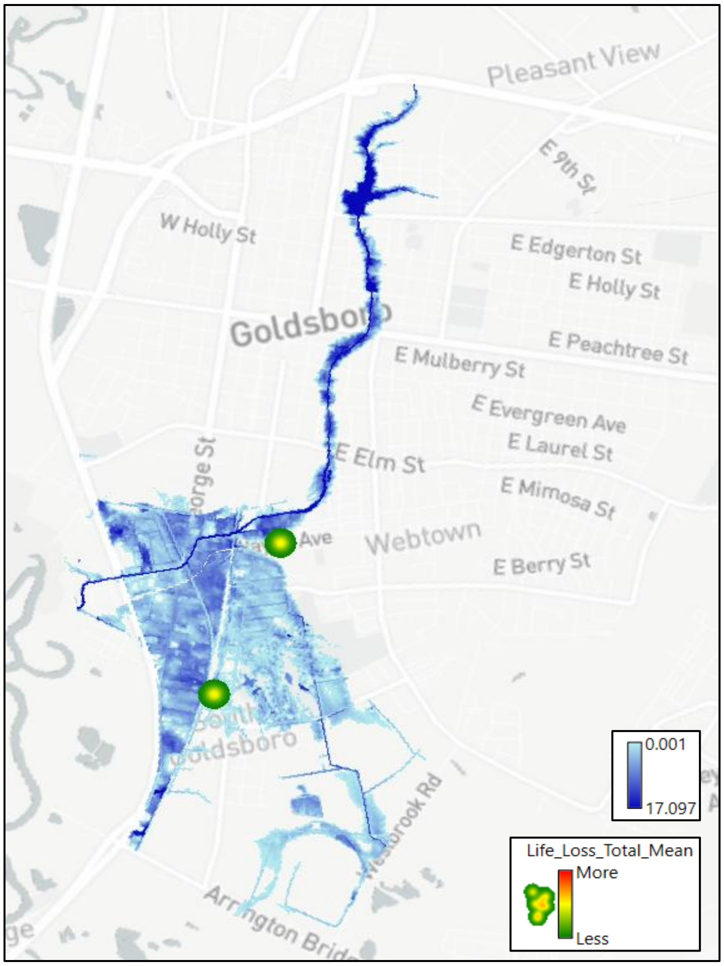

Figure 25. Big Ditch FWOP 0.002 AEP Average Night Life Loss Heat Map

6.1.4.2. Big Ditch Average Annual Life Loss Estimates

The AALL for Big Ditch is zero due to zero average life loss occurring across the range of hydraulic events.

Table 51. Big Ditch Average Annual Life Loss Estimate

Scenario	Average Annual Life Loss	Average Annual Life Loss Reduction
FWOP	0.000	N/A

6.1.5. Mainstem Neuse River Life Safety Risk

The mainstem Neuse River LifeSim model includes the FWOP hydraulic conditions and FWP hydraulic conditions for Neuse Mainstem Structural Alternative 1. The RAS modeling for the mainstem of the Neuse River Basin used steady flow due to model instabilities when attempting to use unsteady flow. Steady state RAS modeling does not produce arrival time grids or velocity grids--only maximum depth grids. To estimate life loss in LifeSim, an arrival time grid was created with a uniform arrival time of one hour across the entire basin. This allows LifeSim to estimate life loss based on maximum depths on structures and the uncertainty timing parameters.

This method of calculating life loss is more uncertain, but accurately shows the estimated change in life loss because the same uncertainties exist in the FWOP and FWP LifeSim results.

6.1.5.1. Future Without Project Life Safety Risk

Table 52 shows the FWOP life safety results for the mainstem Neuse River Mainstem. Detailed below are the number of structures inundated, PAR, average life loss, and average depth on structures. The number of structures inundated is significantly higher than the other three modeled areas due to the much larger inundation extents, which impacts several population centers. The average life loss is relatively high (i.e., within or above the life loss order of magnitude of 10 to 100) for the 0.01 AEP, 0.005 AEP, and 0.002 AEP events. The life loss is scattered throughout the basin and is driven by flood depths and the high amount of PAR.

Table 52. Neuse River FWOP Life Safety Risk by Event

Hydraulic Scenario	Structures Inundated	PAR Day	PAR Night	LOL Day	LOL Night	Average Depth (ft)
0.002 AEP	16,300	33,453	34,595	122.4	126.0	4.0
0.005 AEP	13,085	23,548	25,461	48.7	51.8	3.3
0.01 AEP	10,994	19,804	20,192	20.6	23.0	2.9
0.02 AEP	8,406	14,847	14,862	6.4	7.2	2.5
0.04 AEP	5,678	8,990	9,551	2.7	3.2	2.1
0.1 AEP	2,575	3,546	3,903	0.5	0.6	1.7
0.2 AEP	1,043	760	1,197	0.1	0.2	1.6
0.5 AEP	276	157	288	0.1	0.2	2.2

Figure 26 shows the average nighttime life loss for the FWOP 0.002 AEP event. The heat map indicates if life loss was sampled within these areas for any of the 5,000 iterations. Life loss is scattered throughout the basin with some higher life loss areas identified in red.

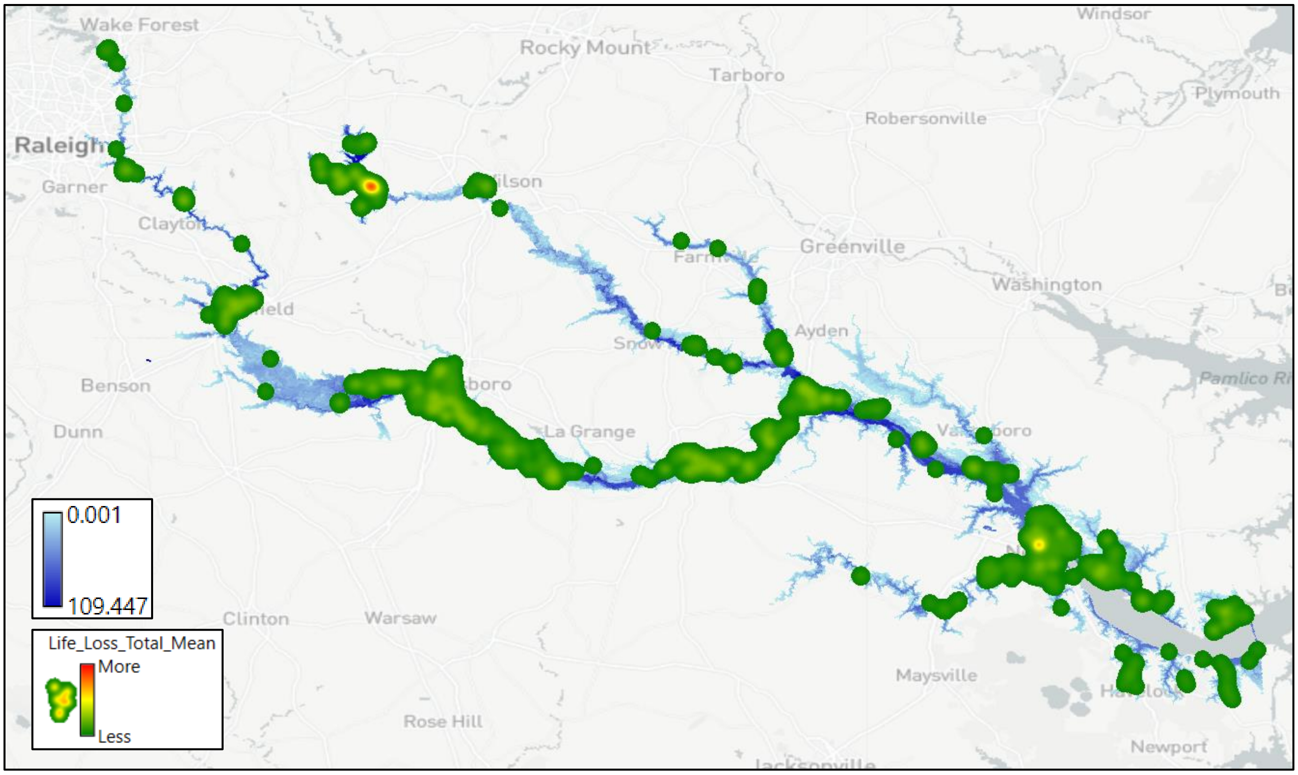

Figure 26. Neuse River Basin FWOP 0.002 AEP Average Night Life Loss Heat Map

6.1.5.2. Neuse River Mainstem Structural Alternative 1 Life Safety Risk

Table 53 shows life safety results for the Neuse River Mainstem Structural Alternative 1. The results are similar to the FWOP results. The average life loss remains relatively high for the less frequent events and the number of structures inundated is not significantly reduced. The life loss is scattered throughout the basin and is driven by flood depths and the amount of PAR.

Table 53. Neuse River Structural Alternative 1 Life Safety Risk by Event

Hydraulic Scenario	Structures Inundated	PAR Day	PAR Night	LOL Day	LOL Night	Average Depth (ft)
0.002 AEP	16,238	32,743	34,234	119.3	123.3	4.0
0.005 AEP	12,992	23,409	25,260	48.1	51.2	3.3
0.01 AEP	10,940	19,439	20,063	21.7	24.5	2.9
0.02 AEP	8,382	14,732	14,845	6.4	7.2	2.5
0.04 AEP	5,642	8,944	9,487	2.6	3.1	2.0
0.1 AEP	2,563	3,538	3,894	0.5	0.5	1.7
0.2 AEP	1,035	704	1,188	0.1	0.2	1.6
0.5 AEP	275	157	288	0.1	0.2	2.2

Figure 27 shows the average nighttime life loss for the Structural Alternative 1 0.002 AEP event. The heat map indicates if life loss was sampled within these areas during any of the 5,000 iterations. Life loss is scattered throughout the basin with some higher life loss areas identified in red.

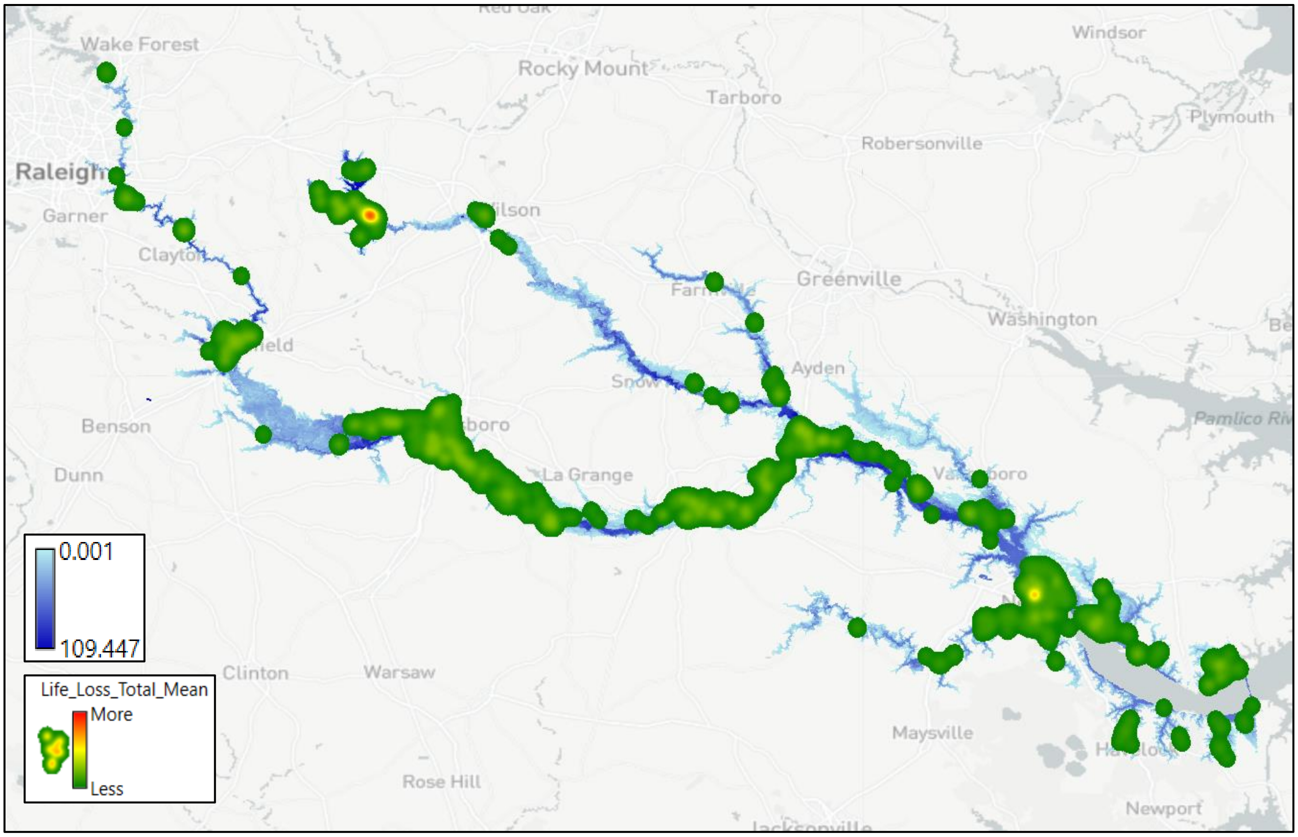

Figure 27. Neuse River Basin Alternative 1 Average Night Life Loss Heat Map

6.1.5.3. Mainstem Neuse River Average Annual Life Loss Estimates

Table 45 in the Hominy Creek Life Safety section details the AALL calculation method used to estimate AALL for the mainstem Neuse River. The AALL calculation is similar to how HEC-FDA calculates expected annual damages, but the AALL calculation does not include uncertainty. The AALL estimates could be further refined if additional life loss result statistics were utilized in the calculation (e.g., standard deviation, maximum, and minimum). However, the simplified AALL estimates clearly demonstrates if life safety risk is reduced following the implementation of structural measures. The FWOP's AALL is 0.944 lives/year, which is the highest of the four areas, but is relatively low (i.e., within the order of magnitude of 0.1 to 1 life loss). Alternative 1 does not significantly reduce AALL; the AALL reduction is 0.001.

Table 54. Mainstem Neuse River Average Annual Life Loss Estimates

Scenario	Average Annual Life Loss	Average Annual Life Loss Reduction
FWOP	0.944	N/A
Alternative 1	0.943	0.001

6.1.6. Life Safety Conclusion

In Hominy Swamp Creek, Crabtree Creek, and Big Ditch, there is no significant life safety risk for the 0.01 and more frequent AEP events, nor is there significant life loss reduction between the FWOP and FWP structural alternatives. For the mainstem Neuse River, life loss is greater, particularly for the 0.01 and 0.002 AEP events, due to the size of the area included (the model spans nearly the entire basin, from New Bern to Raleigh). However, there is no significant difference between FWOP and the FWP structural alternatives.

6.2. Social Vulnerability Without-Project Condition

Social vulnerability under the OSE account evaluates the beneficial and adverse impacts water resource plans have on social well-being. This section discusses how the without project condition affects residents within the study area. Social Vulnerability is based on a qualitative assessment, which largely relies on general consequences of flooding caused by natural disasters. Therefore, this section is not intended to comprehensively or quantitatively describe each aspect of social vulnerability, and is limited to logic that is based on previous flood events.

6.2.1. Health and Safety

The health and safety of a community can be negatively impacted by flooding, and these effects can continue for many years after the event. Elderly individuals can be the most affected by flooding, especially regarding their health, longevity, and safety. Studies have shown that older residents are more likely to experience depressive symptoms after natural disasters, especially when their community lacks cohesion because of these events.[4] However, all individuals are affected by flooding disasters and may experience major psychological trauma[5] that can include post-traumatic stress disorder, anxiety, depression[6], and worsen existing related psychological conditions.[7] Figure 6 shows the percent of individuals over the age of 65, and these areas may be more severely affected by future flooding events in terms of health and safety outcomes.

Flooding can also present a serious hazard to residents’ safety outside of psychological conditions. Flooding continues to claim many lives each year as people are unable to evacuate or climb to safety. When flood waters threaten a community, local officials disseminate a warning to their residents who must first receive such a warning, understand its implications, and act quickly. It is generally assumed residents can get out of harm’s way be evacuating (on foot, car, or likewise) or by climbing to higher elevation (like ascending to the second or third level of a home). These options both carry risks. Physical evacuation can lead to overcrowded roads, where fleeing residents are left trapped in their cars if flood waters arrive. Climbing to a higher elevation may provide some level of safety from floodwaters, however residents are left stranded in their structure until the floodwaters recede. Further, elderly residents may have trouble climbing stairs/ladders that can offer protection from rising flood waters.

6.2.2. Economic Vitality

Disruption to the economy, business losses, and loss of wages may negatively impact the local economy for some time after flooding and contribute to a gradual deterioration of the economy.[8] Many of the reaches in the study area are characterized by high poverty rates and unemployment,

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[4] Chao, S. F. (2016). Outdoor activities and depressive symptoms in displaced older adults following natural disaster: Community cohesion as mediator and moderator. Aging & mental health, 20(9), 940-947.

[5] Fernandez A, Black J, Jones M, et al. (2015). Flooding and mental health: a systematic mapping review. PloS One.;10(4):e0119929.

[6] Goldmann E, Galea S. (2014) Mental health consequences of disasters. Ann. Rev Public Health. 35:169-183.

[7] Hetherington, E., McDonald, S., Wu, M., & Tough, S. (2018). Risk and protective factors for mental health and community cohesion after the 2013 Calgary flood. Disaster medicine and public health preparedness, 12(4), 470-477.

[8] Cavallo, E., Galiani, S., Noy, I., & Pantano, J. (2013). Catastrophic natural disasters and economic growth. Review of Economics and Statistics, 95(5), 1549-1561.

as shown in tables and figures in Section 2.2. Further, many of these communities do not have large employers that give residents a reason to remain in the community. North Carolina’s economy has maintained a strong growth rate, so residents may relocate to other areas within the state to avoid flooding. The communities they leave behind are more likely to see stagnant growth as residents choose other regions with greater housing and occupational stability.

Residents who believe they are greatly affected by a flooding disaster are more likely to have a reduced perception of their community’s recovery.[9] In this case, the effects of hazards within the physical environment translate into negative perceptions about the local economy. This can lead to a downward spiral among residents where they feel trapped in their community.

6.2.3. Social Connectedness

As the community deals with a disaster, they may lose or gain social connectedness, however this can vary depending on the existing social structure of the community. Communities with many close bonds may have higher cohesion following a flood. At the individual level, those who remain in the community to volunteer and participate are more likely to experience positive community cohesion.[10] However, residents who were marginalized or did not participate prior to a flood are not likely to remain in the community and help build this community cohesion. In areas with many transient workers or impoverished residents, these effects will be especially pronounced.

Further, the level of existing organizations, such as volunteer groups, non-profits, and community outreach programs can help to mitigate the negative effects of flooding on social connectedness. This allows community members to connect as they begin the rebuilding process. Many of the impact areas within this study have a variety of these programs in place that could be a source of support following a flood. For example, the Crabtree Creek area has several of these organizations including the Salvation Army, the Food Bank of Central and Eastern North Carolina, and Wake County Public Health Center. However, in areas with more persons living below the poverty level, there are fewer of these programs.

6.2.4. Identity

Residents’ identity with their community can suffer from the effects of flooding. When residents are detached prior to a disaster, they are more likely to lose any identity they had with their community.[11] However, in communities that have strong bonds prior to flooding, these ties are at risk of being frayed by stress and disagreement over post-disaster decisions. While a serious flooding event may cause residents to question their identity to the community; living in a floodplain with the constant threat of flooding can cause detachment. The constant threat of flooding means community members are aware their home and/or place of work may be temporary, leading residents to view their position in the community as temporary.

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[9] Bergstrand, K., & Mayer, B. (2020). “The Community Helped Me:” Community Cohesion and Environmental Concerns in Personal Assessments of Post-Disaster Recovery. Society & Natural Resources, 33(3), 386-405.

[10] Ludin, S. M., Rohaizat, M., & Arbon, P. (2019). The association between social cohesion and community disaster resilience: A cross-sectional study. Health & social care in the community, 27(3), 621-631.

[11] Tapsell, S. M., Penning-Rowsell, E. C., Tunstall, S. M., & Wilson, T. L. (2002). Vulnerability to flooding: health and social dimensions. Philosophical transactions of the royal society of London. Series A: Mathematical, Physical and Engineering Sciences, 360(1796), 1511-1525.

6.2.5. Social Vulnerability and Resiliency

Socially vulnerable populations include those who are demographically or socioeconomically at a disadvantage relative to the average population. These social groups are more susceptible to the adverse impacts of natural disasters, including experiencing disproportionate death, injury, loss, or disruption of livelihood.[12] Resiliency, or the capacity to recover quickly from a flood event, may be lower for socially vulnerable populations. As discussed above, the elderly have an increased risk of developing depressive disorders from flooding events while at the same time, the elderly are more likely to struggle with evacuation and post-flood cleanup. Young children, while not as physically limited as elderly residents, may also experience psychological hardships because of damage caused by flooding events. The tables Section 2.2 show the percent minority and households below the federal poverty line within the study area. These populations face more hardship when rebuilding from disasters. Such communities are especially vulnerable to economic changes and social fraying.

6.2.6. Participation

The development of flood damage reduction strategies offers opportunities for increasing local participation and creation of trust. Communities with high levels of participation from residents may be better off following a flood compared to communities with lower participation rates. One measure of civic participation is voter turnout. Higher voter turnout suggests community members are more invested in the outcomes of their local and regional events.[13] Table 55 shows the voter turnout for counties within the study area.

Table 55. November 2020 Voter Turnout

County	Voter Turnout	County	Voter Turnout	County	Voter Turnout
Beaufort	77%	Greene	77%	Pamlico	78%
Carteret	82%	Johnston	78%	Person	79%
Craven	73%	Jones	75%	Pitt	71%
Durham	74%	Lenoir	74%	Wake	80%
Edgecombe	71%	Nash	76%	Wayne	73%
Franklin	79%	Onslow	62%	Wilson	72%
Granville	79%	Orange	76%		

6.2.7. Summary of Baseline Profile

These conditions create a qualitative account of the social issues at stake without any flood reduction measures. Residents in the floodplain will be impacted in nearly every aspect of their life because of flooding events. Further, simply living in a floodplain with the constant threat of flooding can cause lasting effects. Community and personal health are intertwined, and when flooding threatens one aspect, both suffer.

6.3. Social Vulnerability under Alternative 2

The proposed nonstructural elevation and floodproofing plan will have positive outcomes for the social and health aspects of residents' lives. This section discusses the different categories laid out above and explains how Alternative 2 impacts each category. Overall, the residents within

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[12] FEMA 2021. "Social Vulnerability". https://hazards.fema.gov/nri/social-vulnerability

[13] Eagles, M., & Erfle, S. (1989). Community cohesion and voter turnout in English parliamentary constituencies. British Journal of Political Science, 19(1), 115-125.

these communities are likely to experience an increase in these multidimensional measures of health and well-being. The floodproofing measures proposed by this alternative aim to include all affected homes and involve a wide array of community members during the project's implementation.

6.3.1. Health and Safety

Under the with-project conditions, the protected communities will likely be healthier and safer from impending floodwaters. Floodproofing measures designed to reduce damage to homes and their contents create a safer environment for the communities they help. Most importantly, these measures will keep residents above the floodwaters. Residents will not have to risk evacuating on foot or by car and getting trapped in moving waters. Because their homes are floodproofed, they are less likely to become inundated during a flood, preventing possible disease associated with post-flood structures.[14] Mental health and psychological safety will also be protected by these measures. Residents will be less likely to worry about rebuilding following a flood event. They will be less likely to worry about temporary relocations and the loss of their personal belongings while the floodwaters remain high.

6.3.2. Economic Vitality

When residents can remain in their homes and have a reduced level of flood risk, they can stay in their community and work in their traditional occupations, and/or help clean up. By remaining in the community, they can create a positive attitude about their community's recovery and help their neighbors.[15] The local economy is intrinsically tied to its members' health. When residents can remain in their occupations following a flood, they are likely to be healthier, both immediately and in the long run. Residents can contribute to their local economic growth and provide a quick restart to local production and consumption, thus helping the other members of their community.

6.3.3. Social Connectedness

Under Alternative 2, residents of flood-prone communities would be more likely to feel social connectedness after a flood because of the reduction in risk to individuals and their homes. While social connectedness can fray following a disaster, when residents team up to help each other out, they are more likely to feel like they belong to a part of a community. Residents can engage in civic participation when they feel they are a part of the long-term community. If homes and residents' belongings are undamaged, individuals could have increased capacity to help each other clean up other debris caused by flooding.

6.3.4. Identity

Similar to improvements in social connectedness, floodproofing projects may increase residents' identity within the community allowing them to stay longer and contribute to the social fabric and economy. The floodproofing is likely to help residents feel that they are protected against

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[14] Ohl, C. A., & Tapsell, S. (2000). Flooding and human health: the dangers posed are not always obvious. Bmj, 321(7270), 1167-1168.

[15] Bergstrand, K., & Mayer, B. (2020). "The Community Helped Me:" Community Cohesion and Environmental Concerns in Personal Assessments of Post-Disaster Recovery. Society & Natural Resources, 33(3), 386-405.

potential flooding events, creating a sense of resiliency that is helpful following a flood.[16] Because floodproofing visibly helps the members of the community with homes in the path of flooding, they are more likely to contribute to their community's well-being.

6.3.5. Social Vulnerability and Resiliency

The floodproofing plan proposed in this project will reduce the risk to socially vulnerable populations by including certain homes within the study areas for floodproofing measures. It will help these community members remain resilient in the face of flooding by providing them with a reduced level of flood risk they would not otherwise have. Elderly residents can feel safer in their current homes and reduce their level of concern over losing their homes and belongings which can take many years to replace. These floodproofing measures will allow residents in ethnically minority groups to feel more attached to their communities through increased safety measures.

6.3.6. Participation

The proposed plan is likely to induce higher community participate to a wide array of residents. When community members feel they are better protected from flooding, they are less likely to feel transient or like temporary members of the community. Because of this, the community members can get more involved when they see they have a long-term future within their current communities. Communities with floodproofing measures could see higher participation in terms of voter turnout, as residents take interest in measures that affect their local community.

6.4. Social Vulnerability under Alternative 3

This section discusses the impacts to social vulnerability under the buyout and acquisition plan. While negative impacts to residents are reduced by removing individuals from the floodplain, there are potential negative impacts to certain social vulnerability indicators under this alternative.

6.4.1. Health and Safety

Under Alternative 3, the protected communities will likely be healthier and safer from impending floodwaters. Removing structures and residents from the floodplain will eliminate flooding to these structures and prevent residents from getting caught by floodwaters in event of a flooding-induced evacuation.

Mental health and psychological safety could be better or similar to the without-project condition. Residents will not need to worry about rebuilding following a flood event. However, residents may suffer stress or a sense of loss of community by leaving their communities and current homes.

6.4.2. Economic Vitality

Economic vitality under Alternative 3 in the immediate community will suffer. Local businesses may suffer when residents permanently relocate to another area and residential structures are bought out and demolished. Additionally, relocating residents may impact their jobs, and

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[16] Redshaw, S., Ingham, V., McCutcheon, M., Hicks, J., & Burmeister, O. (2018). Assessing the impact of vulnerability on perceptions of social cohesion in the context of community resilience to disaster in the Blue Mountains. Australian journal of rural health, 26(1), 14-19.

potentially cause individuals to choose jobs outside of their original communities. Local and regional economic growth may decline as a result of buyouts and acquisitions.

6.4.3. Social Connectedness

Social connectedness is likely to be negatively impacted by Alternative 3. Residents in flood-prone communities that are forced to relocate and leave their communities may experience a loss of friendships, and a loss of a sense of belonging until they form bonds in their new communities.

6.4.4. Identity

Similar to social connectedness, a sense of identity may be negatively impacted by Alternative 3. Residents whose homes are bought out and relocate to other communities may experience a loss of identity from leaving their communities and the homes they had previously lived in.

6.4.5. Social Vulnerability and Resiliency

Buyouts and acquisitions will remove the risk of flooding to homes that are selected for participation. Individuals who have high social vulnerability metrics, including the elderly, low-income, and minority populations, will benefit from the reduced risk of flooding.

6.4.6. Participation

Under Alternative 3, participation in existing communities will likely decline as residents move outside of the flood-prone communities. Residents near the bought-out structures may be less inclined to get involved when they see their neighbors leaving the community. Participation in local elections and community measures would decline.

6.5. Summary of Other Social Effects

This OSE analysis describes adverse effects from flooding for the future without project condition and the potential beneficial and adverse social effects from Alternatives 2 and 3. Public health and safety are negatively affected by flooding under the future without project condition. Economic vitality will also be adversely affected from flooding in the absence of a federal project. Community cohesion, participation, and identity will be negatively impacted under the future without project condition. Finally, social vulnerability will be at risk under the future without project and individuals vulnerable to economic loss will continue to experience stress related to flood events. Alternative 2 would mitigate this impact by reducing the likelihood of flood damage. Under Alternative 2, individuals will be less likely to lose employment, income, and be impacted by stress related to flood events.

7.0. REGIONAL ECONOMIC DEVELOPMENT

The Regional Economic Development (RED) account registers changes in the distribution of regional economic activity that result from each alternative plan. Evaluations of regional effects are carried out using nationally consistent projections of income, employment, output, and population. The RED account displays information not analyzed in other accounts in the feasibility report that could have a material bearing on the decision-making process.

To evaluate RED, the USACE Regional Economic System (RECONS) model was used. RECONS is a USACE-certified regional economic model, designed to provide accurate and defensible estimates of regional economic impacts and contributions associated with USACE projects, programs, and infrastructure. Regional economic impacts and contributions are measured as economic output, jobs, income, and value added. Estimates are provided simultaneously for three levels of geographic impact area: local, state, and national. RECONS is an input/output (IO) model that uses IMPLAN data, which is comprehensive economic data gathered from government agencies and the private sector. Within RECONS, the Civil Works Spending Module was used to estimate local, state, and national impacts. Each business line is subdivided into numerous work activities, which improves the accuracy of the estimates for regional and national job creation, and retention and other economic measures such as income, value added, and sales. For project expenditures, the business line selected was Flood Damage Control/Flood Risk Management and the work activity selected was Flood Risk Management Construction. Since RECONS is an IO model, construction dollars must be spent for an impact to occur. IO models assumes that there is a relationship between the volume of output of an industry and the volume of various inputs used to produce that output. The impact of construction dollars on the economy more broadly is based on the multiplier effect, or the proportional amount of increase in final income that results from an injection of spending due to the project. Therefore, only with-project conditions are analyzed. In the absence of the project, it is likely that regional economic development would suffer due to continued flooding, as detail in Section 6.2.

The economic impacts presented below exclude IDC, since this portion of project costs are not spent within the region. Purchases of land are similarly excluded since this cost is considered a transfer from one individual to another.

7.1. Hominy Swamp Creek Alternative 2 RED

For Hominy Swamp Creek, the generic area used was Wilson County, which fully contains the flood extent area. Total county-wide impacts would be the creation of an estimated 58 FTE jobs, and value added would be $3.5 million. Total national jobs would be 96 FTE jobs, and value added would be $8.2 million.

Table 56. Hominy Swamp Creek Alternative 2 RECONS

Area	Local Capture	Output	Jobs*	Labor Income	Value Added
Local					
Direct Impact		$3,604,236	43.0	$2,681,737	$2,244,325
Secondary Impact		$2,252,162	14.7	$718,981	$1,244,372
Total Impact	$3,604,236	$5,856,398	57.7	$3,400,718	$3,488,697
State					
Direct Impact		$4,220,972	48.2	$3,034,047	$2,731,772

Secondary Impact		$4,363,922	25.2	$1,422,937	$2,446,524
Total Impact	$4,220,972	$8,584,895	73.3	$4,456,985	$5,178,295
US					
Direct Impact		$4,993,878	52.3	$3,354,099	$3,219,434
Secondary Impact		$9,224,316	44.2	$2,938,340	$5,029,481
Total Impact	$4,993,878	$14,218,194	96.5	$6,292,439	$8,248,914

Note: values in FY22 price level
* Jobs are presented in full-time equivalence (FTE)

7.2. Crabtree Creek Alternative 2 RED

For Crabtree Creek, the generic area used was Wake County, which fully contains the flood extent area. As a result of the nonstructural measures in Crabtree Creek, Wake County would gain an estimated 156 FTE jobs, and total value added in the county would exceed $12 million. Nationally, there would be an estimated 212 FTE jobs created, and total value added would be approximately $18.5 million.

Table 57. Crabtree Creek Alternative 2 RECONS

Area	Local Capture	Output	Jobs*	Labor Income	Value Added
Local					
Direct Impact		$9,889,238	99.7	$7,335,245	$6,478,531
Secondary Impact		$9,674,503	56.3	$3,360,343	$5,732,029
Total Impact	$9,889,238	$19,563,741	155.9	$10,695,588	$12,210,560
State					
Direct Impact		$10,008,066	105.5	$7,390,528	$6,525,490
Secondary Impact		$10,480,794	61.4	$3,491,037	$5,977,473
Total Impact	$10,008,066	$20,488,860	166.9	$10,881,565	$12,502,963
US					
Direct Impact		$11,212,495	111.7	$7,818,828	$7,228,288
Secondary Impact		$20,710,876	101.0	$6,597,302	$11,292,432
Total Impact	$11,212,495	$31,923,372	212.7	$14,416,130	$18,520,719

Note: values in FY22 price level
* Jobs are presented in full-time equivalence (FTE)

7.3. Big Ditch Alternative 2 RED

For Big Ditch, the generic area used was Wayne County. In Wayne County, it is estimated that approximately 9 FTE jobs would be created, and value added would be $660,000. Nationally, nearly 19 FTE jobs would be created, and $1.7 million in value added to the economy would be the result of the nonstructural measures along Big Ditch.

Table 58. Big Ditch Alternative 2 RECONS

Area	Local Capture	Output	Jobs*	Labor Income	Value Added
Local					
Direct Impact		$646,029	6.6	$428,786	$458,177
Secondary Impact		$369,653	2.3	$111,255	$201,215
Total Impact	$646,029	$1,015,682	8.9	$540,040	$659,392
State					
Direct Impact		$872,441	9.2	$607,605	$590,802
Secondary Impact		$866,612	5.0	$282,861	$486,965
Total Impact	$872,441	$1,739,053	14.1	$890,465	$1,077,767
US					
Direct Impact		$1,011,333	10.1	$695,766	$684,971
Secondary Impact		$1,813,553	8.7	$581,725	$994,555
Total Impact	$1,011,333	$2,824,885	18.8	$1,277,491	$1,679,526

Note: values in FY22 price level
* Jobs are presented in full-time equivalence (FTE)

7.4. Mainstem Neuse River Alternative 2 RED

For the mainstem Neuse River, Lenoir County was used, which contains the reaches impacted by the nonstructural plan. The mainstem Neuse River nonstructural measure covers the largest area and highest number of structures, and therefore results in the highest input costs and the highest RED impacts of any of the separable areas. In Lenoir County, it is estimated that approximately 1,216 jobs would be created and $73 million in value added to the economy would be generated. Nationally, it is estimated that 2,109 jobs would be created, and the construction would result in $180 million in value added to the economy.

Table 59. Neuse Mainstem RECONS, FY22 PL

Area	Local Capture	Output	Jobs*	Labor Income	Value Added
Local					
Direct Impact		$76,094,068	933.4	$56,464,328	$47,919,489
Secondary Impact		$44,040,682	283.1	$14,015,481	$25,050,013
Total Impact	$76,094,068	$120,134,750	1,216.40	$70,479,809	$72,969,502
State					
Direct Impact		$92,762,642	1,062.50	$65,850,250	$60,086,837
Secondary Impact		$96,631,073	556.8	$31,523,129	$54,181,969
Total Impact	$92,762,642	$189,393,716	1,619.30	$97,373,379	$114,268,806
US					
Direct Impact		$109,277,047	1,143.00	$73,269,634	$70,365,867
Secondary Impact		$201,848,324	966.2	$64,297,349	$110,056,105
Total Impact	$109,277,047	$311,125,371	2,109.20	$137,566,983	$180,421,972

Note: values in FY22 price level
* Jobs are presented in full-time equivalence (FTE)

8.0. SUMMARY OF FOUR ACCOUNTS

This section summarizes the four planning accounts and provides support for the Recommended Plan.

8.1. National Economic Development

As described in Section 5, Alternative 2 maximizes net NED benefits. Alternative 2 is therefore the Recommended Plan. Total net benefits are approximately $2.8 million and the benefit-cost ratio is 1.63 at a discount rate of 2.25 percent. Alternative 2 decreases expected annual damages from $43 million under the without-project condition to $36.2 million under the with-project condition across four areas: Hominy Swamp Creek, Crabtree Creek, Big Ditch, and Neuse Mainstem.

8.2. Other Social Effects

Section 6.0 presents Other Social Effects and includes life safety risk and social vulnerability for the future without-project condition and future with project condition. Social vulnerability is reduced by the Recommended Plan by floodproofing structures that would otherwise be damaged in event of a flood in four separable areas throughout the basin. Furthermore, social cohesion is preserved by the Recommended Plan, which allows residents to remain in their current houses and communities, rather than relocate them outside the floodplain. In the absence of a federal project, socially vulnerable individuals will continue to suffer from the impacts of repeated flooding.

8.3. Regional Economic Development

Section 7.0 presents Regional Economic Development, which is quantified by the RECONS model. The total number of full-time equivalent jobs created in the state for the Recommended Plan is estimated to be 1,874. Total value added at the state level exceeds $133 million. In the absence of a federal project, regional economic development will likely decline due to repeated flooding in the area.

8.4. Environmental Quality

Environmental quality is summarized for the future without-project and future with project condition in the Main Report. The Recommended Plan has minimal impact on native soils and bedrock, no wetland impacts, and no impact on water quality. Since the Recommended Plan doesn’t include structural measures that reduce water surface elevation, flood events will continue to have impacts on vegetation and wildlife.