Neuse River Basin Flood Risk Management Feasibility Study - Technical Report

Appendix B. Economic Analysis

US Army Corps of Engineers

February 2023

Page Intentionally Left Blank

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Page Intentionally Left Blank

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 risk 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 as 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 (WOP) and with-project (WP) 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 range of possible flood events, considering 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 extends 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 that also contribute 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. 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 (BCR), 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 BCR 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 from and who is adversely affected by each alternative.

Flood and coastal storm risk management reports must include an assessment of potential mortality (life loss) for the future without project (FWOP) 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 in a manner 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 and 23 counties and covers approximately 6,200 square miles of land.

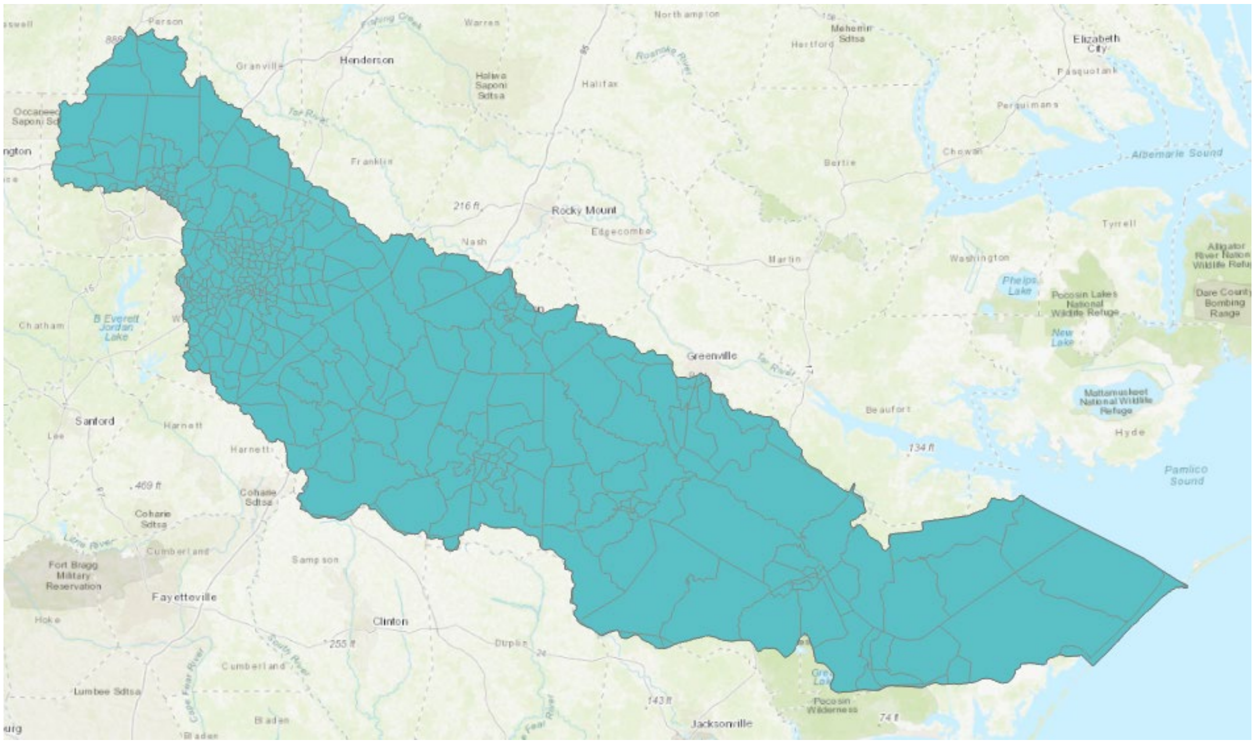


Figure 1. Neuse River Basin Study Area Census Tracts

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.

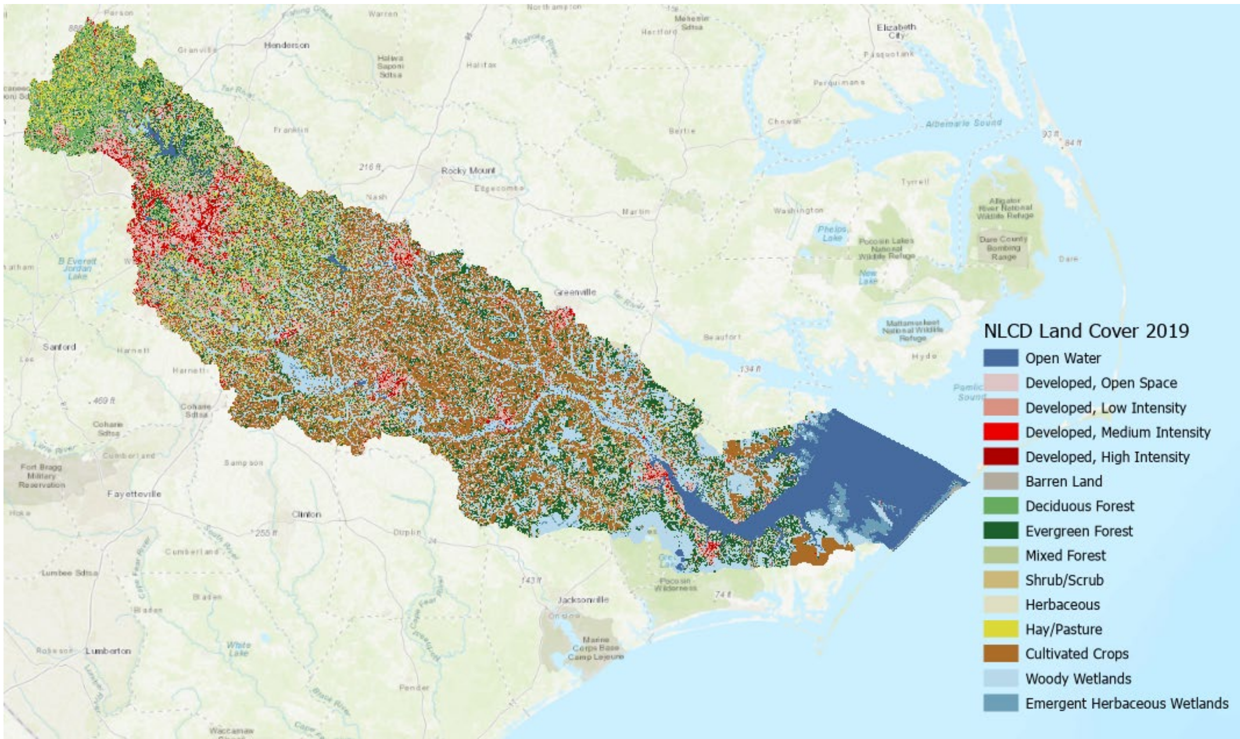


Figure 2. Study Area Land Use

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 (PAR) 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.

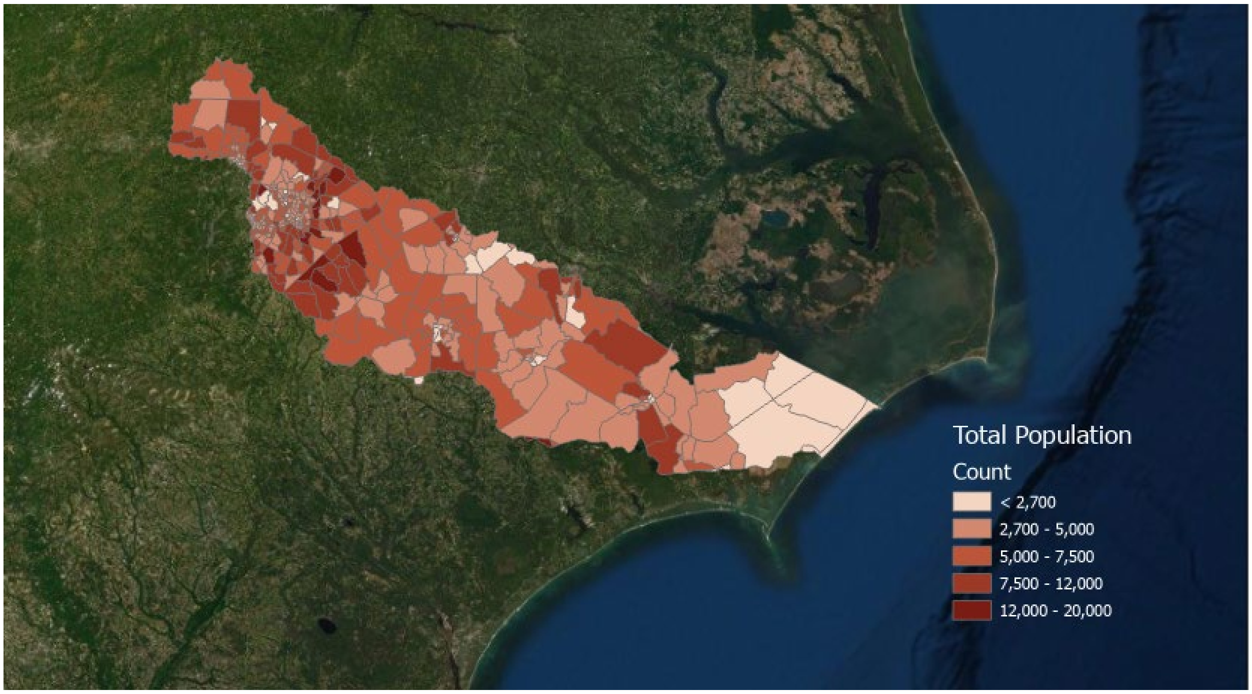


Figure 3. Population Count by Census Tract, ACS 2019 5-year Estimates

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.

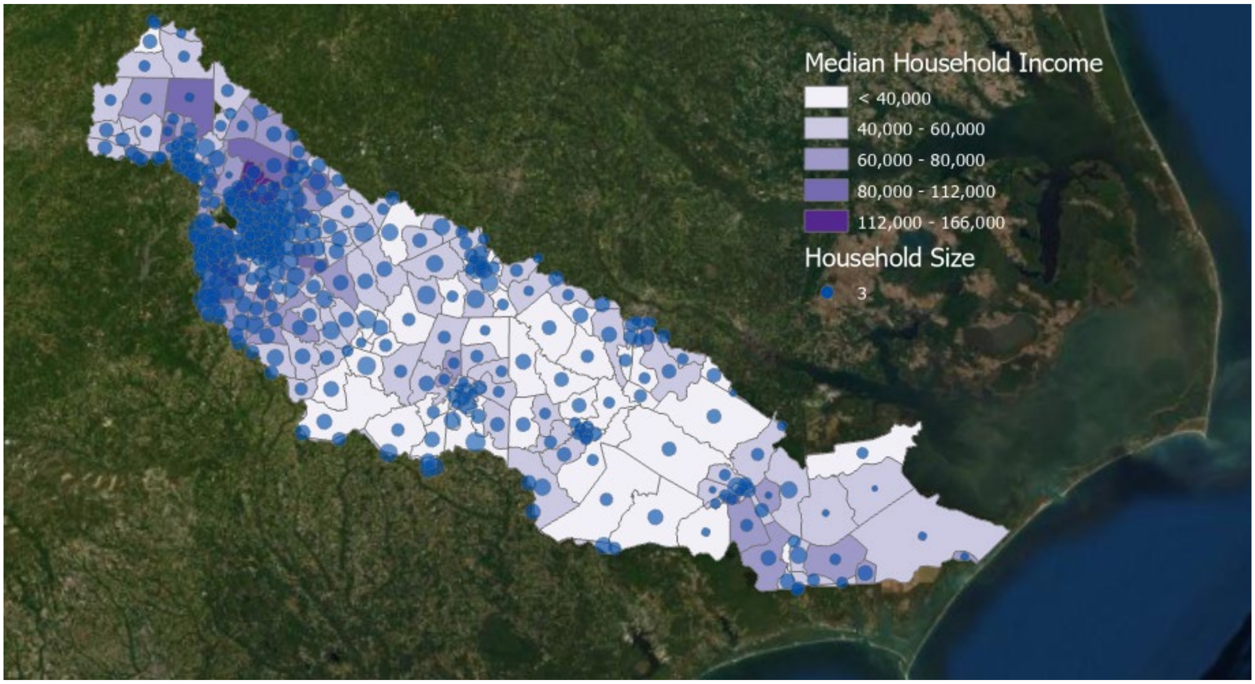


Figure 4. Median Household Income in 2015 Inflation Adjusted Dollars vs Household Size

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.

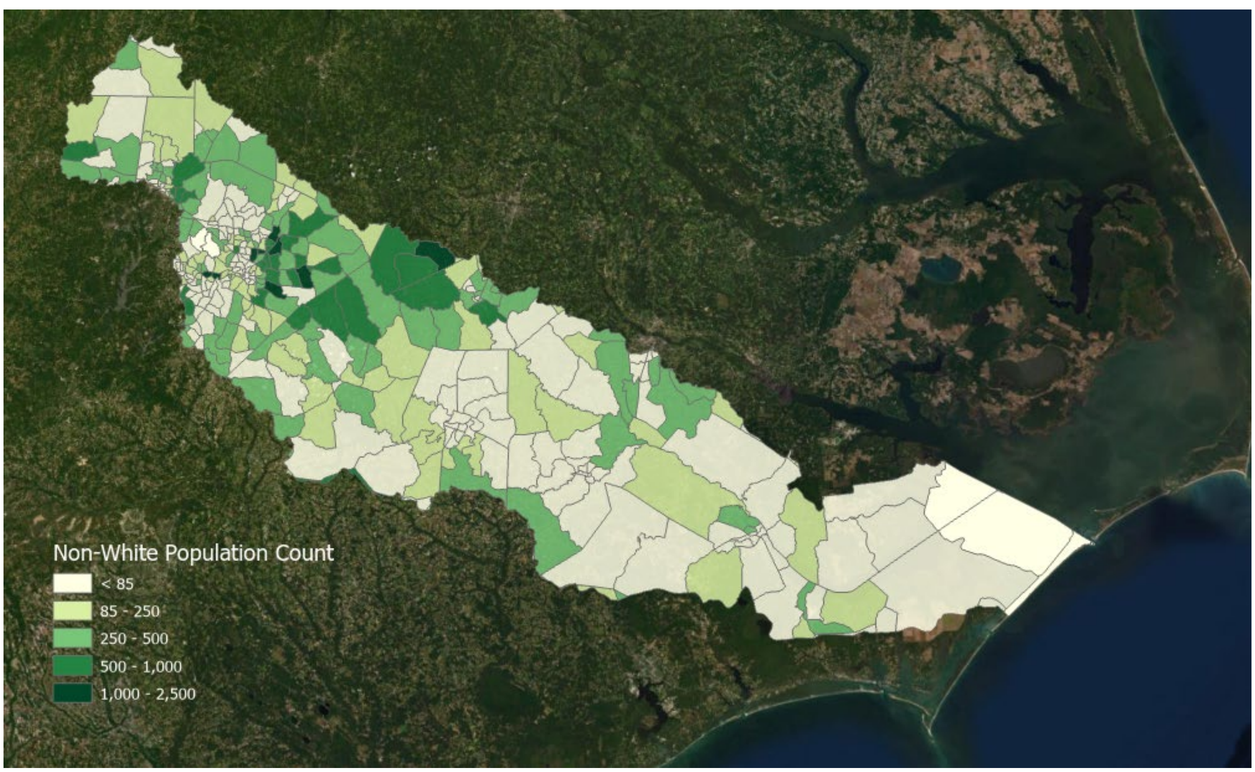


Figure 5. Non-White Population Count by Census Tract, ACS 2019 5-year Estimates

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.

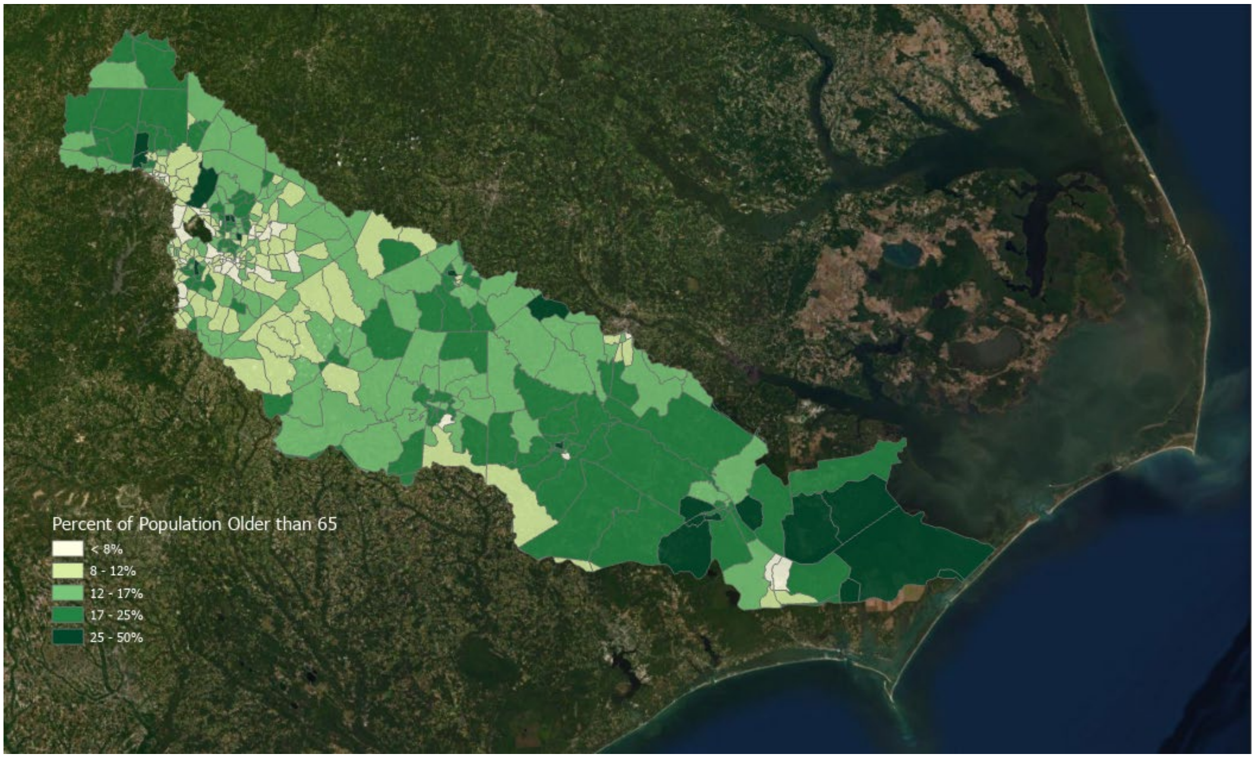


Figure 6. Percent of Population Age 65 or Older, ACS 2019 5-year Estimates

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.

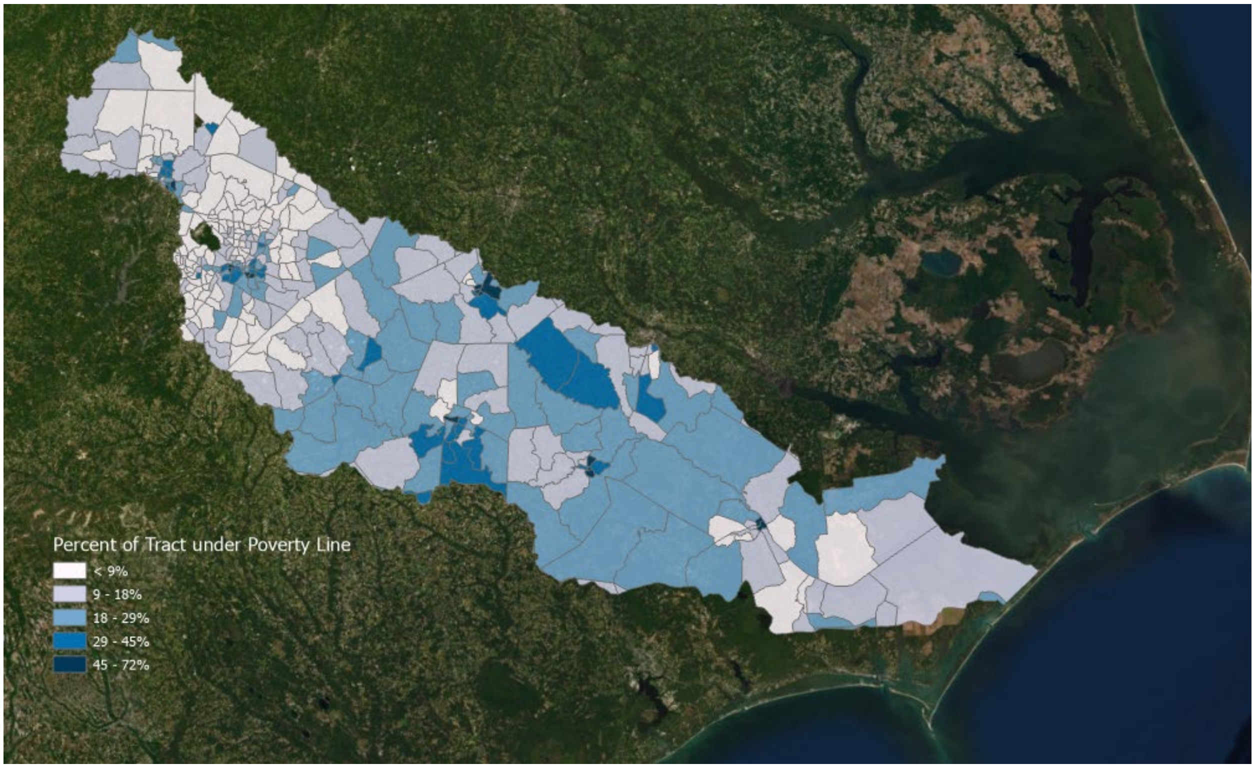


Figure 7. Percent of Population under Poverty Line by Census Tract, 2015 ACS 5-year Estimates

The Center for Disease Control computes a Social Vulnerability Index (SVI) based on composite census data.[1] The SVI is represented as a percentile ranking in Figure 8 below by census tract. Census tracts with a score of 0.95 would be, on average, 95 percent more vulnerable than the rest of North Carolina, for example. Census tracts with a score of 0.30 would be 30 percent more vulnerable than the rest of the state. Census tracts that are lighter orange or yellow represent lower SVI scores, while census tracts that are darker orange or red represent higher SVI scores, indicating higher social vulnerability. Figure 8 shows that there are socially vulnerable areas throughout the basin, with lower social vulnerability scores near the confluence with the Atlantic Ocean and in certain parts of Raleigh.

[1] https://www.atsdr.cdc.gov/placeandhealth/svi/data_documentation_download.html

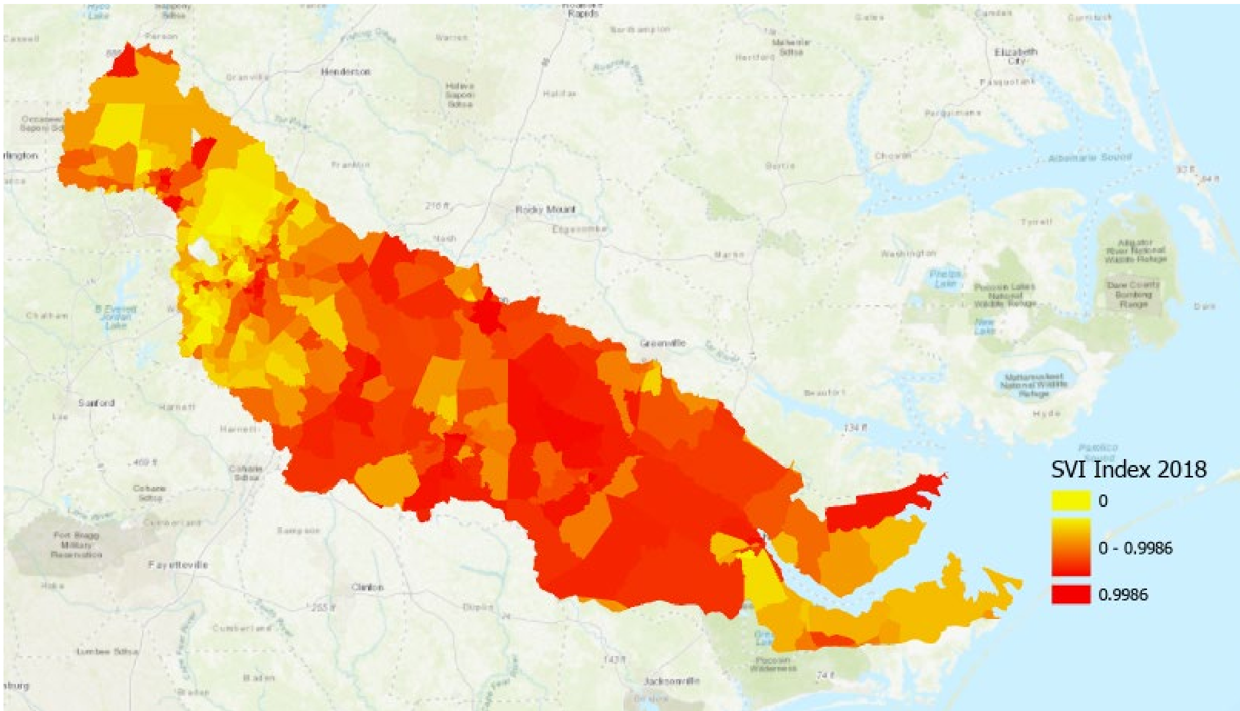


Figure 8. CDC Social Vulnerability Index

Source: https://www.atsdr.cdc.gov/placeandhealth/svi/data_documentation_download.html

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 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) 2023 price levels. Annualized benefits and costs were computed using a 50-year period of analysis and the FY 2023 federal discount rate of 2.5 percent. For Crabtree Creek and mainstem Neuse River, equivalent annual damages are presented. For all other separable areas, expected annual damages are presented, since existing and future hydraulic conditions are the same. 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 BCR. HEC-FDA is a USACE-certified risk-based program and is standard for economic computations for FRM 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 WOP 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 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.[2] This process is depicted in Figure 9.

[2] 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.

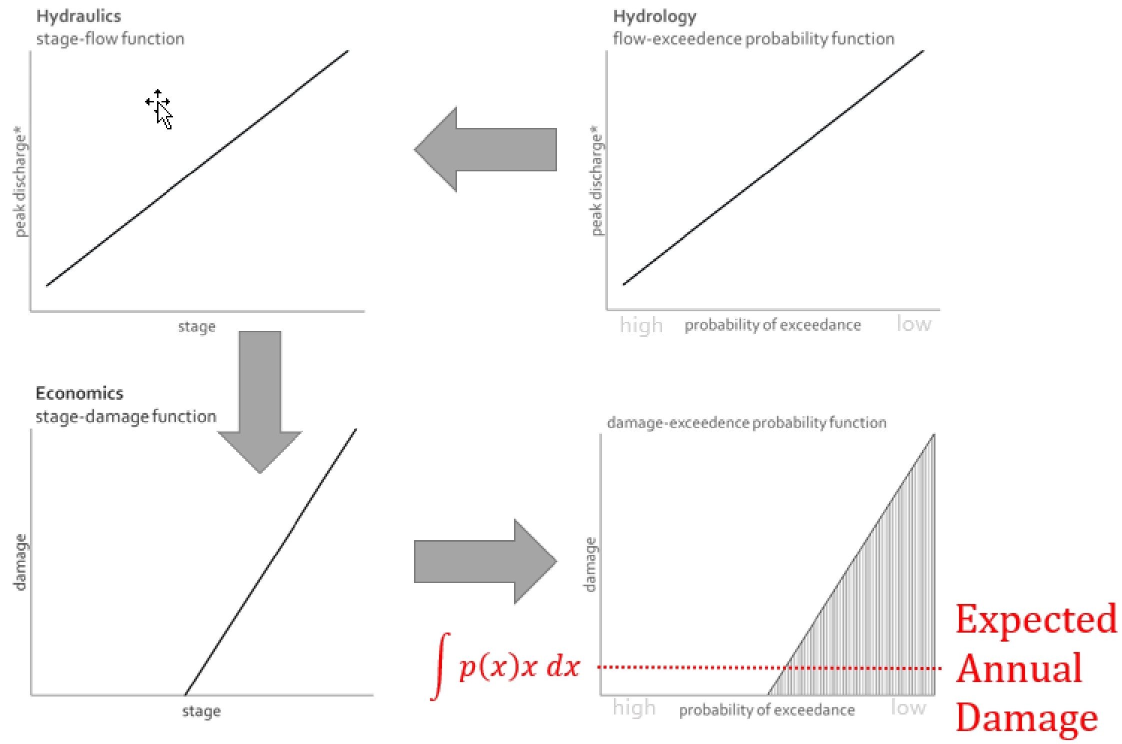


Figure 9. EAD Computation Process

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 was 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 river station at the nearest cross section.

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. EAD 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 for the Neuse Mainstem and Crabtree Creek basins and 25 years for Hominy Swamp and Big Ditch. For additional information on the period of record, refer to Appendix A (H&H) of this report. 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 (CSVRs) 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 on 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 10 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 11-Figure 13 depict the tributary reaches in more detail. Due to the coastal nature of Reach MS1 and complexities that arose after initial modeling in HEC-RAS and HEC-FDA, this reach was removed from the study and recommended to be evaluated in a separate study. As a result, damages for MS1 are not shown in the tables below.

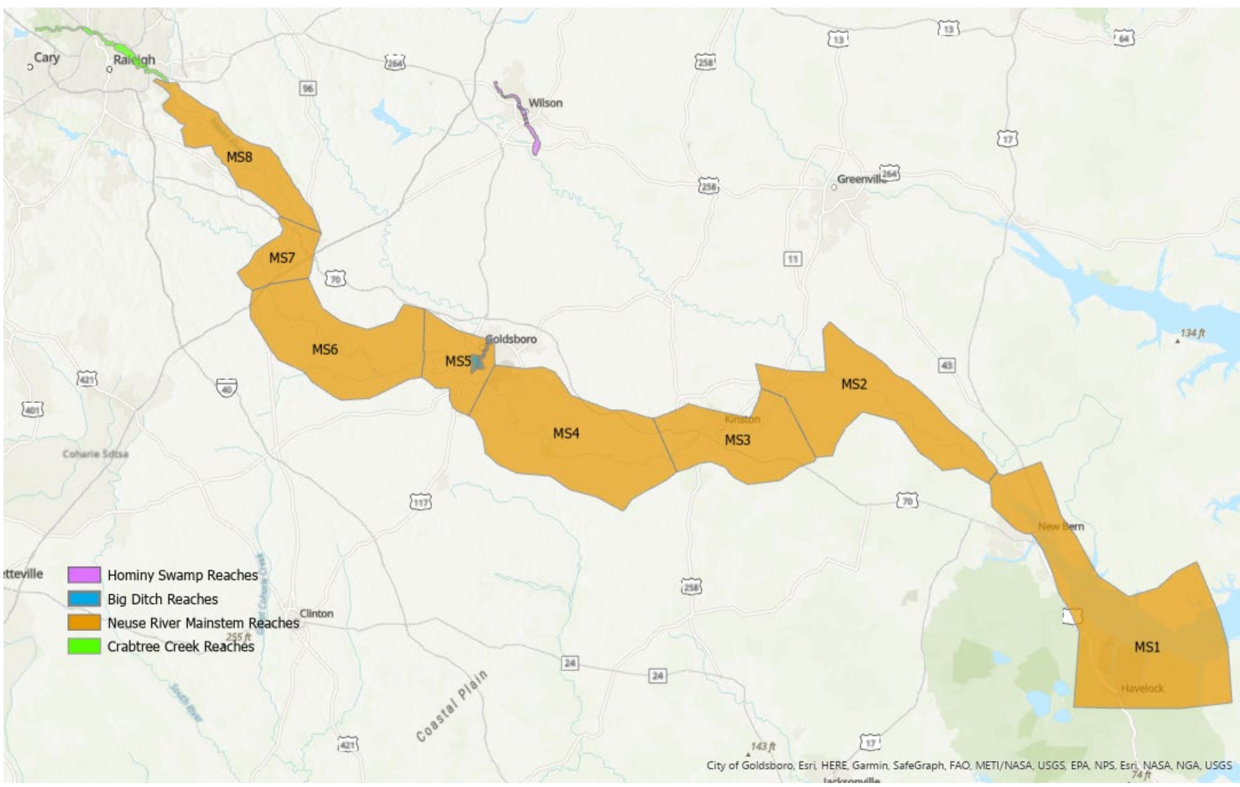


Figure 10. Study Area Reaches

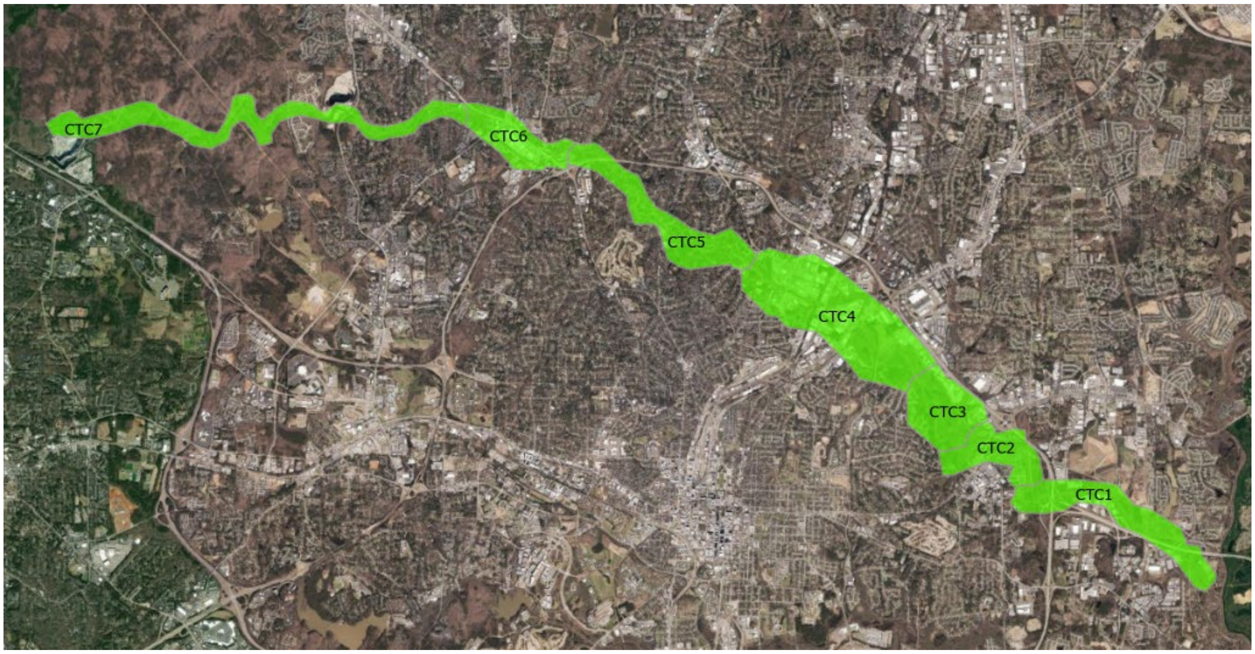


Figure 11. Crabtree Creek Reaches

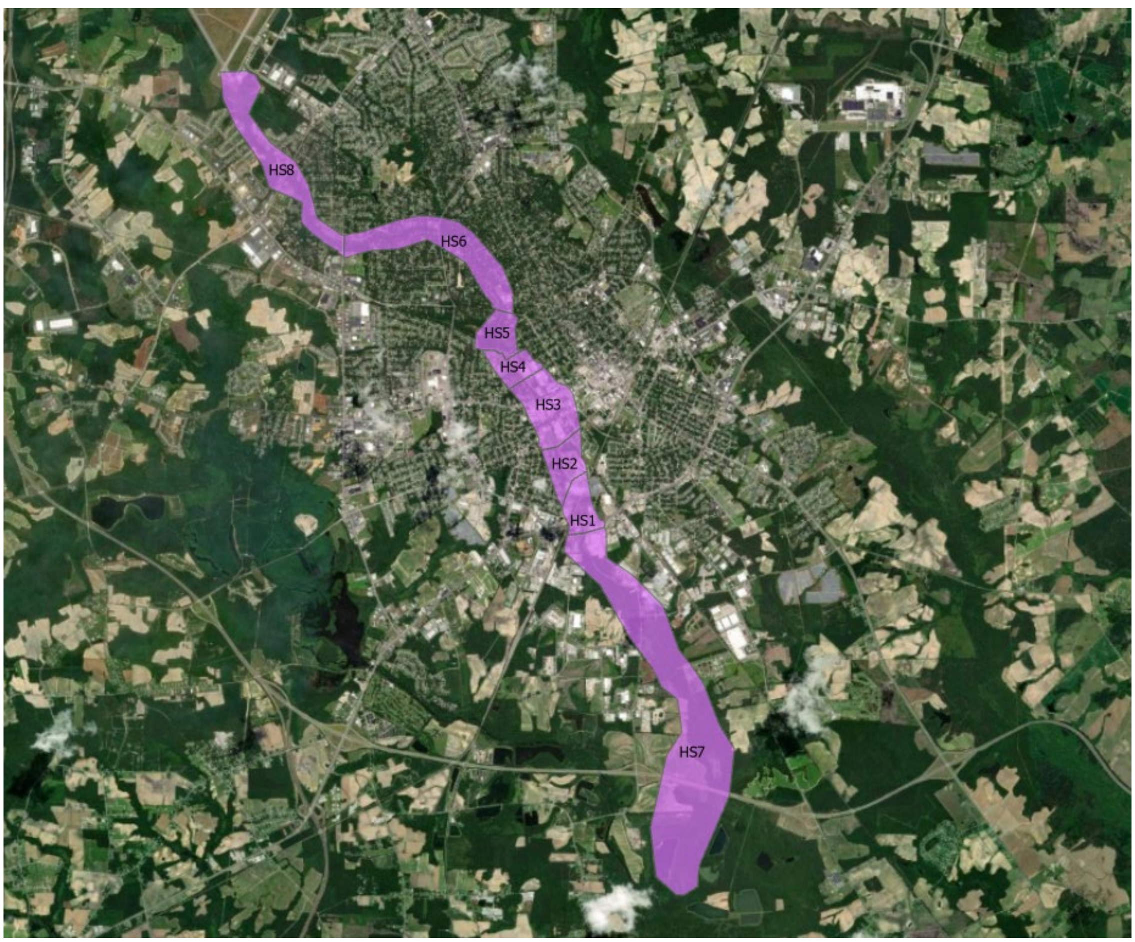


Figure 12. Hominy Swamp Creek Reaches

Figure 13. 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-Table 8 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 last 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, CSVRs 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, 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 FY23 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 FY23 PL

	Structures	Depreciated Structure Value $	Depreciated Content Value $
Big Ditch			
Residential	274	$64,852,696	$51,645,365
Commercial	74	$81,393,878	$34,185,429
Public	6	$26,764,756	$35,329,478
Crabtree Creek			
Residential	328	$95,609,383	$73,667,097
Commercial	34	$87,841,537	$36,893,446
Public	0	$0	$0
Hominy Swamp Creek			
Residential	200	$49,347,379	$38,872,285
Commercial	51	$63,063,427	$26,486,639
Public	4	$17,405,676	$22,975,493
Mainstem Neuse River			
Residential	11,612	$1,942,089,061	$1,695,897,047
Commercial	2,455	$5,518,396,342	$2,317,726,463
Public	99	$221,372,955	$292,212,301
Total	**15,327**	**$8,168,137,090**	**$4,625,891,043**

Note that the Big Ditch tributary floodplain overlaps the mainstem Neuse River flood extent, 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.

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 (%)
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	43.27

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. CSVRs for residential structures are 100 percent, with an error term of zero. CSVRs 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, 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, 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 WP 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 to remove floodwater, sediment, debris, mold, mildew, and toxins. These cleanup costs are considered a damage category in the calculation of WP 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.[3]

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 value, 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 repair of roads, bridges, water facilities, public buildings, utilities, 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 maximum emergency cost values.[4] PA per household was calculated by taking the total sum of

[3] https://www.npr.org/2018/09/26/651517127/florence-floodwaters-total-thousands-of-cars-stranding-locals
[4] FEMA data retrieved from https://www.fema.gov/disaster/4393, on May 20, 2021.

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 NED benefits. The structure inventory (including values, elevations, 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 FWOP, future with-project (FWP), existing WOP, and existing WP 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 initially 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. Additionally, existing and future conditions were deemed to be equivalent for Big Ditch and Hominy Swamp Creek, so only the future condition was developed in HEC-RAS. Future and existing condition water surface profiles were developed for Crabtree 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 Length (N) of 25-years for Big Ditch and Hominy Swamp and a record length of 30-years for mainstem Neuse River and Crabtree Creek. 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 specified by H&H for each profile and reach that varied from 0.28 to 0.78 feet for Big Ditch, 0.17 to 1.03 feet for Crabtree Creek, 0.15 to 0.96 feet for Hominy Swamp Creek, and 0.17 to 1.02 feet for mainstem Neuse River.

4.0. WITHOUT-PROJECT ANALYSIS AND RESULTS

4.1. FWOP 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. WOP flooding also impacts OSE, which includes loss of life, and is quantified in this section.

HEC-FDA software was used to calculate economic damages for this study. Expected annual flood damages are the basis for calculating WP benefits and are crucial to the evaluation of the project. EAD 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 EAD, 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.

FWOP and FWP conditions were developed in HEC-RAS and modeled in HEC-FDA for three separable areas: Crabtree Creek, Hominy Swamp Creek, and mainstem Neuse River. FWOP conditions were developed for Big Ditch (no FWP structural alternative was modeled for Big Ditch).

Due to the complex riverine and coastal influences of Reach MS1 in mainstem Neuse River, this reach was removed from the study after initial HEC-RAS and HEC-FDA modeling were complete and is recommended for a separate study that can adequately address the coastal nature of flooding in this area. For this reason, damage and benefit estimates exclude Reach MS1.

4.2. FWOP Flooding Characteristics

The WOP 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.

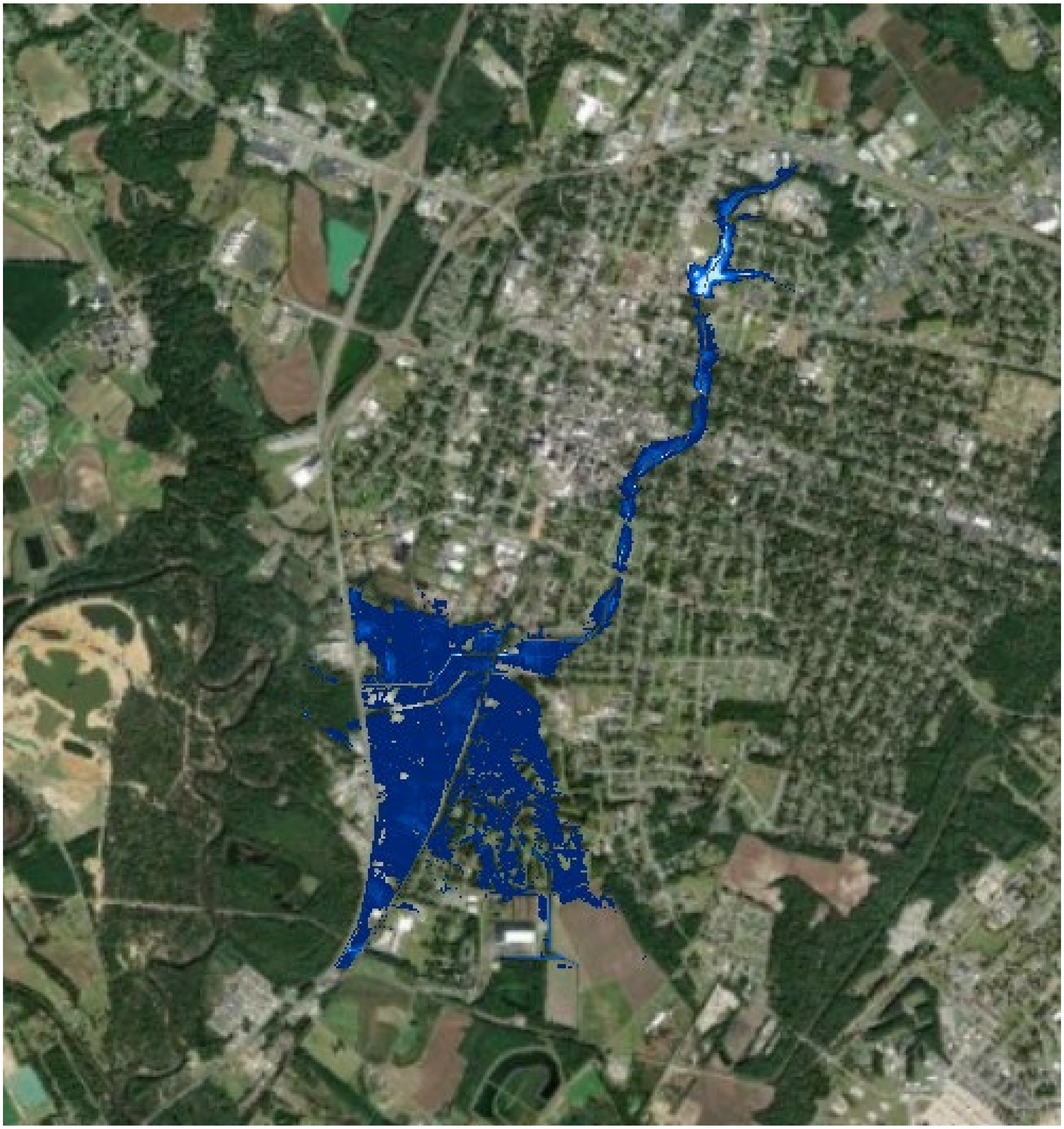


Figure 14. Big Ditch 0.002 AEP FWOP Flood Extent

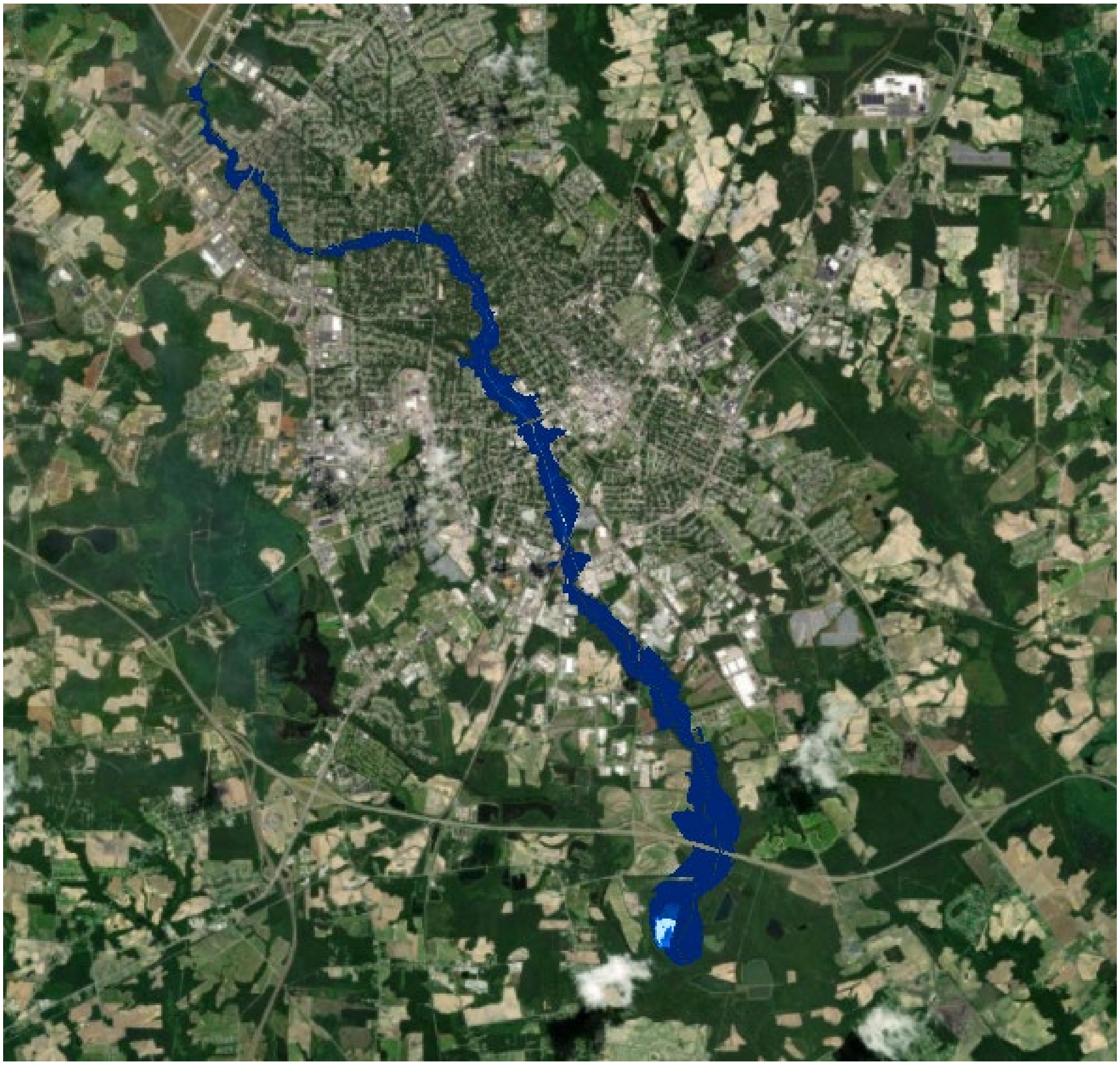


Figure 15. Hominy Swamp Creek 0.002 AEP FWOP Flood Extent

Figure 16. Crabtree Creek 0.002 AEP FWOP Flood Extent

Figure 17. Mainstem Neuse 0.002 AEP FWOP Flood Extent

4.3. Flood Risk: Probability and Consequences

4.3.1. FWOP EAD

Expected annual damages describe the consequences of flooding on an annual basis considering a full range of flood events. FWOP EAD are shown in Table 13-Table 25 by reach and damage category for each separable area.

Table 14 display the WOP EAD for Hominy Swamp Creek. Residential, commercial, and public structures account for $875,000 in EAD, while other damages account for $132,000 annually. Total WOP EAD for Hominy Swamp Creek are just over $1 million.

Table 13. Hominy Swamp Creek FWOP EAD (Structures)

Reach	Residential	Commercial	Public	Total
HS1	$5	$40	$0	$45
HS2	$58	$31	$23	$112
HS3	$146	$158	$0	$304
HS4	$81	$68	$0	$149
HS5	$90	$70	$0	$160
HS6	$40	$40	$0	$80
HS7	$12	$13	$0	$25
HS8	$0	$0	$0	$0
Total	**$432**	**$420**	**$23**	**$875**

Note: values in $000s, FY23 price level

Table 14. Hominy Swamp Creek FWOP EAD (Other)

Reach	Auto	Clean-Up	Emergency	Total
HS1	$2	$4	$5	$11
HS2	$4	$6	$7	$17
HS3	$11	$10	$21	$42
HS4	$3	$5	$7	$15
HS5	$9	$10	$16	$35
HS6	$2	$4	$5	$11
HS7	$0	$0	$1	$1
HS8	$0	$0	$0	$0
Total	**$31**	**$39**	**$62**	**$132**

Note: values in $000s, FY23 price level

Table 15 displays the number of damaged structures and WOP expected damages by flood event along Hominy Swamp Creek. The 10 percent AEP event results in an expected $1.8 million in damages and approximately 82 impacted structures. The 0.2 percent AEP event results in an expected $33 million in damages and impacts approximately 239 structures.

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

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	6	$451	9	$1,028	10	$1,297	11	$2,099
HS2	15	$13	29	$451	38	$1,469	57	$8,710
HS3	16	$910	29	$2,738	35	$3,146	51	$5,419
HS4	18	$167	22	$1,741	23	$2,244	30	$6,246
HS5	9	$121	20	$353	21	$1,117	26	$6,826
HS6	12	$130	29	$535	34	$1,184	42	$3,001
HS7	6	$25	13	$246	19	$478	22	$850
HS8	0	$0	0	$0	0	$0	0	$0
Total	**82**	**$1,817**	**151**	**$7,092**	**180**	**$10,935**	**239**	**$33,152**

Note: values in $000s; FY23 price level

Table 17 display the WOP EAD for Crabtree Creek. Residential, commercial, and public structures account for $5.6 million in EAD, while other damages account for $526,000 annually. Total WOP EAD for Crabtree Creek are just over $6 million.

Table 16. Crabtree Creek FWOP EAD (Structures)

Reach	Residential	Commercial	Public	Total
CTC1	$1	$0	$0	$1
CTC2	$528	$4,122	$0	$4,650
CTC3	$3	$35	$0	$37
CTC4	$287	$375	$0	$662
CTC5	$57	$56	$0	$113
CTC6	$33	$110	$0	$143
CTC7	$11	$0	$0	$11
Total	**$919**	**$4,698**	**$0**	**$5,617**

Note: values in $000s; FY23 price level

Table 17. Crabtree Creek FWOP EAD (Other)

Reach	Auto	Clean-Up	Emergency	Total
CTC1	$0	$0	$0	$0
CTC2	$110	$146	$141	$397
CTC3	$10	$7	$16	$32
CTC4	$17	$16	$36	$69
CTC5	$3	$3	$7	$13
CTC6	$3	$3	$5	$10
CTC7	$1	$1	$2	$4
Total	**$144**	**$175**	**$206**	**$526**

Note: values in $000s; FY23 price level

Table 18 displays the number of damaged structures and expected damages by flood event along Crabtree Creek. The 10 percent AEP event results in an expected $5 million in damages and approximately 78 impacted structures. The 0.2 percent AEP event results in an expected $49 million in damages and impacts approximately 229 structures.

Table 18. Crabtree Creek FWOP 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	1	$0	1	$0	1	$0	1	$0
CTC2	12	$4,517	12	$4,517	12	$4,517	12	$4,517
CTC3	1	$42	6	$52	10	$59	18	$897
CTC4	51	$680	92	$6,866	105	$12,737	143	$25,558
CTC5	7	$49	24	$1,220	27	$2,429	33	$5,048
CTC6	5	$22	17	$386	17	$969	19	$13,067
CTC7	1	$42	2	$84	3	$98	3	$167
Total	**78**	**$5,351**	**154**	**$13,125**	**175**	**$20,809**	**229**	**$49,254**

Note: values in $000s; FY23 price level

Table 20 display the WOP EAD for Big Ditch. Residential, commercial, and public structures account for $1.5 million in EAD, while other damages account for $49,000 annually. Total EAD for Big Ditch are just over $1.6 million. Reaches BD4 and BD5 were included in the FDA model but do not meet the 800 cfs discharge criteria established in ER 1165-2-21. Expectedly, these reaches do not incur WOP damages. Structures in reaches BD1 and BD2 overlap with the Mainstem Neuse flood extent and are included in the tables below, but in analyzing the WP alternatives, these structures were included in mainstem reach MS5 since the mainstem source flooding produced higher flood depths.

Table 19. Big Ditch FWOP EAD (Structures)

Reach	Residential	Commercial	Public	Total
BD1	$172	$104	$1,143	$1,419
BD2	$66	$41	$0	$107
BD3	$30	$2	$0	$32
BD4	$0	$0	$0	$0
BD5	$0	$0	$0	$0
Total	**$268**	**$146**	**$1,144**	**$1,558**

Notes: values in $000s; FY23 price level

Table 20. Big Ditch FWOP EAD (Other)

Reach	Auto	Clean-Up	Emergency	Total
BD1	$6	$13	$22	$40
BD2	$1	$3	$4	$7
BD3	$0	$1	$1	$2
BD4	$0	$0	$0	$0
BD5	$0	$0	$0	$0
Total	**$6**	**$16**	**$27**	**$49**

Notes: values in $000s; FY23 price level

Table 21 displays the number of damaged structures and expected damages by flood event along Big Ditch. The 10 percent AEP event results in an expected $4 million in damages and approximately 179 impacted structures. The 2 percent AEP event results in an expected $6.8 million in damages and impacts approximately 212 structures.

Table 21. Big Ditch FWOP 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	69	$3,844	74	$6,019	77	$6,883	80	$9,016
BD2	101	$133	126	$671	138	$1,143	144	$2,833
BD3	9	$85	12	$188	12	$240	12	$374
BD4	0	$0	0	$0	0	$0	0	$0
BD5	0	$0	0	$0	0	$0	0	$0
Total	**179**	**$4,061**	**212**	**$6,878**	**227**	**$8,265**	**236**	**$12,223**

Note: values in $000s; FY23 price level

Table 22 and Table 23 display the FWOP EAD for the mainstem Neuse River. Residential, commercial, and public structures account for $17 million in EAD, while other damages account for approximately $2 million annually. Total FWOP EAD for the mainstem are just over $19 million. Damages in Reach MS1 were modeled in FDA but were removed from the study and will be analyzed as part of a separate study that will specifically focus on the coastal nature of the area in this reach.

Table 22. Mainstem Neuse River FWOP EAD (Structures)

Reach	Residential	Commercial	Public	Total
MS2	$1,112	$1,027	$13	$2,152
MS3	$1,263	$1,944	$119	$3,326
MS4	$1,375	$1,408	$734	$3,517
MS5	$1,549	$2,222	$2,381	$6,153
MS6	$447	$577	$239	$1,263
MS7	$246	$374	$0	$620
MS8	$23	$10	$48	$81
Total	**$6,015**	**$7,563**	**$3,534**	**$17,112**

Notes: values in $000s; FY23 price level

Table 23. Mainstem Neuse River FWOP EAD (Other)

Reach	Auto	Clean-Up	Emergency	Total
MS2	$52	$67	$133	$253
MS3	$117	$115	$210	$442
MS4	$125	$122	$224	$471
MS5	$129	$125	$229	$484
MS6	$48	$48	$89	$185
MS7	$28	$26	$45	$99
MS8	$3	$3	$5	$10
Total	**$503**	**$506**	**$935**	**$1,944**

Notes: values in $000s; FY23 price level

Table 24 displays the number of damaged structures and expected damages by flood event along mainstem Neuse River. The 10 percent AEP event results in an expected $6.8 million in damages and approximately 573 impacted structures. The 0.2 percent AEP event results in over $1 billion in expected damages and impacts approximately 7,500 structures. While the other models focus on smaller tributaries 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 FWOP Structure Damages and Count by AEP

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
MS2	254	$4,066	507	$12,420	609	$19,823	945	$69,882
MS3	181	$1,939	658	$31,388	1,027	$64,730	2,177	$205,723
MS4	0	$0	772	$39,005	1,339	$79,369	1,598	$197,289
MS5	0	$0	1,026	$53,377	1,390	$104,865	1,925	$456,711
MS6	100	$602	205	$8,527	294	$20,188	382	$55,136
MS7	35	$136	125	$4,055	156	$10,732	438	$44,347
MS8	3	$31	7	$138	23	$269	74	$9,069
Total	**573**	**$6,773**	**3,300**	**$148,910**	**4,838**	**$299,977**	**7,539**	**$1,038,156**

Note: values in $000s; FY23 price level

Table 25 shows aggregate FWOP damages by separable area. Total WOP damages near $28 million. Damages to structures and contents account for $25 million of that total, while other damage categories account for approximately $2.6 million.

Table 25. Neuse River Basin FWOP EAD

Stream	Structure & Content Damages	Other Damages	Total Damages
Hominy Swamp Creek	$875	$132	$1,007
Crabtree Creek	$5,617	$526	$6,143
Big Ditch	$1,558	$49	$1,607
Mainstem Neuse River	$17,112	$1,944	$19,056
Total	**$25,162**	**$2,651**	**$27,813**

Notes: values in $000s; FY23 price level; MS1 not included in estimates

4.3.2. FWOP Project Performance by Reach

WOP performance statistics help inform the risk of a flood event for a specific frequency. Three components are indicators of project performance: AEP, long-term exceedance probability (LTEP), and conditional non-exceedance probability (CNEP). AEP is the likelihood flooding occurs in any given year. LTEP is the probability that flooding occurs in a period of 10, 30, or 50 years. CNP, also called assurance, is the probability that flooding does not 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 display the project performance statistics by reach for each separable area under the WOP 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 occurrence of a 0.02, 0.01, or 0.002 AEP event.

Table 26. Hominy Swamp Creek FWOP Performance

Reach	Expected AEP	LTEP 10 Years	LTEP 30 Years	LTEP 50 Years	CNP 2%	CNP 1%	CNP 0.2%
HS1	1.00	1.00	1.00	1.00	0.00	0.00	0.00
HS2	0.37	0.99	1.00	1.00	0.00	0.00	0.00
HS3	0.88	1.00	1.00	1.00	0.00	0.00	0.00
HS4	0.39	0.99	1.00	1.00	0.00	0.00	0.00
HS5	1.00	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	0.23	0.93	1.00	1.00	0.02	0.02	0.01
HS8	0.11	0.68	0.97	1.00	0.17	0.12	0.03

Table 27 shows high probability of flooding in any given year in reaches CTC1, CTC2, 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 FWOP 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	1.00	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	1.00	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 FWOP Performance

Reach	Expected AEP	LTEP 10 Years	LTEP 30 Years	LTEP 50 Years	CNP 2%	CNP 1%	CNP 0.2%
BD1	0.31	0.97	1.00	1.00	0.12	0.10	0.06
BD2	1.00	1.00	1.00	1.00	0.00	0.00	0.00
BD3	0.84	1.00	1.00	1.00	0.00	0.00	0.00
BD4	0.00	0.00	0.00	0.01	0.87	0.70	0.46
BD5	0.00	0.00	0.00	0.01	0.87	0.72	0.48

Table 29 shows high probability of flooding in any given year in reaches MS2, MS3, MS4, and MS7. 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 MS6 for the 0.02 and 0.01 AEP events.

Table 29. Mainstem Neuse River FWOP Performance

Reach	Expected AEP	LTEP 10 Years	LTEP 30 Years	LTEP 50 Years	CNP 2%	CNP 1%	CNP 0.2%
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	1.00	1.00	1.00	1.00	0.00	0.00	0.00
MS5	0.09	0.62	0.95	0.99	0.10	0.09	0.02
MS6	0.05	0.41	0.79	0.93	0.23	0.15	0.03
MS7	1.00	1.00	1.00	1.00	0.00	0.00	0.00
MS8	0.82	1.00	1.00	1.00	0.00	0.00	0.00

4.4. Existing Without-Project Condition

Hydraulic modeling resulted in insignificant differences for projected impervious area changes between an existing and future condition for Big Ditch and Hominy Swamp Creek. As a result, existing conditions frequency simulation results were assumed to be representative of FWOP conditions, as described in Appendix A of this report. For this reason, existing WOP EAD are equivalent to the numbers shown above for Big Ditch and Hominy Swamp Creek. Existing EAD for Crabtree Creek and mainstem Neuse River are shown in this section.

4.4.1. Existing WOP EAD

This section presents existing condition WOP EAD estimates for Crabtree Creek and mainstem Neuse River. Table 30 and Table 31 show that existing WOP EAD is approximately $500,000 for Crabtree Creek. Flood depths for the FWOP condition are significantly higher than for the existing condition in Reach CTC2, which results in much lower EAD for the existing condition.

Table 30. Crabtree Creek Existing WOP EAD (Structures)

Reach	Residential	Commercial	Public	Total
CTC1	$0	$0	$0	$0
CTC2	$2	$24	$0	$26
CTC3	$1	$24	$0	$25
CTC4	$135	$176	$0	$311
CTC5	$25	$24	$0	$49
CTC6	$13	$17	$0	$30
CTC7	$4	$0	$0	$4
Total	**$181**	**$264**	**$0**	**$445**

Note: values in $000s; FY23 price level

Table 31. Crabtree Creek Existing WOP EAD (Other)

Reach	Auto	Clean-Up	Emergency	Total
CTC1	$0	$0	$0	$0
CTC2	$0	$1	$1	$2
CTC3	$7	$5	$14	$26
CTC4	$8	$8	$17	$32
CTC5	$1	$1	$3	$6
CTC6	$1	$1	$2	$4
CTC7	$1	$0	$1	$2
Total	**$18**	**$16**	**$38**	**$72**

Note: values in $000s; FY23 price level

Table 32 and Table 33 display existing WOP EAD for mainstem Neuse River, which totals approximately $17 million. Of this, structures and contents account for $15.6 million in damages, and other damages account for just under $2 million. Note that there is no difference in existing and future damages for Reaches MS3 through MS8. Most of the hydraulic differences between existing and FWOP flood depths occur in MS1 and MS2.

Table 32. Mainstem Neuse River Existing WOP EAD (Structures)

Reach	Residential	Commercial	Public	Total
MS2	$413	$246	$11	$669
MS3	$1,261	$1,941	$118	$3,321
MS4	$1,375	$1,408	$734	$3,517
MS5	$1,549	$2,222	$2,381	$6,153
MS6	$447	$577	$239	$1,263
MS7	$246	$374	$0	$620
MS8	$23	$10	$48	$81
Total	**$5,315**	**$6,778**	**$3,531**	**$15,624**

Notes: values in $000s; FY23 price level

Table 33. Mainstem Neuse River Existing WOP EAD (Other)

Reach	Auto	Clean-Up	Emergency	Total
MS2	$29	$34	$65	$128
MS3	$117	$114	$210	$441
MS4	$125	$122	$224	$471
MS5	$129	$125	$229	$484
MS6	$48	$48	$89	$185
MS7	$28	$26	$45	$99
MS8	$3	$3	$5	$10
Total	**$480**	**$473**	**$866**	**$1,819**

Notes: values in $000s; FY23 price level

4.4.2. Existing WOP Project Performance

The table below shows WOP performance for the existing condition for Crabtree Creek. AEP is lower in all reaches except for CTC1 than in the FWOP condition.

Table 34. Crabtree Creek Existing WOP 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	0.32	0.98	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	0.44	1.00	1.00	1.00	0.00	0.00	0.00
CTC5	0.34	0.98	1.00	1.00	0.00	0.00	0.00
CTC6	0.16	0.82	0.99	1.00	0.01	0.01	0.00
CTC7	0.12	0.72	0.98	1.00	0.04	0.03	0.00

Table 35 displays WOP performance for the existing condition for mainstem Neuse River. Project performance is nearly equivalent to the FWOP performance statistics for all reaches. This is largely because the major differences between existing and future conditions for the mainstem Neuse River hydraulics were in MS1, which, as stated above, was removed from this study and recommended for a separate study.

Table 35. Mainstem Neuse River Existing WOP Performance

Reach	Expected AEP	LTEP 10 Years	LTEP 30 Years	LTEP 50 Years	CNP 2%	CNP 1%	CNP 0.2%
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	0.09	0.62	0.95	0.99	0.10	0.09	0.02
MS5	0.05	0.41	0.79	0.93	0.23	0.15	0.03
MS6	1.00	1.00	1.00	1.00	0.00	0.00	0.00
MS7	0.82	1.00	1.00	1.00	0.00	0.00	0.00
MS8	0.16	0.82	0.99	1.00	0.02	0.02	0.00

4.5. Without-Project Equivalent Annual Damages

This section presents equivalent annual damages for the WOP condition for Crabtree Creek and mainstem Neuse River. Expected annual damages are interpolated between existing and future years and discounted back to present value to obtain equivalent annual damages. As previously noted, existing and future conditions are the same for Hominy Swamp and Big Ditch, and therefore WOP equivalent annual damages are the same as FWOP EAD for those areas, and only Crabtree Creek and Neuse River Mainstem are shown below. Equivalent annual damages are calculated using both the current federal discount rate of 2.5 percent, and the OMB rate of 7 percent.

Table 36. Crabtree Creek WOP Equivalent Annual Damages 2.5% (Structures)

Reach	Residential	Commercial	Public	Total
CTC1	$0	$0	$0	$0
CTC2	$207	$1,621	$0	$1,828
CTC3	$2	$28	$0	$30
CTC4	$194	$253	$0	$448
CTC5	$38	$36	$0	$74
CTC6	$21	$53	$0	$74
CTC7	$7	$0	$0	$7
Total	**$468**	**$1,992**	**$0**	**$2,460**

Note: values in $000s; FY23 price level

Table 36 and Table 37 show that equivalent annual damages calculated at the current discount rate of 2.5 percent are nearly $3 million in Crabtree Creek. Reach CTC2 accounts for most of these damages.

Table 37. Crabtree Creek WOP Equivalent Annual Damages 2.5% (Other)

Reach	Auto	Clean-Up	Emergency	Total
CTC1	$0	$0	$0	$0
CTC2	$43	$58	$55	$156
CTC3	$8	$6	$14	$28
CTC4	$11	$11	$25	$47
CTC5	$2	$2	$4	$8
CTC6	$2	$2	$3	$6
CTC7	$1	$1	$1	$3
Total	**$67**	**$78**	**$103**	**$249**

Note: values in $000s; FY23 price level

Table 38 and Table 39 display equivalent annual damages calculated at discount rate of 7 percent. Total equivalent annual damages are just under $2 million at this discount rate, with damages to structures and contents accounting for $1.7 million.

Table 38. Crabtree Creek WOP Equivalent Annual 7% (Structures)

Reach	Residential	Commercial	Public	Total
CTC1	$0	$0	$0	$0
CTC2	$134	$1,050	$0	$1,184
CTC3	$1	$27	$0	$28
CTC4	$173	$226	$0	$399
CTC5	$33	$32	$0	$65
CTC6	$18	$40	$0	$58
CTC7	$6	$0	$0	$6
Total	**$366**	**$1,375**	**$0**	**$1,741**

Note: values in $000s; FY23 price level

Table 39. Crabtree Creek WOP Equivalent Annual Damages 7% (Other)

Reach	Auto	Clean-Up	Emergency	Total
CTC1	$0	$0	$0	$0
CTC2	$28	$37	$36	$101
CTC3	$8	$5	$14	$27
CTC4	$10	$10	$22	$42
CTC5	$2	$2	$4	$7
CTC6	$1	$1	$3	$5
CTC7	$1	$0	$1	$2
Total	**$50**	**$56**	**$80**	**$186**

Note: values in $000s; FY23 price level

Table 40 and Table 41 show WOP equivalent annual damages calculated at the current federal discount rate of 2.5 percent for the mainstem Neuse River. These damages exceed $18 million.

Table 40. Mainstem Neuse River WOP Equivalent Annual Damages 2.5% (Structures)

Reach	Residential	Commercial	Public	Total
MS2	$685	$550	$12	$1,247
MS3	$1,262	$1,942	$118	$3,323
MS4	$1,375	$1,408	$734	$3,517
MS5	$1,549	$2,222	$2,381	$6,153
MS6	$447	$577	$239	$1,263
MS7	$246	$374	$0	$620
MS8	$23	$10	$48	$81
Total	**$5,588**	**$7,084**	**$3,532**	**$16,204**

Notes: values in $000s; FY23 price level

Table 41. Mainstem Neuse River WOP Equivalent Annual Damages 2.5% (Other)

Reach	Auto	Clean-Up	Emergency	Total
MS2	$38	$47	$91	$176
MS3	$117	$115	$210	$442
MS4	$125	$122	$224	$471
MS5	$129	$125	$229	$484
MS6	$48	$48	$89	$185
MS7	$28	$26	$45	$99
MS8	$3	$3	$5	$10
Total	**$489**	**$486**	**$893**	**$1,868**

Notes: values in $000s; FY23 price level

Table 42 and 43 display WOP equivalent annual damages at the 7 percent discount rate. Since damages are the same for the existing and WOP conditions for reaches MS4 through MS8, equivalent annual damage calculations at 7 percent are the same as equivalent annual damages at 2.5 percent for these reaches. Damages for MS2 are approximately $200,000 lower when calculated using a 7 percent discount rate.

Table 42. Mainstem Neuse River WOP Equivalent Annual Damages 7% (Structures)

Reach	Residential	Commercial	Public	Total
MS2	$588	$441	$11	$1,041
MS3	$1,262	$1,942	$118	$3,322
MS4	$1,375	$1,408	$734	$3,517
MS5	$1,549	$2,222	$2,381	$6,153
MS6	$447	$577	$239	$1,263
MS7	$246	$374	$0	$620
MS8	$23	$10	$48	$81
Total	**$5,491**	**$6,975**	**$3,531**	**$15,997**

Notes: values in $000s; FY23 price level

Table 43. Mainstem Neuse River WOP Equivalent Annual Damages 7% (Other)

Reach	Auto	Clean-Up	Emergency	Total
MS2	$35	$42	$82	$159
MS3	$117	$115	$210	$441
MS4	$125	$122	$224	$471
MS5	$129	$125	$229	$484
MS6	$48	$48	$89	$185
MS7	$28	$26	$45	$99
MS8	$3	$3	$5	$10
Total	**$486**	**$481**	**$883**	**$1,850**

Notes: values in $000s; FY23 price level

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 and plan. The difference between the WOP condition equivalent annual damages and the WP equivalent annual damages for each alternative represents the damages reduced, or benefits, of the plan. Damages calculated in HEC-FDA are based on physical inundation reduction to homes, businesses, and 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 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 that these plans were not viable. Additionally, combinations of structural and nonstructural measures were evaluated, and none were economically viable.

During the refinement of the TSP, hydraulic engineering, cost engineering, and subsequent economic modeling changes largely driven by Agency Technical Review (ATR) comments resulted in a smaller footprint being included in the nonstructural plan (Alternative 2). Initially this plan included dry floodproofing and elevation of structures in Hominy Swamp Creek, Crabtree Creek, Big Ditch, and the mainstem Neuse River. Once engineering outputs and costs were finalized, the footprint was reduced to include only Crabtree Creek, which was the only area that could be economically included. It is important to note that all four separable areas were analyzed for nonstructural elevations and floodproofing.

5.2. Description of Final Array of Alternatives

This section describes the final array of alternatives. The WOP 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 includes dry floodproofing for 12 structures in Crabtree Creek. To evaluate which structures should be recommended for elevation or floodproofing, structures in each of the four separable areas (Hominy Swamp Creek, Crabtree Creek, Big Ditch, and mainstem Neuse River) were aggregated by reach and by AEP event. The cost of floodproofing or elevating a structure was compared to damages reduced by elevating or floodproofing to determine the most appropriate floodproofing method. Structures were then aggregated by AEP event floodplain for the 10-, 4-, 2- and 1-percent AEP events and aggregated by flood event and reach. Without-project damages were initially 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 examined additional flood elevation levels was conducted after the TSP (tentatively selected plan) milestone and analyzed elevating structures to the 50-year plus 2 feet flood elevation. There was no significant difference in recommendations for any of the separable areas when analyzing this elevation. Therefore, the 100-year flood elevation plus 2 feet remained the target floodproofing elevation.

With-project (floodproofed/elevated) first floor elevations were then adjusted in HEC-FDA to compute WP 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, and the final plan is labeled as WP. 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 elevating 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 comply with local and state codes.

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 buildings 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.

The final iteration of Alternative 2 includes dry floodproofing twelve structures in Crabtree Creek. This summary is shown in Table 44.

Table 44. Alternative 2 Nonstructural Measure Summary

Reach	AEP Event	Elevated Structures	Floodvent Structures	Dry Floodproofed Structures	Total Structures
CTC2	0.01	0	0	12	12

Table 45 displays structure characteristics for structures included in Alternative 2. Of the twelve structures included in the alternative, ten are multi-family residences, one is an office, and one is a restaurant. All structures are in Reach CTC2 and are damaged by at least the 0.10 AEP event.

Table 45. Alternative 2 Structure Summary

Building ID	Damage Category	Occupancy Type	Square Footage	Depreciated Replacement Value
37183147937	COM	Commercial/Office	1,782	$ 185,000
37183149886	COM	Multi-Family	11,500	$ 957,000
37183150767	COM	Multi-Family	14,850	$ 1,229,000
37183150923	COM	Multi-Family	11,340	$ 785,000
37183151005	COM	Multi-Family	11,340	$ 785,000
37183151167	COM	Multi-Family	10,836	$ 750,000
37183151502	COM	Multi-Family	22,428	$ 1,552,000
37183151676	COM	Multi-Family	11,500	$ 957,000
37183152164	COM	Multi-Family	21,672	$ 1,501,000
37183152170	COM	Multi-Family	11,500	$ 957,000
37183152384	COM	Multi-Family	7,700	$ 637,000
37183153451	COM	Restaurant	10,723	$ 1,459,000

5.2.2. Alternative 3

Alternative 3 is a buyout/acquisition plan that includes buying out 156 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 of these areas is provided in Table 46.

Table 46. Alternative 3 Measure Summary

Buyout Polygon Area	Reach	Structure Count 0.10 AEP Event
Kinston NS-1	MS3	53
Goldsboro NS-4	MS5, BD1, BD2	50
Wilson NS-1	HS1-HS7	23
Total		**126**

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 costs for buyout and acquisition. Structures damaged by the 10 percent AEP event in these areas were kept in the final array since this maximized net NED benefits. Following the Agency Technical Review, this alternative was evaluated using costs from the Total Project Cost Summary (TPCS) obtained from cost engineering.

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 BCR 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 does not have a wide overbank extent, limiting the initial WOP 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 FWOP and FWP 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 Damages and Benefit Summaries

This section displays the WP damages and benefits for the final array of alternatives. With-project benefits for both Alternative 2 and Alternative 3 assume 100 percent participation. A sensitivity analysis was conducted that analyzed 75 and 50 percent participation and didn't change total net benefits significantly since the benefits and costs decreased proportionally with the number of properties that were excluded.

5.3.1. Alternative 2 With-Project EAD

Expected annual damages for the WP and FWP conditions are the basis for calculating equivalent annual benefits and are presented in this section. Since Alternative 2 only includes reach CTC2, EAD for all other reaches are equivalent for both the WOP and WP conditions.

Table 47 and Table 48 show that existing condition EAD in CTC2 decrease to $5,000 (from $28,000) with the implementation of the project.

Table 47. Alternative 2 WP EAD Existing Condition (Structures)

Reach	Residential	Commercial	Public	Total
CTC1	$0	$0	$0	$0
CTC2	$0	$4	$0	$4
CTC3	$1	$24	$0	$25
CTC4	$135	$176	$0	$311
CTC5	$25	$24	$0	$49
CTC6	$13	$17	$0	$30
CTC7	$4	$0	$0	$4
Total	**$178**	**$245**	**$0**	**$423**

Table 48. Alternative 2 WP EAD Existing Condition (Other)

Reach	Auto	Clean-Up	Emergency	Total
CTC1	$0	$0	$0	$0
CTC2	$0	$0	$0	$1
CTC3	$7	$5	$14	$26
CTC4	$8	$8	$17	$32
CTC5	$1	$1	$3	$6
CTC6	$1	$1	$2	$4
CTC7	$1	$0	$1	$2
Total	**$18**	**$15**	**$37**	**$70**

Note: values in $000s; FY23 price level

Table 49 and Table 50 show that WP future EAD in CTC2 are over $3.5 million, a decrease from $5 million in the absence of the project. Damages in all other reaches do not change with the project in place.

Table 49. Alternative 2 WP EAD Future Condition (Structures)

Reach	Residential	Commercial	Public	Total
CTC1	$1	$0	$0	$1
CTC2	$0	$3,291	$0	$3,291
CTC3	$3	$35	$0	$37
CTC4	$287	$375	$0	$662
CTC5	$57	$56	$0	$113
CTC6	$33	$110	$0	$143
CTC7	$11	$0	$0	$11
Total	**$391**	**$3,867**	**$0**	**$4,259**

Table 50. Alternative 2 WP EAD Future Condition (Other)

Reach	Auto	Clean-Up	Emergency	Total
CTC1	$0	$0	$0	$0
CTC2	$114	$108	$74	$295
CTC3	$10	$7	$16	$32
CTC4	$17	$16	$36	$69
CTC5	$3	$3	$7	$13
CTC6	$3	$3	$5	$10
CTC7	$1	$1	$2	$4
Total	**$147**	**$137**	**$140**	**$424**

Note: values in $000s; FY23 price level

5.3.2. Alternative 2 Equivalent Annual Benefits

Equivalent annual benefits are the damages reduced by implementing the project. They are calculated by taking the difference between the equivalent annual WOP and equivalent annual WP damages. Equivalent annual damages are calculated by interpolating between the existing and future EAD estimates and discounting back to present value. Equivalent annual benefits calculated at the current federal discount rate of 2.5 percent and the OMB rate of 7 percent are shown below.

Table 51. Alternative 2 Equivalent Annual Benefits 2.5%

Reach	Structure and Contents	Other Related Damages	Total
CTC1	$0	$0	$0
CTC2	$542	$41	$583
CTC3	$0	$0	$0
CTC4	$0	$0	$0
CTC5	$0	$0	$0
CTC6	$0	$0	$0
CTC7	$0	$0	$0
Total	**$542**	**$41**	**$583**

Note: values in $000s; FY23 price level

Table 51 shows that equivalent annual benefits for Alternative 2 are $583,000 when calculated at a discount rate of 2.5 percent. Table 52 shows that equivalent annual benefits for the same alternative are $383,000 using a discount rate of 7 percent.

Table 52. Alternative 2 Equivalent Annual Benefits 7%

Reach	Structure and Contents	Other Related Damages	Total
CTC1	$0	$0	$0
CTC2	$356	$27	$383
CTC3	$0	$0	$0
CTC4	$0	$0	$0
CTC5	$0	$0	$0
CTC6	$0	$0	$0
CTC7	$0	$0	$0
Total	**$356**	**$27**	**$383**

Note: values in $000s; FY23 price level

5.3.3. Alternative 2 Residual Equivalent Annual Damages

Table 53 and Table 54 display residual damages that occur under the WP condition. Residual equivalent annual damages for Alternative 2 are approximately $2 million in Crabtree Creek using a discount rate of 2.5 percent and $1.5 million using a discount rate of 7 percent. Without-project damages for all other separable areas are equivalent to residual damages for Alternative 2 since no project is implemented in these areas.

Table 53. Alternative 2 Residual Equivalent Annual Damages 2.5%

Reach	Structure and Contents	Other Related Damages	Total
CTC1	$0	$0	$0
CTC2	$1,285	$116	$1,401
CTC3	$30	$28	$58
CTC4	$448	$47	$494
CTC5	$74	$8	$82
CTC6	$74	$6	$80
CTC7	$7	$3	$10
Total	**$1,918**	**$208**	**$2,126**

Note: values in $000s; FY23 price level

Table 54. Alternative 2 Residual Equivalent Annual Damages 7%

Reach	Structure and Contents	Other Related Damages	Total
CTC1	$0	$0	$0
CTC2	$828	$75	$903
CTC3	$28	$27	$55
CTC4	$399	$42	$440
CTC5	$65	$7	$72
CTC6	$58	$5	$64
CTC7	$6	$2	$9
Total	**$1,384**	**$159**	**$1,543**

Note: values in $000s; FY23 price level

5.3.4. Alternative 3 With-Project EAD

This section presents WP EAD for Alternative 3. Potential buyout areas were delineated prior to HEC-RAS/FDA models being completed. Therefore, they cover multiple modeling reaches. Associated reaches for the buyout areas are displayed below.

Table 55. Alternative 3 Buyout Areas and Reaches

Area	Reaches
Hominy Swamp Creek (HS-NS4)	HS1-HS7
Big Ditch (BD-NS2)	BD1, BD2
Mainstem (MS-NS3)	MS3, MS5

Table 56 and Table 57 show that WP EAD in Big Ditch total nearly $1.3 million with Alternative 3 in place. This number is equivalent to residual damages.

Table 56. Big Ditch Alternative 3 Future Condition EAD (Structures)

Reach	Residential	Commercial	Public	Total
BD1	$52	$51	$1,164	$1,267
BD2	$0	$0	$0	$0
BD3	$0	$0	$0	$0
BD4	$0	$0	$0	$0
BD5	$0	$0	$0	$0
Total	**$52**	**$51**	**$1,164**	**$1,267**

Notes: values in $000s; FY23 price level

Table 57. Big Ditch Alternative 3 Future Condition EAD (Other)

Reach	Auto	Clean-Up	Emergency	Total
BD1	$1	$6	$6	$12
BD2	$0	$0	$0	$0
BD3	$0	$0	$0	$0
BD4	$0	$0	$0	$0
BD5	$0	$0	$0	$0
Total	**$1**	**$6**	**$6**	**$12**

Notes: values in $000s; FY23 price level

Table 58 and Table 59 show that WP EAD in Hominy Swamp Creek total nearly $500,000 with Alternative 3 in place. This number is equivalent to residual damages.

Table 58. Hominy Swamp Creek Alternative 3 Future Condition EAD (Structures)

Reach	Residential	Commercial	Public	Total
HS1	$24	$0	$0	$24
HS2	$58	$31	$23	$112
HS3	$32	$8	$0	$40
HS4	$44	$55	$0	$100
HS5	$14	$66	$0	$79
HS6	$16	$40	$0	$57
HS7	$12	$1	$0	$13
HS8	$0	$0	$0	$0
Total	**$201**	**$201**	**$23**	**$425**

Note: values in $000s, FY23 price level

Table 59. Hominy Swamp Creek Alternative 3 Future Condition EAD (Other)

Reach	Auto	Clean-Up	Emergency	Total
HS1	$1	$1	$1	$3
HS2	$4	$6	$7	$18
HS3	$3	$3	$5	$11
HS4	$2	$3	$3	$8
HS5	$1	$1	$2	$4
HS6	$1	$2	$3	$6
HS7	$0	$0	$1	$1
HS8	$0	$0	$0	$0
Total	**$11**	**$16**	**$23**	**$51**

Note: values in $000s, FY23 price level

Table 60 and Table 61 show EAD for the future condition with Alternative 3 in place. Alternative 3 WP EAD are approximately $17 million.

Table 60. Mainstem Neuse River Alternative 3 Future Condition EAD (Structures)

Reach	Residential	Commercial	Public	Total
MS2	$1,112	$1,027	$13	$2,152
MS3	$1,223	$1,829	$50	$3,102
MS4	$1,375	$1,408	$734	$3,517
MS5	$1,514	$2,216	$1,077	$4,807
MS6	$447	$577	$239	$1,263
MS7	$246	$374	$0	$620
MS8	$23	$10	$48	$81
Total	**$5,939**	**$7,442**	**$2,161**	**$15,542**

Notes: values in $000s; FY23 price level

Table 61. Mainstem Neuse River Alternative 3 Future Condition EAD (Other)

Reach	Auto	Clean-Up	Emergency	Total
MS2	$52	$67	$133	$253
MS3	$117	$115	$210	$441
MS4	$125	$122	$224	$471
MS5	$129	$125	$228	$481
MS6	$48	$48	$89	$185
MS7	$28	$26	$45	$99
MS8	$3	$3	$5	$10
Total	**$502**	**$506**	**$933**	**$1,941**

Notes: values in $000s; FY23 price level

Table 62 and 63 display EAD for the existing condition with Alternative 3 in place. EAD for this condition are approximately $16 million.

Table 62. Mainstem Neuse River Alternative 3 Existing Condition EAD (Structures)

Reach	Residential	Commercial	Public	Total
MS2	$413	$246	$11	$669
MS3	$1,221	$1,826	$49	$3,096
MS4	$1,375	$1,408	$734	$3,517
MS5	$1,514	$2,217	$1,077	$4,807
MS6	$447	$577	$239	$1,263
MS7	$246	$374	$0	$620
MS8	$23	$10	$48	$81
Total	**$5,239**	**$6,658**	**$2,157**	**$14,054**

Notes: values in $000s; FY23 price level

Table 63. Mainstem Neuse River Alternative 3 Existing Condition EAD (Other)

Reach	Auto	Clean-Up	Emergency	Total
MS2	$29	$34	$65	$128
MS3	$117	$114	$209	$441
MS4	$125	$122	$224	$471
MS5	$129	$125	$228	$481
MS6	$48	$48	$89	$185
MS7	$28	$26	$45	$99
MS8	$3	$3	$5	$10
Total	**$479**	**$472**	**$865**	**$1,816**

Notes: values in $000s; FY23 price level

5.3.5. Alternative 3 With-Project Benefits

This section presents the WP average annual benefits for Alternative 3 by separable area. These benefits include the damages reduced by removing the structures in the buyout areas indicated. For Big Ditch and Hominy Swamp, benefits are equivalent at the 2.5 percent and 7 percent discount rates since existing and future conditions are the same. In mainstem Neuse River, damages are shown at the 2.5 percent and 7 percent discount rates since existing and FWOP hydraulic conditions differ.

Table 64. Big Ditch Alternative 3 Equivalent Annual Benefits

Reach	Structure and Contents	Other Related Damages	Total
BD1	$152	$28	$180
BD2	$107	$7	$114
BD3	$32	$2	$33
BD4	$0	$0	$0
BD5	$0	$0	$0
Total	**$291**	**$37**	**$328**

Note: values in $000s, FY23 price level

Average annual benefits with Alternative 3 in place are approximately $328,000 in Big Ditch and $525,00 in Hominy Swamp Creek.

Table 65. Hominy Swamp Creek Alternative 3 Equivalent Annual Benefits

Reach	Structure and Contents	Other Related Damages	Total
HS1	$21	$0	$21
HS2	$0	$0	$0
HS3	$264	$31	$295
HS4	$49	$7	$57
HS5	$81	$31	$112
HS6	$23	$5	$28
HS7	$12	$0	$12
HS8	$0	$0	$0
Total	**$450**	**$74**	**$525**

Note: values in $000s, FY23 price level

Benefits are the same at 2.5 and 7 percent discount rates for Big Ditch and Hominy Swamp Creek since existing and FWOP conditions are equivalent. In mainstem Neuse River, although existing and future conditions are different, benefits are the same at 2.5 percent and 7 percent because there are no differences in hydraulic conditions in the reaches that incur benefits. Table 66 and Table 67 show that equivalent annual benefits are approximately $1.6 million at both discount rates in mainstem Neuse River reaches.

Table 66. Mainstem Neuse River Alternative 3 Equivalent Annual Benefits 2.5%

Reach	Structure and Contents	Other Related Damages	Total
MS2	$0	$0	$0
MS3	$224	$0	$225
MS4	$0	$0	$0
MS5	$1,346	$3	$1,348
MS6	$0	$0	$0
MS7	$0	$0	$0
MS8	$0	$0	$0
Total	**$1,570**	**$3**	**$1,573**

Note: values in $000s, FY23 price level

Table 67. Mainstem Neuse River Alternative 3 Equivalent Annual Benefits 7%

Reach	Structure and Contents	Other Related Damages	Total
MS2	$0	$0	$0
MS3	$224	$0	$225
MS4	$0	$0	$0
MS5	$1,346	$3	$1,348
MS6	$0	$0	$0
MS7	$0	$0	$0
MS8	$0	$0	$0
Total	**$1,570**	**$3**	**$1,573**

Note: values in $000s, FY23 price level

Table 68 displays total WP average annual benefits for Alternative 3. Equivalent average annual benefits are the same at the 2.5 percent and 7 percent discount rates for all areas and total $2.4 million.

Table 68. Equivalent Annual Benefits Alternative 3

Area	Alternative 3 Average Annual Benefits 2.5%	Alternative 3 Average Annual Benefits 7%
Hominy Swamp Creek	$525	$525
Big Ditch	$328	$328
Mainstem	$1,573	$1,573
Total	**$2,426**	**$2,426**

Note: values in $000s; FY23 price level

5.3.6. Alternative 3 Residual Equivalent Annual Damages

Residual damages are the damages that occur with the alternative in place. These damages are shown by damage category and reach and are summarized by basin in this section. At the 2.5 percent discount rate, residual equivalent annual damages for Alternative 3 are approximately $18.2 million. This number is approximately $18 million at the 7 percent discount rate. The magnitude between these numbers is small due to equivalent existing and future hydraulic conditions in Hominy Swamp Creek and Big Ditch and equivalent existing and future conditions in reaches MS4-MS8 along the mainstem Neuse River.

Table 69. Alternative 3 Residual Equivalent Annual Damages 2.5%

Area	Structure and Contents	Other Related Damages
Hominy Swamp Creek	$425	$59
Big Ditch	$1,267	$12
Mainstem	$14,634	$1,865
Total	**$16,326**	**$1,936**

Note: values in $000s; FY23 price level

Table 70. Alternative 3 Residual Equivalent Annual Damages 7%

Area	Structure and Contents	Other Related Damages
Hominy Swamp Creek	$425	$59
Big Ditch	$1,267	$12
Mainstem	$14,427	$1,847
Total	**$16,119**	**$1,918**

Note: values in $000s; FY23 price level

5.4. 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 Alternative 2 were initially 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 floodproofing was computed for a three-month period at 2.5 and 7 percent.

Costs for Alternative 3 were prepared by Real Estate and Cost Engineering and include demolition costs, the market value cost of the structure and land, and contingency. A TPCS was prepared by Cost Engineering. For buyouts, IDC was computed for a three-month period at 2.5 and 7 percent.

All costs are in FY23 price levels and reflect a project life cycle of 50 years at the current discount rate of 2.5 percent and the OMB discount rate of 7 percent. Total project first costs for Alternative 2 are approximately $6.6 million, and average annual costs are $230,000 at 2.5 percent and $480,000 at 7 percent. Total project costs for Alternative 3 are approximately $116 million, and average annual costs are roughly $4 million at 2.5 percent and $8.6 million at 7 percent.

Table 71. Costs by Alternative 2.5%

	Alternative 2 Nonstructural Floodproofing	Alternative 3 Buyouts/Acquisitions
Construction Cost		
Hominy Swamp Creek		$6,300
Crabtree Creek	$4,200	
Big Ditch		$10,800
Mainstem Neuse River		$32,900
Subtotal Project Firsts Costs	$4,200	$50,000
Lands and Damages	$1,200	$51,600
Planning, Engineering, and Design	$700	$7,500
Construction Management	$500	$7,500
Total Project First Costs	$6,600	$116,600
Interest During Construction	$10	$1,000
Total Gross Investment	$6,610	$117,600
Average Annual Cost	**$230**	**$4,100**

Notes: values in $000s; FY23 price level; FY23 discount rate of 2.5%; 50-year period of analysis

Table 72. Costs by Alternative 7%

	Alternative 2 Nonstructural Floodproofing	Alternative 3 Buyouts/Acquisitions
Construction Cost		
Hominy Swamp Creek		$6,300
Crabtree Creek	$4,200	
Big Ditch		$10,800
Mainstem Neuse River		$32,900
Subtotal Project Firsts Costs	$4,200	$50,000
Lands and Damages	$1,200	$51,600
Planning, Engineering, and Design	$700	$7,500
Construction Management	$500	$7,500
Total Project First Costs	$6,600	$116,600
Interest During Construction	$40	$2,700
Total Gross Investment	$6,640	$119,300
Average Annual Cost	**$480**	**$8,600**

Notes: values in $000s; FY23 price level; FY23 discount rate of 7%; 50-year period of analysis

5.5. 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. 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 BCR, 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 BCR 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 73 shows that Alternative 2 results in net NED benefits of $350,000, while Alternative 3 results in net NED benefits of -$1.7 million. Alternative 2 is therefore the plan that maximizes net NED benefits, also known as the NED plan. Note that initially Alternative 2 included structures in Hominy Swamp Creek and Mainstem Neuse River. Cost increases resulted in negative net benefits and the removal of these areas from the alternative. Annual benefits for Alternative 3 are the same at both discount rates since there is no change between existing and future conditions in reaches that are included in this alternative.

Table 73. Net Benefit Comparison 2.5%

Category	Alternative 2	Alternative 3
Annual Benefits	$580	$2,400
Hominy Swamp Creek		$500
Crabtree Creek	$580	
Big Ditch		$300
Mainstem Neuse River		$1,600
Annual Costs	$230	$4,100
Net Annual Benefits	**$350**	**-$1,700**

Notes: values in $000s; FY23 price level; FY23 discount rate of 2.5%; 50-year period of analysis

Table 74. Net Benefit Comparison 7%

Category	Alternative 2	Alternative 3
Annual Benefits	$380	$2,400
Hominy Swamp Creek		$500
Crabtree Creek	$380	
Big Ditch		$300
Mainstem Neuse River		$1,600
Annual Costs	$480	$8,600
Net Annual Benefits	**$-100**	**-$6,200**

Notes: values in $000s; FY23 price level; FY23 discount rate of 2.5%; 50-year period of analysis

Table 75 displays average annual costs and benefits and the BCR. The BCR is 2.5 for Alternative 2 at the current discount rate of 2.5 percent and is 0.6 for Alternative 3 at the same discount rate. Alternative 2 maximizes net benefits and is the NED Plan.

Table 75. Benefit Cost Analysis 2.5%

	Alternative 2	Alternative 3
Annual Cost	$230	$4,100
Annual Benefits	$580	$2,400
Net Annual Benefits	$350	-$1,700
Benefit to Cost Ratio	**2.5**	**0.6**

Notes: values in $000s; FY23 price level; FY23 discount rate of 2.5%; 50-year period of analysis

5.5.1. Benefit and Cost Distributions

This section displays the distribution of damage reduced for the NED Plan (Alternative 2). At the discount rate of 2.5 percent, there is a 75 percent chance that damages reduced will exceed $568,000 and a 25 percent chance that damages reduced will exceed $594,000.

Table 76. Equivalent Annual Damage Reduced Distribution NED Plan, 2.5%

Reach	WOP EAD	With Project	Damage Reduced	Probability Damage Reduced Exceeds Indicated Value		
				0.75	0.50	0.25
CTC1	$0	$0	$0	$0	$0	$0
CTC2	$1,984	$1,401	$583	$568	$591	$594
CTC3	$58	$58	$0	$0	$0	$0
CTC4	$494	$494	$0	$0	$0	$0
CTC5	$82	$82	$0	$0	$0	$0
CTC6	$80	$80	$0	$0	$0	$0
CTC7	$10	$10	$0	$0	$0	$0
Total	**$2,709**	**$2,126**	**$583**	**$568**	**$591**	**$594**

Note: values in $000s; FY23 price level

At the discount rate of 7 percent, there is a 75 percent chance that damages reduced will exceed $380,000 and a 25 percent chance that damages reduced will exceed $385,000.

Table 77. Equivalent Annual Damage Reduced Distribution NED Plan, 7%

Reach	WOP EAD	With Project	Damage Reduced	Probability Damage Reduced Exceeds Indicated Value		
				0.75	0.50	0.25
CTC1	$0	$0	$0	$0	$0	$0
CTC2	$1,286	$903	$383	$380	$381	$385
CTC3	$55	$55	$0	$0	$0	$0
CTC4	$440	$440	$0	$0	$0	$0
CTC5	$73	$73	$0	$0	$0	$0
CTC6	$64	$64	$0	$0	$0	$0
CTC7	$9	$9	$0	$0	$0	$0
Total	**$1,927**	**$1,543**	**$383**	**$380**	**$381**	**$385**

Note: values in $000s; FY23 price level

Tables 78 and 79 display the distribution of benefits and costs for the NED Plan calculated at 2.5 percent and 7 percent, respectively. Note that costs are static. There is a 75 percent chance that the BCR exceeds 2.4 and a 25 percent chance that the BCR exceeds 2.5 when calculated at a discount rate of 2.5 percent.

Table 78. Benefit-Cost Distribution NED Plan, 2.5%

Category		Probability Benefits Exceed Indicated Value		
		0.75	0.5	0.25
Average Equivalent Annual Benefits	$580	$570	$590	$590
Average Annual Costs	$230	$230	$230	$230
Net Annual Benefits	$350	$340	$360	$360
Benefit-Cost Ratio	**2.5**	**2.4**	**2.5**	**2.5**

Note: values in $000s; FY23 price level

Table 79 shows that there is a 75 percent chance that the BCR of the NED Plan exceeds 0.8 and a 25 percent chance that the BCR exceeds 0.8 when calculated at a discount rate of 7 percent.

Table 79. Benefit-Cost Distribution NED Plan, 7%

Category		Probability Benefits Exceed Indicated Value		
		0.75	0.5	0.25
Average Equivalent Annual Benefits	$380	$380	$380	$390
Average Annual Costs	$480	$480	$480	$480
Net Annual Benefits	-$100	-$100	-$100	-$90
Benefit-Cost Ratio	**0.8**	**0.8**	**0.8**	**0.8**

Note: values in $000s; FY23 price level

5.5.2. Participation Rate

The benefit-cost analysis assumes a 100 percent participation rate for the NED Plan. Since nonstructural measures under this alternative are voluntary, actual implementation will depend on whether home and business owners decide to participate in the project. There was no available data for participation rates for similar projects in the region at the time this study was conducted. As a result, a sensitivity analysis using a 50 percent and 75 percent participation rate was used to estimate whether the project would still be justified.

To analyze each separable area, structures in the NED Plan were assigned a variable using a random number generator then sorted by that random number. Structures in the 75th and 50th percentiles of the random number variable were selected for participation. In Crabtree Creek, Alternative 2 was still justified.

Alternative 3 assumes a 100 percent participation rate since acquisitions recommended by USACE are non-voluntary.

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, FRM studies must include a life safety study objective, and the decision document should describe OSE.

6.1. Life Safety

In accordance with ER 1105-2-101, life loss qualifies as an OSE category. A life safety analysis includes the estimation of the PAR and associated statistical parameters for life loss. For this analysis, life loss was calculated using LifeSim 2.0 for the FWOP condition and existing WOP condition (if applicable) for the following 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 existing WOP and FWOP quantify life safety risk during flood events at various flood frequencies. The LifeSim results across each of the flood frequency events capture existing and future life safety risk within the basin. Inputs, assumptions, modeling results, and average annual life loss calculations are detailed in subsequent sections. The inclusion of structural measures could transform risk or transfer risk to other areas within the basin. Structural WP alternatives were modeled in LifeSim, but as noted previously in this report, these alternatives were removed from the study due to lack of economic viability. It is estimated that the nonstructural NED Plan of floodproofing would have limited impact on life loss, so life loss estimates were not simulated for this plan. Existing WOP and FWOP life loss estimates are shown in this section.

Table 80. LifeSim Structural Alternatives Modeled

Separable Area	Conditions Modeled	
Hominy Swamp Creek	FWOP	n/a
Crabtree Creek	FWOP	Existing WOP
Big Ditch	FWOP	n/a
Mainstem Neuse River	FWOP	Existing WOP

6.1.1. Data Sources and Input Parameters

Each of the four LifeSim models utilize the same structure inventory inputs and uncertainty parameters. 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 indexed using 2017 county growth estimates.

Structure placement and structure attributes in the LifeSim model will not exactly match the structure placement and structure attributes used in the HEC-FDA modeling. The number of structures inundated by event and alternative will vary between the HEC-FDA model and the LifeSim model. 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 18; the real-world actions are shown in blue, and the corresponding LifeSim model parameters are shown below in white.

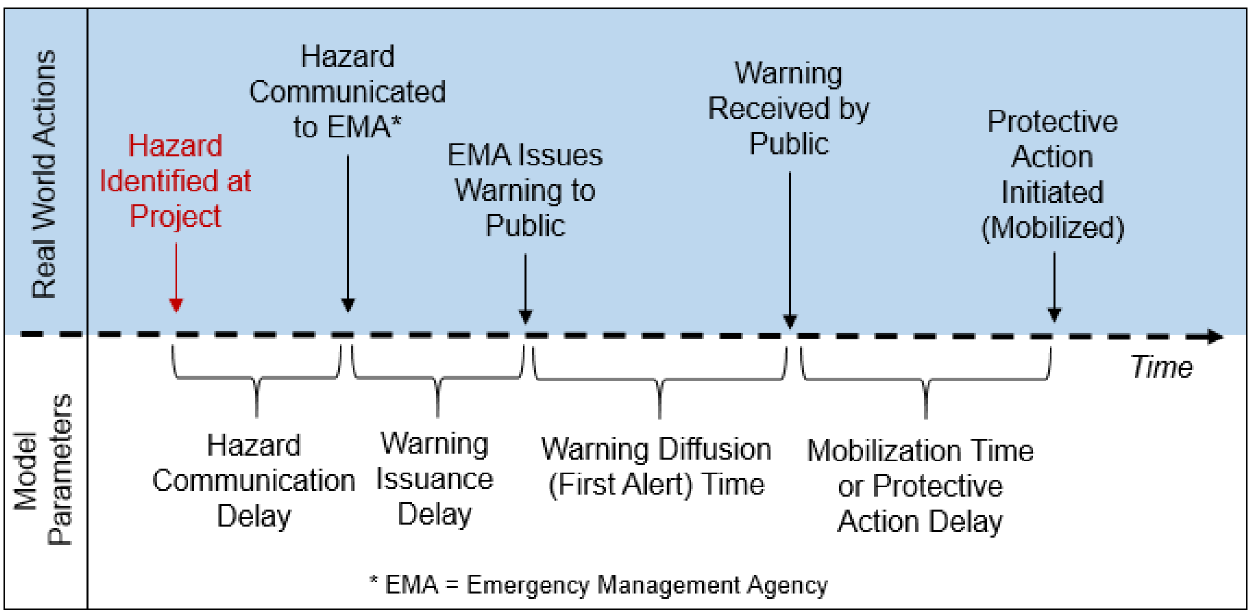


Figure 18. LifeSim Warning and Response Timeline

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 that 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 most 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 that 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 NED 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 19-Figure 21 below.

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 18). Additionally, an elicitation typically results in more optimistic mobilization rates, which is the driver for life loss in the Neuse River Basin.

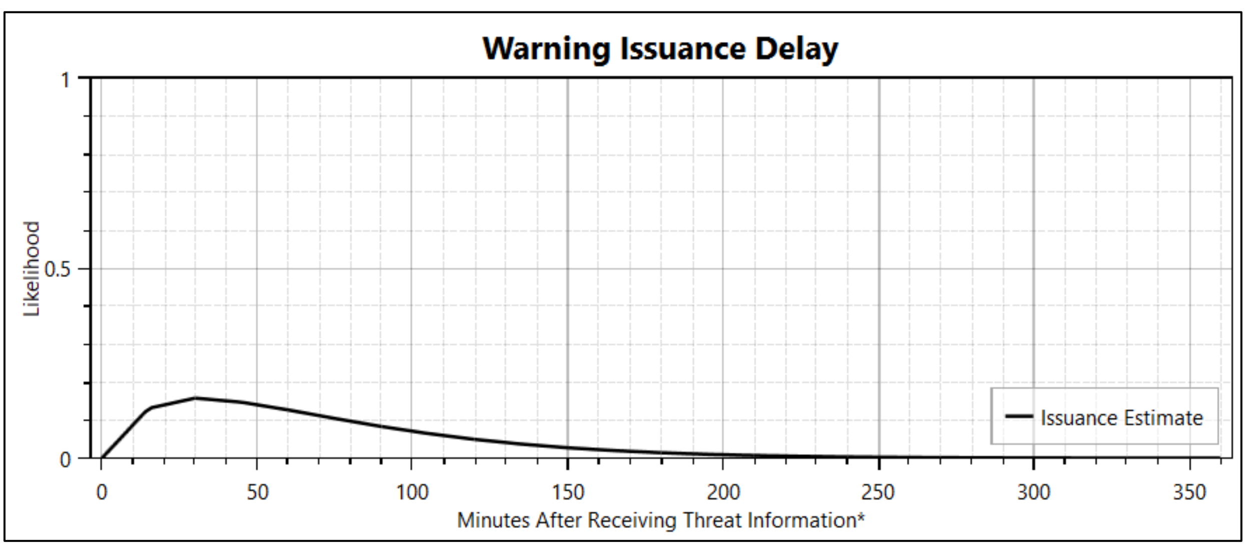
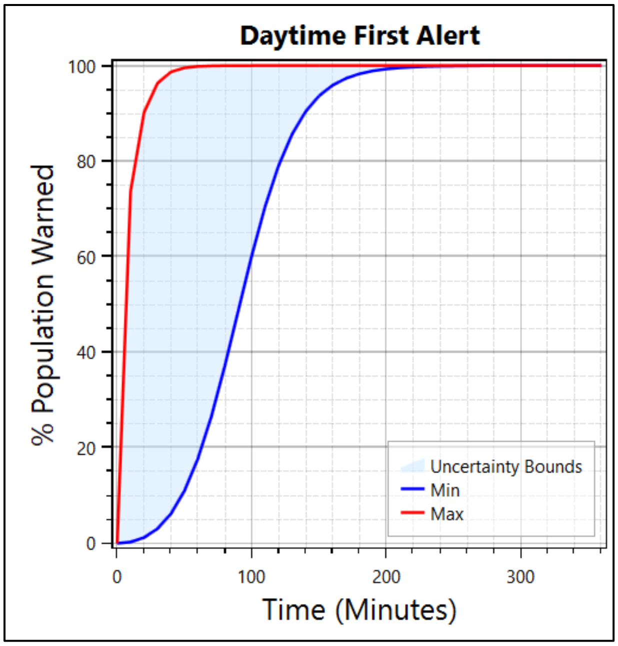


Figure 19. Unknown Warning Issuance Delay Curve



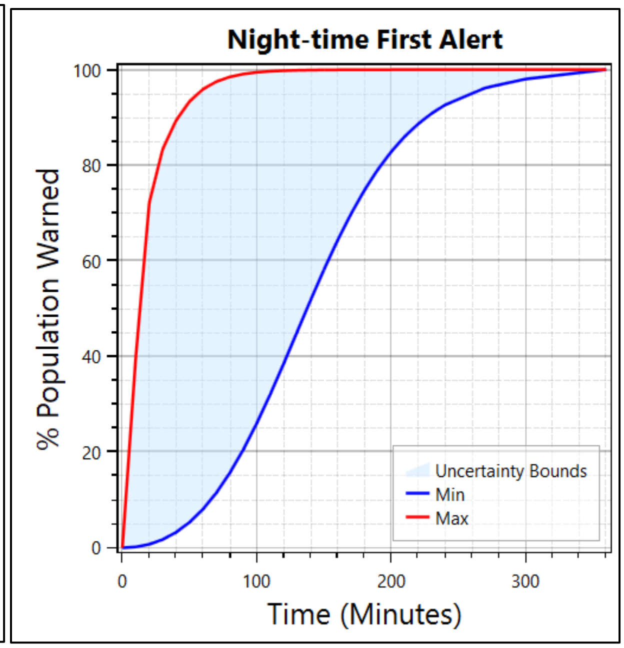


Figure 20. Unknown Warning Diffusion Curve

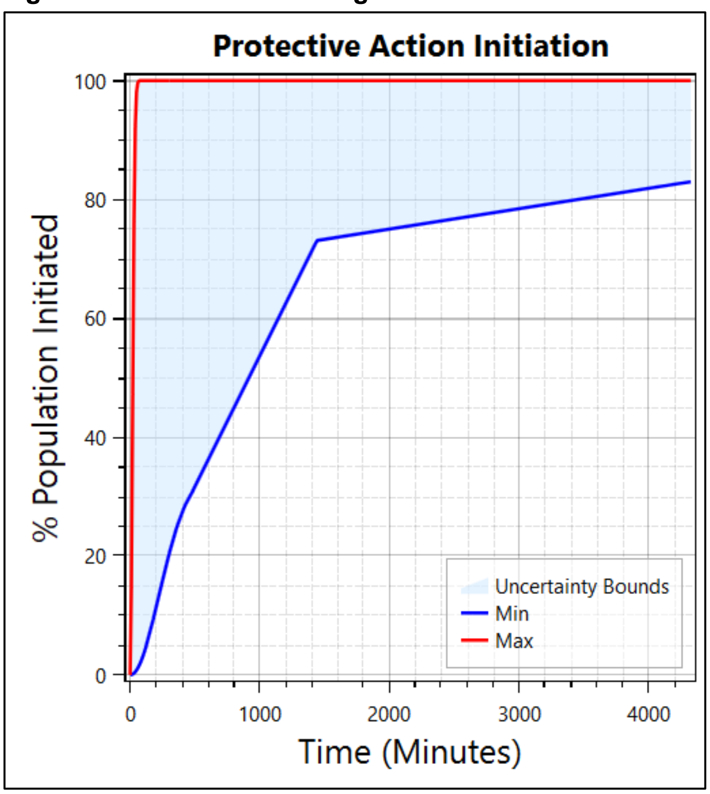


Figure 21. Unknown / Perception: Unknown Warning PAI Curve

6.1.2. Hominy Swamp Creek Life Safety Risk

The Hominy Swamp Creek LifeSim model includes the FWOP hydraulic conditions. 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, PAR, average life loss (LL), average depth on structures, and average velocity on structures.

6.1.2.1. Hominy Swamp Creek FWOP Life Safety Risk

Table 81 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 life loss to increase to 2.3 and 2.7, respectively. Overall, the life safety risk in this area is not significant for most 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 is driven by low velocities, low depths, and the relatively small PAR impacted by each event.

Table 81. Hominy Swamp Creek FWOP Life Safety Risk by AEP

Hydraulic Scenario	Structures Inundated	PAR Day	PAR Night	LL Day	LL 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 22 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.

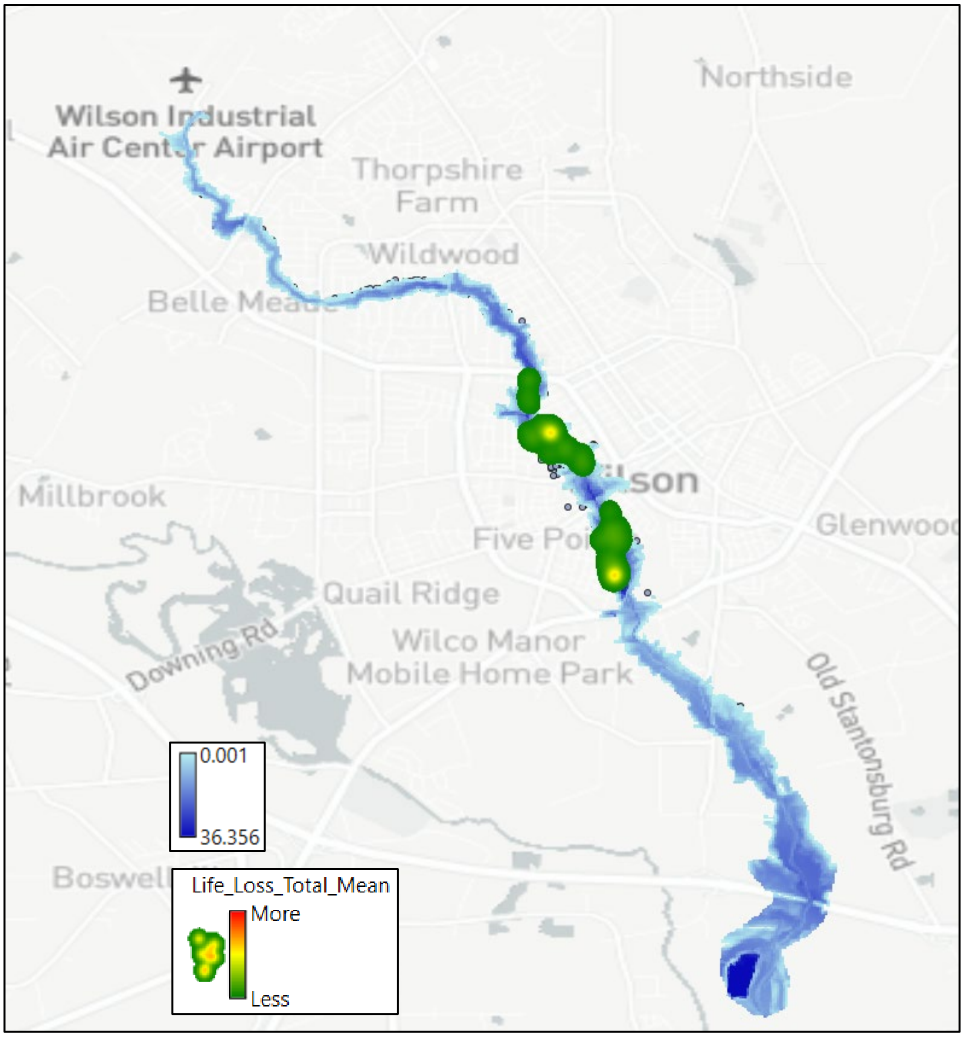


Figure 22. Hominy Swamp Creek FWOP 0.002 AEP Average Night Life Loss Heat Map

6.1.2.2. 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 82. 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 EAD, 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).

Table 83. Hominy Swamp Creek Average Annual Life Loss

Scenario	Average Annual Life Loss
FWOP	0.013

6.1.3. Crabtree Creek Life Safety Risk

The Crabtree Creek LifeSim model includes the existing WOP and FWOP hydraulic conditions. 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 84 shows the existing WOP life loss results for Crabtree Creek; Table 85 shows the FWOP life loss results for Crabtree Creek. Detailed in both tables below are the number of structures inundated, PAR, average life loss, average depth on structures, and average velocity on structures. For the existing WOP, life safety risk is overall relatively low, life loss is sampled beginning at the 0.005 AEP event; more frequent events do not result in life loss.

Table 84. Crabtree Creek Existing WOP Life Safety Risk by AEP

Hydraulic Scenario	Structures Inundated	PAR Day	PAR Night	LL Day	LL Night	Average Depth (ft)	Average Velocity (ft/s)
0.002 AEP	412	3,589	3,537	0.1	0.1	3.1	0.2
0.005 AEP	365	3,018	2,974	0.01	0.01	1.5	0.2
0.01 AEP	145	959	947	0	0	1.6	0.4
0.02 AEP	78	183	182	0	0	1.3	0.4
0.04 AEP	40	118	118	0	0	1.0	0.3
0.1 AEP	4	15	15	0	0	0.4	0.3
0.2 AEP	0	0	0	0	0	N/A	N/A
0.5 AEP	0	0	0	0	0	N/A	N/A

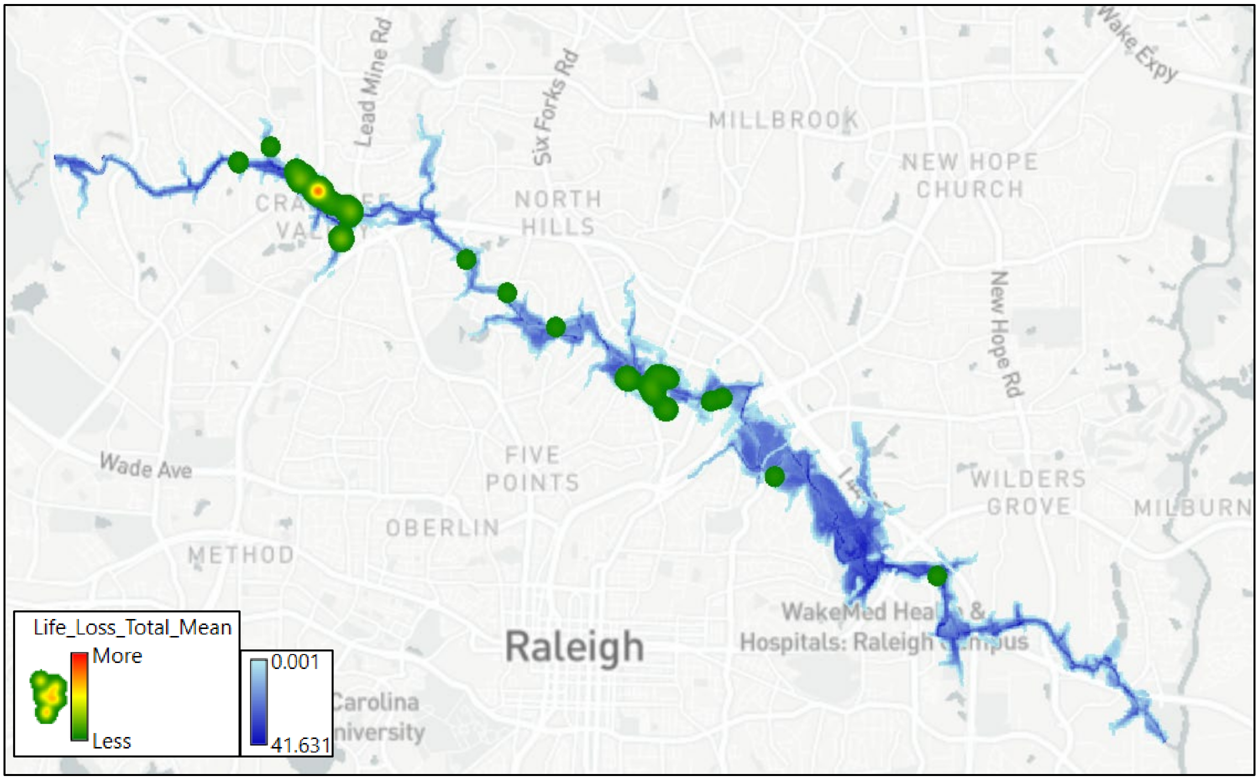
The PAR in this area is larger than Hominy Swamp Creek and Big Ditch due to the presence of schools, large commercial buildings, and apartment buildings. As shown in the table, the depths and velocities of floodwaters are significant enough to cause fatalities beginning at the 0.005 AEP event; however, 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 85. Crabtree Creek FWOP Life Safety Risk by AEP

Hydraulic Scenario	Structures Inundated	PAR Day	PAR Night	LL Day	LL 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 Average Annual Life Loss Estimates

Table 82 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 EAD, 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 increases from the existing WOP to the FWOP. The AALL for the existing WOP is 0.0003, which is essentially zero. The AALL for the FWOP is 0.0144 lives/year, which is relatively low (i.e., within the order of magnitude of 0.1 to 1 life loss), but significantly higher than the existing WOP.

Table 86. Crabtree Creek Average Annual Life Loss

Scenario	Average Annual Life Loss
Existing WOP	0.0003
FWOP	0.0144

6.1.4. Big Ditch Life Safety Risk

The Big Ditch LifeSim model only includes the FWOP hydraulic conditions. 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 87 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 fewer structures, thus decreasing the sample size and skewing the average depths and velocities.

Table 87. Big Ditch FWOP Life Safety Risk by AEP

Hydraulic Scenario	Structures Inundated	PAR Day	PAR Night	LL Day	LL 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 24 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.

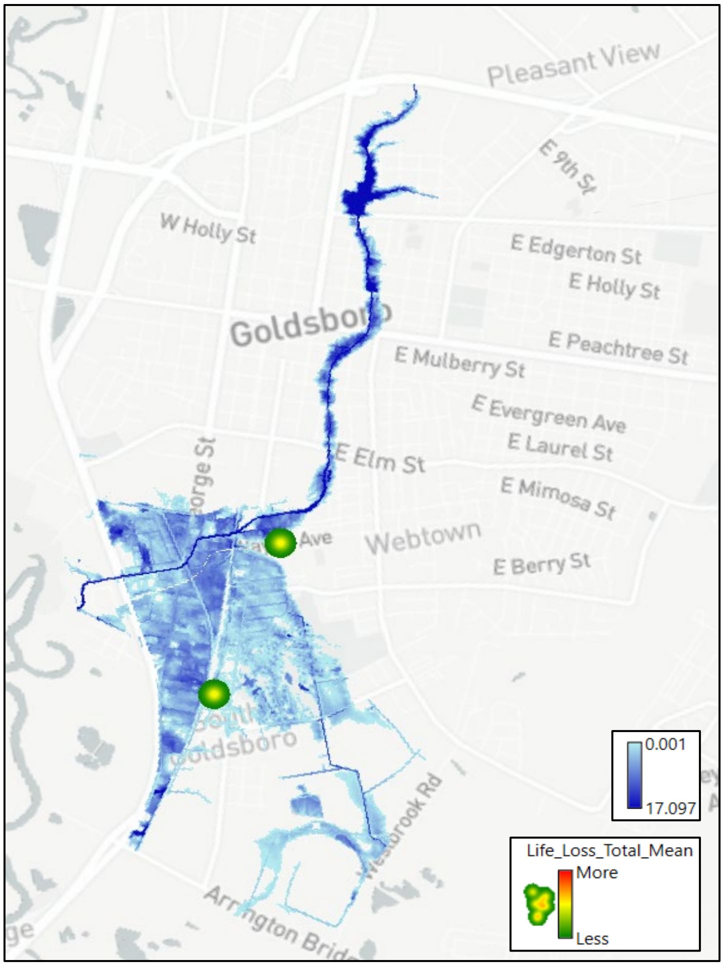


Figure 24. Big Ditch FWOP 0.002 AEP Average Night Life Loss Heat Map

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 88. Big Ditch Average Annual Life Loss Estimate

Scenario	Average Annual Life Loss
FWOP	0.000

6.1.5. Mainstem Neuse River Life Safety Risk

The mainstem Neuse River LifeSim model includes the existing WOP and FWOP hydraulic conditions. 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.

6.1.5.1. Future Without Project Life Safety Risk

Table 89 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 PAR.

Table 89. Neuse River FWOP Life Safety Risk by AEP

Hydraulic Scenario	Structures Inundated	PAR Day	PAR Night	LL Day	LL 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

Table 90: Neuse River Existing WOP Life Safety Risk by AEP

Hydraulic Scenario	Structures Inundated	PAR Day	PAR Night	LL Day	LL Night	Average Depth (ft)
0.002 AEP	9,836	21,351	21,300	14.7	14.9	3.7
0.005 AEP	7,620	15,207	15,176	5.8	5.9	3.0
0.01 AEP	5,931	11,975	11,942	2.6	2.7	2.6
0.02 AEP	4,532	9,251	9,224	1.3	1.2	2.2
0.04 AEP	3,143	5,975	5,962	0.5	0.5	1.9
0.1 AEP	1,718	3,229	3,224	0.1	0.1	1.7
0.2 AEP	1,022	2,140	2,133	0.0	0.0	1.5
0.5 AEP[1]	N/A	N/A	N/A	N/A	N/A	N/A

[1]The 0.5 AEP results are not included because there is limited confidence in the H&H for this event, so it was not used in the AALL calculations.

Figure 25 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.

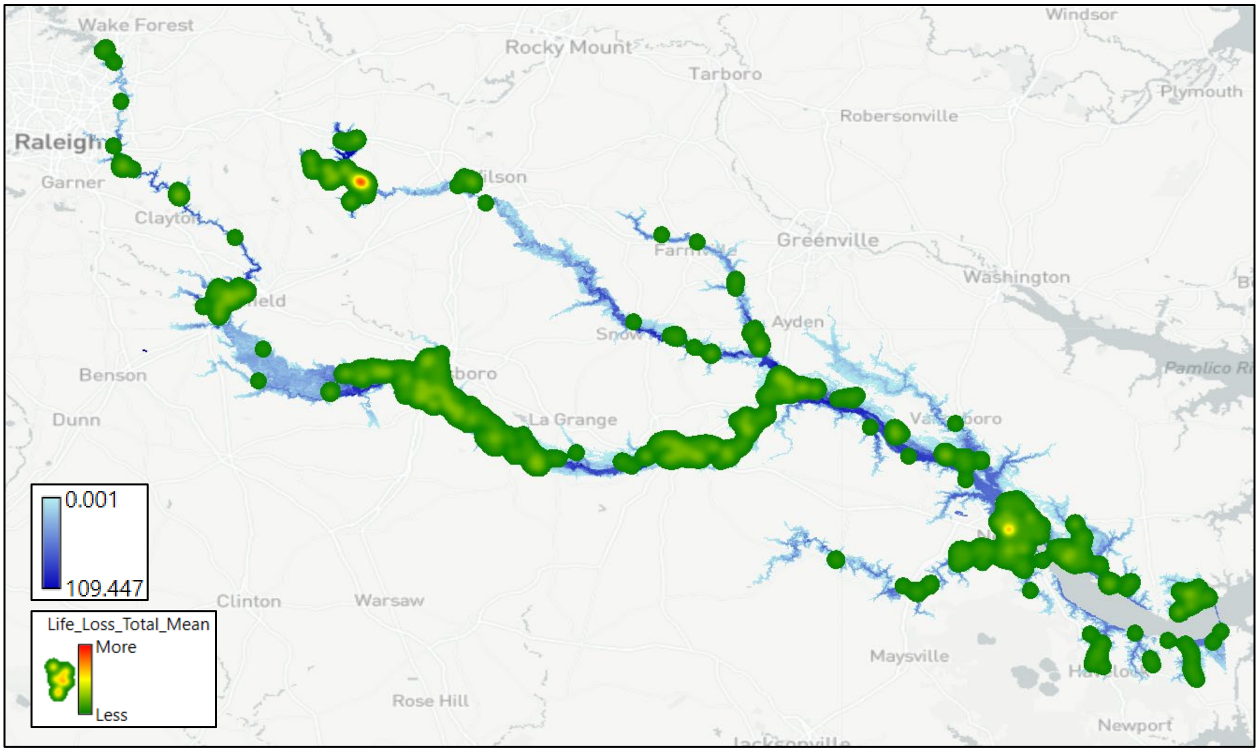


Figure 25. Neuse River Basin FWOP 0.002 AEP Average Night Life Loss Heat Map

6.1.5.2. Mainstem Neuse River Average Annual Life Loss Estimates

Table 82 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 EAD, 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).

Table 91. Mainstem Neuse River Average Annual Life Loss Estimates

Scenario	Average Annual Life Loss
Existing WOP	0.49
FWOP	3.03

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).

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 WOP 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. [5] However, all individuals are affected by flooding disasters and may experience major psychological trauma[6] that can include post-traumatic stress disorder, anxiety, and depression[7] and worsen existing related psychological conditions.[8] 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 by 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 structures until the floodwaters recede. Further, elderly residents may have trouble climbing stairs/ladders that can offer protection from rising floodwaters.

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.[9] Many of the reaches in the study area are characterized by high poverty rates and unemployment, 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

[5] 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.

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

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

[8] 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.

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

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 that they are greatly affected by a flooding disaster are more likely to have a reduced perception of their community's recovery.[10] 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 who they feel trapped in their communities.

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.[11] Conversely, 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.

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.[12] 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 that their homes and/or places of work may be temporary, leading residents to view their positions in the community as temporary.

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

[10] 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.
[11] 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.
[12] 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.

the adverse impacts of natural disasters, including experiencing disproportionate death, injury, loss, or disruption of livelihood.[13] 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 in 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 that community members are more invested in the outcomes of their local and regional events.[14] Table 92 shows the voter turnout for counties within the study area.

Table 92. 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 lives 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 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 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

[13] FEMA 2021. "Social Vulnerability". https://hazards.fema.gov/nri/social-vulnerability
[14] Eagles, M., & Erfle, S. (1989). Community cohesion and voter turnout in English parliamentary constituencies. British Journal of Political Science, 19(1), 115-125.

all affected homes and involve a wide array of community members during the project's implementation.

6.3.1. Health and Safety

Under the WP 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. Because their homes are floodproofed, they are less likely to become inundated during a flood, preventing possible disease associated with post-flood structures.[15] 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 positive attitudes about their community's recovery and help their neighbors.[16] 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, they are more likely to feel like they are 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 potential flooding events, creating a sense of resiliency that is helpful following a flood.[17] 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.

[15] Ohl, C. A., & Tapsell, S. (2000). Flooding and human health: the dangers posed are not always obvious. Bmj, 321(7270), 1167-1168.
[16] 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.
[17] 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.

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 WOP 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 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 relocated to other communities may experience a loss of identity from leaving their communities and the homes where they previously lived.

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 FWOP 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 FWOP 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 FWOP condition. Finally, social vulnerability will be at risk under the FWOP, 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 and income and be impacted by stress related to flood events.

7.0. REGIONAL ECONOMIC DEVELOPMENT

The 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 assume 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 WP conditions are analyzed. In the absence of the project, it is likely that RED 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. Crabtree Creek NED Plan 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 86 full-time equivalent (FTE) jobs, and total value added in the county would exceed $6 million. Nationally, there would be an estimated 117 FTE jobs created, and total value added would be approximately $10 million.

Table 93. Crabtree Creek Alternative 2 RECONS

Area	Local Capture	Output	Jobs*	Labor Income	Value Added
Local					
Direct Impact		$5,550,185	54.9	$4,116,796	$3,635,978
Secondary Impact		$5,429,669	31	$1,885,942	$3,217,015
Total Impact	$5,550,185	$10,979,854	85.9	$6,002,737	$6,852,993
State					
Direct Impact		$5,616,876	58.1	$4,147,822	$3,662,333
Secondary Impact		$5,882,187	33.8	$1,959,292	$3,354,767
Total Impact	$5,616,876	$11,499,063	91.9	$6,107,114	$7,017,099
US					
Direct Impact		$6,292,844	61.6	$4,388,199	$4,056,767
Secondary Impact		$11,623,667	55.6	$3,702,636	$6,337,707
Total Impact	$6,292,844	$17,916,511	117.2	$8,090,835	$10,394,474

Note: values in FY23 price level
* Jobs are presented in FTE

8.0. SUMMARY OF FOUR ACCOUNTS

This section summarizes the four planning accounts and identifies the recommended plan.

8.1. NED

As described in Section 5, Alternative 2 maximizes net NED benefits. Total annual net benefits are approximately $350,000, and the BCR is 2.5 at a discount rate of 2.5 percent. Alternative 2 decreases EAD from $2.7 million under the WOP condition to $2.1 million under the WP condition in Crabtree Creek.

8.2. OSE

Section 6.0 presents OSE and includes life safety risk and social vulnerability for the FWOP and FWP conditions. Social vulnerability is reduced by the NED 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 NED Plan, which allows residents to remain in their current houses and communities rather than relocate 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. RED

Section 7.0 presents RED, which is quantified by the RECONS model. The total number of FTE jobs created in the state for the NED Plan is estimated to be 117. Total value added at the state level exceeds $10 million. In the absence of a federal project, RED will likely decline due to repeated flooding in the area.

8.4. EQ

EQ is summarized for the FWOP and FWP conditions in the Main Report. The NED Plan has minimal impact on native soils and bedrock, no wetland impacts, and no impact on water quality. Since the NED Plan does not include structural measures that reduce water surface elevation, flood events will continue to have impacts on vegetation and wildlife.

8.5. Recommended Plan

According to ER 1105-2-100, the plan that reasonably maximizes net economic benefits, the NED plan, should be the selected plan for all project purposes other than ecosystem restoration. This plan must be shown to be preferable to taking no action.

During the final phases of the study, the PDT determined that the NED plan (Alternative 2) did not meet the planning screening acceptability criteria because it conflicted with federal and local design requirements and regulations as outlined in the main report. In addition, since the intent of dry floodproofing measures included in Alternative 2 is to reduce flood damage only, a detailed Emergency Evacuation Plan (EEP) would be required to successfully implement the alternative. It was determined by the PDT that such an EEP would be nearly impossible to enforce in the study area.

There are no identified alternatives other than Alternative 2 that are economically viable under federal regulations and policy. Therefore, the PDT selected no action as the Recommended Plan.