Hazard Mitigation Plan Appendix

Hazard Risk Analyses Supplement to the Carroll County Joint Hazard Mitigation Plan

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Introduction

The Federal Disaster Mitigation Act of 2000 (DMA2K) requires state, local, and tribal governments to develop and maintain a mitigation plan to be eligible for certain federal disaster assistance and hazard mitigation funding programs.

Mitigation seeks to reduce a hazard's impacts, which may include loss of life, property damage, disruption to local and regional economies, and the expenditure of public and private funds for recovery. Sound mitigation must be based on a sound risk assessment that quantifies the potential losses of a disaster by assessing the vulnerability of buildings, infrastructure, and people.

In recognition of the importance of planning in mitigation activities, FEMA Hazus-MH, a powerful disaster risk assessment tool based on geographic information systems (GIS). This tool enables communities of all sizes to predict estimated losses from floods, hurricanes, earthquakes, and other related phenomena and to measure the impact of various mitigation practices that might help reduce those losses.

In 2019, the Georgia Department of Emergency Management partnered with the Carl Vinson Institute of Government at the University of Georgia to develop a detailed risk assessment focused on defining hurricane, riverine flood, and tornado risks in Carroll County, Georgia. This assessment identifies the characteristics and potential consequences of the disaster, how much of the community could be affected by the disaster, and the impact on community assets.

Risk Assessment Process Overview

Hazus-MH Version 2.2 SP1 was used to perform the analyses for Carroll County. The Hazus-MH application includes default data for every county in the US. This Hazus-MH data was derived from a variety of national sources and in some cases the data are also several years old.   Whenever possible, using local provided data is preferred. Carroll County provided building inventory information from the county's property tax assessment system. This section describes the changes made to the default Hazus-MH inventory and the modeling parameters used for each scenario.

County Inventory Changes

The default Hazus-MH site-specific point inventory was updated using data compiled from the Georgia Emergency Management Agency (GEMA). The default Hazus-MH aggregate inventory (General Building Stock) was also updated prior to running the scenarios. Reported losses reflect the updated data sets.

General Building Stock Updates

General Building Stock (GBS) is an inventory category that consists of aggregated data (grouped by census geography — tract or block). Hazus-MH generates a combination of site-specific and aggregated loss estimates based on the given analysis and user input.

The GBS records for Carroll County were replaced with data derived from parcel and property assessment data obtained from Carroll County. The county provided property assessment data was current as of August 2018 and the parcel data current as of August 2018. Records without improvements were deleted. The parcel boundaries were converted to parcel points located in the centroids of each parcel boundary; then, each parcel point was linked to an assessor record based upon matching parcel numbers. The parcel assessor match-rate for Carroll County is 99.8%. The generated building inventory represents the approximate locations (within a parcel) of structures. The building inventory was aggregated by census block. Both the tract and block tables were updated. Table 1 shows the results of the changes to the GBS tables by occupancy class.

Table 1: GBS Building Exposure Updates by Occupancy Class*

General Occupancy	Default Hazus-MH Count	Updated Count	Default Hazus-MH Exposure	Updated Exposure
Agricultural	122	85	$30,448,000	$2,243,000
Commercial	2,215	2,086	$1,315,264,000	$479,986,000
Education	72	30	$97,519,000	$78,941,000
Government	60	53	$39,845,000	$26,335,000
Industrial	753	865	$660,371,000	$228,065,000
Religious	337	104	$246,826,000	$19,837,000
Residential	39,820	38,467	$8,688,824,000	$6,583,271,000
Total	43,379	41,690	$11,079,097,000	$7,418,678,000

*The exposure values represent the total number and replacement cost for all Carroll County Buildings

For Carroll County, the updated GBS was used to calculate hurricane wind losses. The flood losses and tornado losses were calculated from building inventory modeled in Hazus-MH as User-Defined Facility

(UDF)[1], or site-specific points. Figure 1 shows the distribution of buildings as points based on the county provided data.
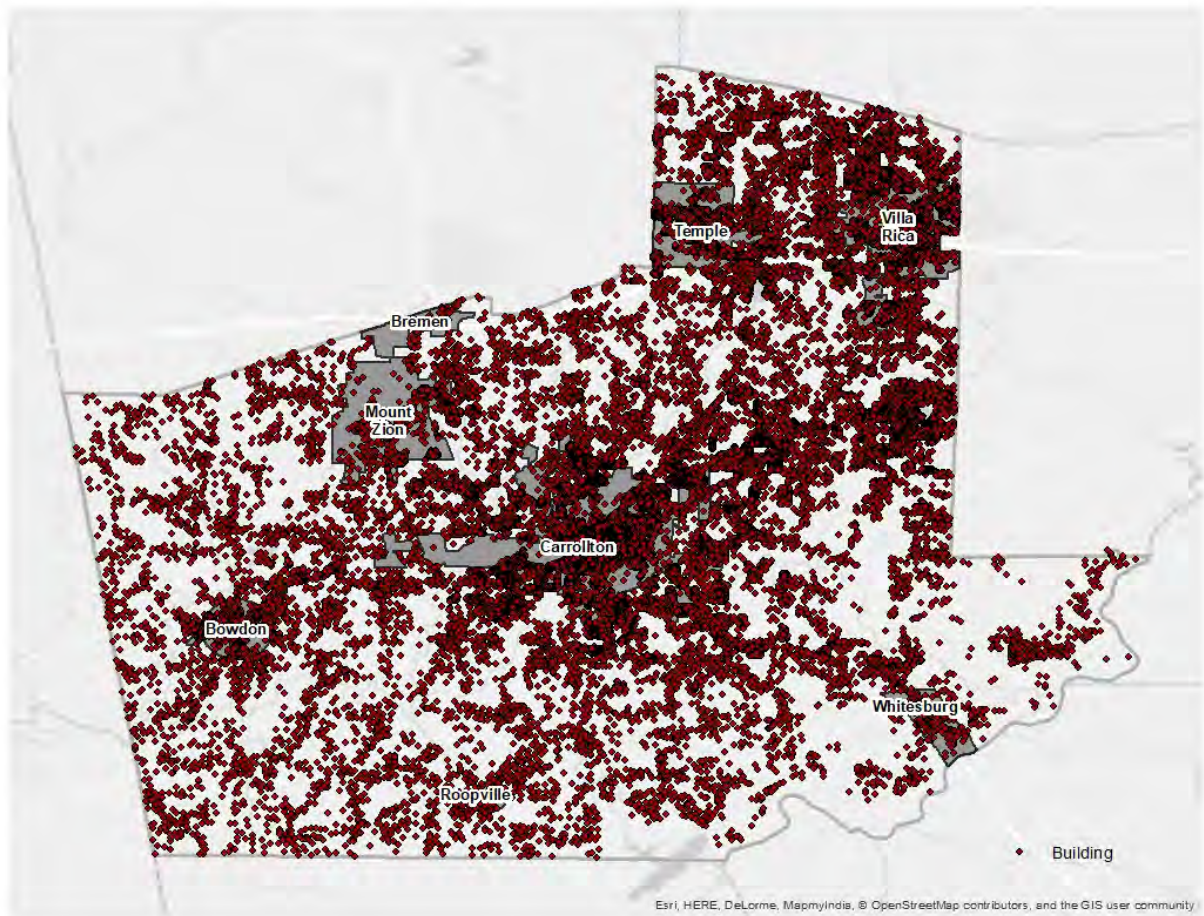
Figure 1: Carroll County Overview

Essential Facility Updates

The default Hazus-MH essential facility data was updated to reflect improved information available in the Georgia Mitigation Information System (GMIS) as of March 2019. For these risk analyses, only GMIS data for buildings that Hazus-MH classified as Essential Facilities was integrated into Hazus-MH because the application provides specialized reports for these five facilities. Essential Facility inventory was updated for the analysis conducted for this report. The following table summarizes the counts and exposures, where available, by Essential Facility classification of the updated data.

Essential facilities include:

- Care facilities
- EOCs
- Fire stations
- Police stations
- Schools

Table 2: Updated Essential Facilities

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[1] The UDF inventory category in Hazus-MH allows the user to enter site-specific data in place of GBS data.

Classification	Updated Count	Updated Exposure
Bowdon		
EOC	0	$0
Care	0	$0
Fire	1	$750,000
Police	1	$411,000
School	2	$5,893,000
Total	4	$7,054,000
Bremen		
EOC	0	$0
Care	0	$0
Fire	0	$0
Police	0	$0
School	0	$0
Total	0	$0
Carrollton		
EOC	1	$267,000
Care	2	$114,230,000
Fire	3	$4,518,000
Police	5	$15,024,000
School	53	$204,425,000
Total	64	$338,464,000
Mount Zion		
EOC	0	$0
Care	0	$0
Fire	1	$166,000
Police	1	$102,000
School	2	$5,290,000
Total	4	$5,558,000

Classification	Updated Count	Updated Exposure
Roopville		
EOC	0	$0
Care	0	$0
Fire	1	$166,000
Police	1	$6,000
School	1	$3,126,000
Total	3	$3,298,000
Temple		
EOC	0	$0
Care	0	$0
Fire	1	$161,000
Police	1	$302,000
School	4	$19,024,000
Total	6	$19,487,000
Villa Rica		
EOC	0	$0
Care	1	$40,500,000
Fire	1	$161,000
Police	2	$2,325,000
School	4	$17,180,000
Total	8	$60,166,000
Whitesburg		
EOC	0	$0
Care	0	$0
Fire	1	$264,000
Police	1	$159,000
School	1	$3,180,000
Total	3	$3,603,000
Unincorporated Areas of Carroll County		
EOC	0	$0
Care	2	$4,841,000
Fire	10	$2,539,000
Police	0	$0
School	10	$47,512,000
Total	22	$54,892,000

Assumptions and Exceptions

Hazus-MH loss estimates may be impacted by certain assumptions and process variances made in this risk assessment.

- The Carroll County analysis used Hazus-MH Version 2.2 SP1, which was released by FEMA in May 2015.
- County provided parcel and property assessment data may not fully reflect all buildings in the county. For example, some counties do not report not-for-profit buildings such as government buildings, schools and churches in their property assessment data. This data was used to update the General Building Stock as well as the User Defined Facilities applied in this risk assessment.
- Georgia statute requires that the Assessor's Office assign a code to all of the buildings on a parcel based on the buildings primary use. If there is a residential or a commercial structure on a parcel and there are also agricultural buildings on the same parcel Hazus-MH looks at the residential and commercial "primary" structures first and then combines the value of all secondary structures on that parcel with the value of the primary structure. The values and building counts are still accurate but secondary structures are accounted for under the same classification as the primary structure. Because of this workflow, the only time that a parcel would show a value for an agricultural building is when there are no residential or commercial structures on the parcel thus making the agricultural building the primary structure. This is the reason that agricultural building counts and total values seem low or are nonexistent.

- GBS updates from assessor data will skew loss calculations. The following attributes were defaulted or calculated:
    - Foundation Type was set from Occupancy Class
    - First Floor Height was set from Foundation Type
    - Content Cost was calculated from Replacement Cost
- It is assumed that the buildings are located at the centroid of the parcel.
- The essential facilities extracted from the GMIS were only used in the portion of the analysis designated as essential facility damage. They were not used in the update of the General Building Stock or the User Defined Facility inventory.

The hazard models included in this risk assessment included:

- Hurricane assessment which was comprised of a wind only damage assessment.
- Flood assessment based on the 1% annual chance event that includes riverine assessments.
- Tornado assessment based on GIS modeling.

Hurricane Risk Assessment

Hazard Definition

The National Hurricane Center describes a hurricane as a tropical cyclone in which the maximum sustained wind is, at minimum, 74 miles per hour (mph)[2]. The term hurricane is used for Northern Hemisphere tropical cyclones east of the International Dateline to the Greenwich Meridian. The term typhoon is used for Pacific tropical cyclones north of the Equator west of the International Dateline. Hurricanes in the Atlantic Ocean, Gulf of Mexico, and Caribbean form between June and November with the peak of hurricane season occurring in the middle of September. Hurricane intensities are measured using the Saffir-Simpson Hurricane Wind Scale (Table 3). This scale is a 1 to 5 categorization based on the hurricane's intensity at the indicated time.

Hurricanes bring a complex set of impacts. The winds from a hurricane produce a rise in the water level at landfall called storm surge. Storm surges produce coastal flooding effects that can be as damaging as the hurricane's winds. Hurricanes bring very intense inland riverine flooding. Hurricanes can also produce tornadoes that can add to the wind damages inland. In this risk assessment, only hurricane winds, and coastal storm surge are considered.

Table 3: Saffir-Simpson Hurricane Wind Scale

Category	Wind Speed (mph)	Damage
1	74 - 95	Very dangerous winds will produce some damage
2	96 - 110	Extremely dangerous winds will cause extensive damage
3	111 - 130	Devastating damage will occur
4	131 -155	Catastrophic damage will occur
5	> 155	Catastrophic damage will occur

The National Oceanic and Atmospheric Administration's National Hurricane Center created the HURDAT database, which contains all of the tracks of tropical systems since the mid-1800s. This database was used to document the number of tropical systems that have affected Carroll County by creating a 20-mile buffer around the county to include storms that didn't make direct landfall in Carroll County but impacted the county. Note that the storms listed contain the peak sustained winds, maximum pressure and maximum attained storm strength for the entire storm duration. Since 1887, Carroll County has had 19 tropical systems within 20 miles of its county borders (Table 4).

Table 4: Tropical Systems affecting Carroll County[3]

YEAR	DATE RANGE	NAME	MAX WIND(Knots)	MAX PRESSURE	MAX CAT
1887	July 20-28	UNNAMED	85	0	H1

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[2] National Hurricane Center (2011). "Glossary of NHC Terms." National Oceanic and Atmospheric Administration. http://www.nhc.noaa.gov/aboutgloss.shtml#h. Retrieved 2012-23-02.

[3] Atlantic Oceanic and Meteorological Laboratory (2012). "Data Center." National Oceanic and Atmospheric Administration. http://www.aoml.noaa.gov/hrd/data_sub/re_anal.html. Retrieved 7-20-2015.

YEAR	DATE RANGE	NAME	MAX WIND(Knots)	MAX PRESSURE	MAX CAT
1898	September 25 - October 06	UNNAMED	115	977	H3
1900	September 11-15	UNNAMED	45	0	TD
1901	June 11-15	UNNAMED	35	0	TD
1902	October 03-13	UNNAMED	90	970	H1
1903	September 09-16	UNNAMED	80	988	H1
1907	September 18-23	UNNAMED	40	0	TD
1912	June 07-17	UNNAMED	60	0	TD
1915	August 31 - September 06	UNNAMED	85	1003	H1
1928	August 07-17	UNNAMED	80	0	H1
1940	August 05-14	UNNAMED	85	1008	H1
1959	October 06-09	IRENE	40	1003	TD
1970	July 19-23	BECKY	55	1015	TD
1971	September 05-18	EDITH	140	1010	H4
1975	September 13-24	ELOISE	110	1009	H2
1994	June 30 - July 07	ALBERTO	55	1014	TD
2004	August 25 - September 10	FRANCES	125	1009	H3
2005	July 03-11	CINDY	65	1011	TD
2011	September 02-06	LEE	50	1007	TD

Category Definitions:

TS – Tropical storm

TD – Tropical depression

H1 – Category 1 (same format for H2, H3, and H4)

E – Extra-tropical cyclone
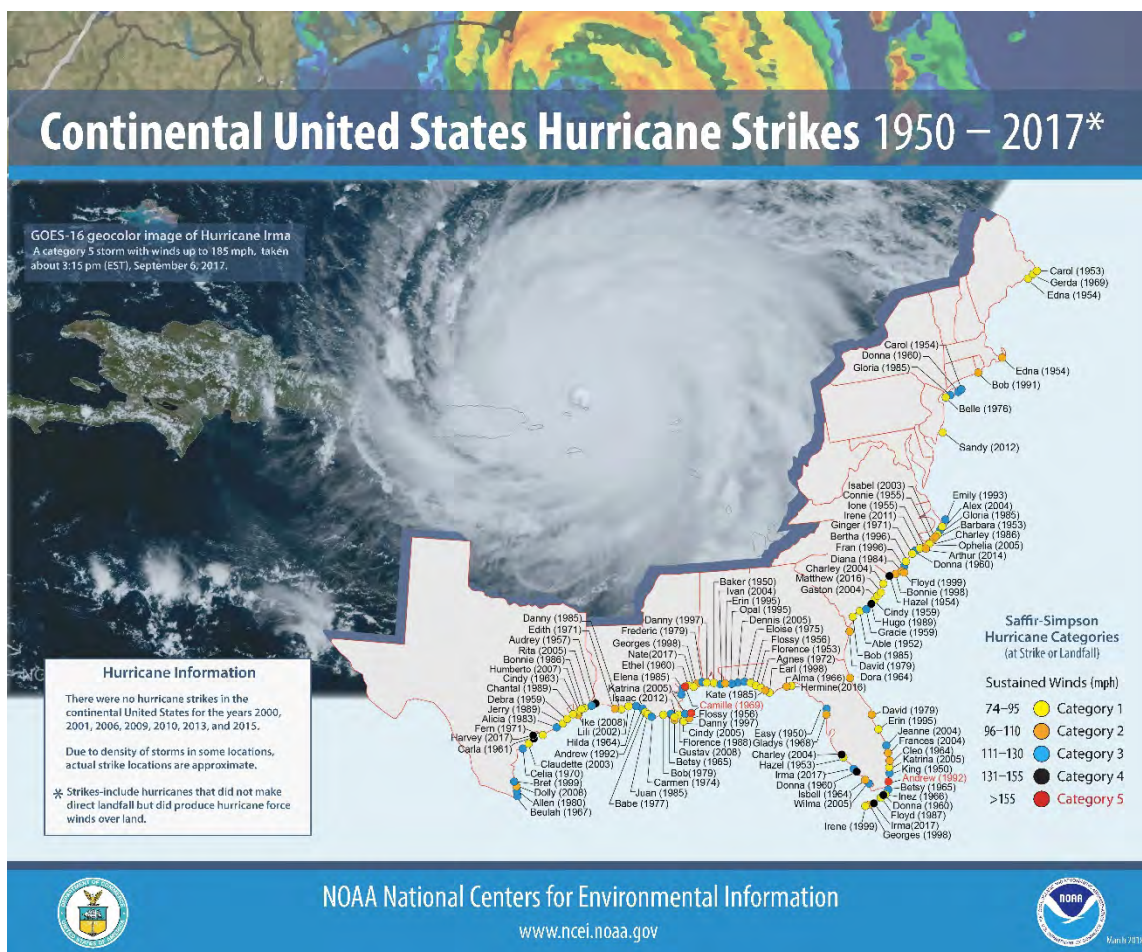
Figure 2: Continental United States Hurricane Strikes: 1950 to 2017[4]

Probabilistic Hurricane Scenario

The following probabilistic wind damage risk assessment modeled a Category 1 storm with maximum winds of 75 mph.

Wind Damage Assessment

Separate analyses were performed to determine wind and hurricane storm surge related flood losses. This section describes the wind-based losses to Carroll County. Wind losses were determined from probabilistic models run for the Category 1 storm which equates to the 1% chance storm event. Figure 3 shows wind speeds for the modeled Tropical Storm.

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[4] Source: NOAA National Centers for Environmental Information
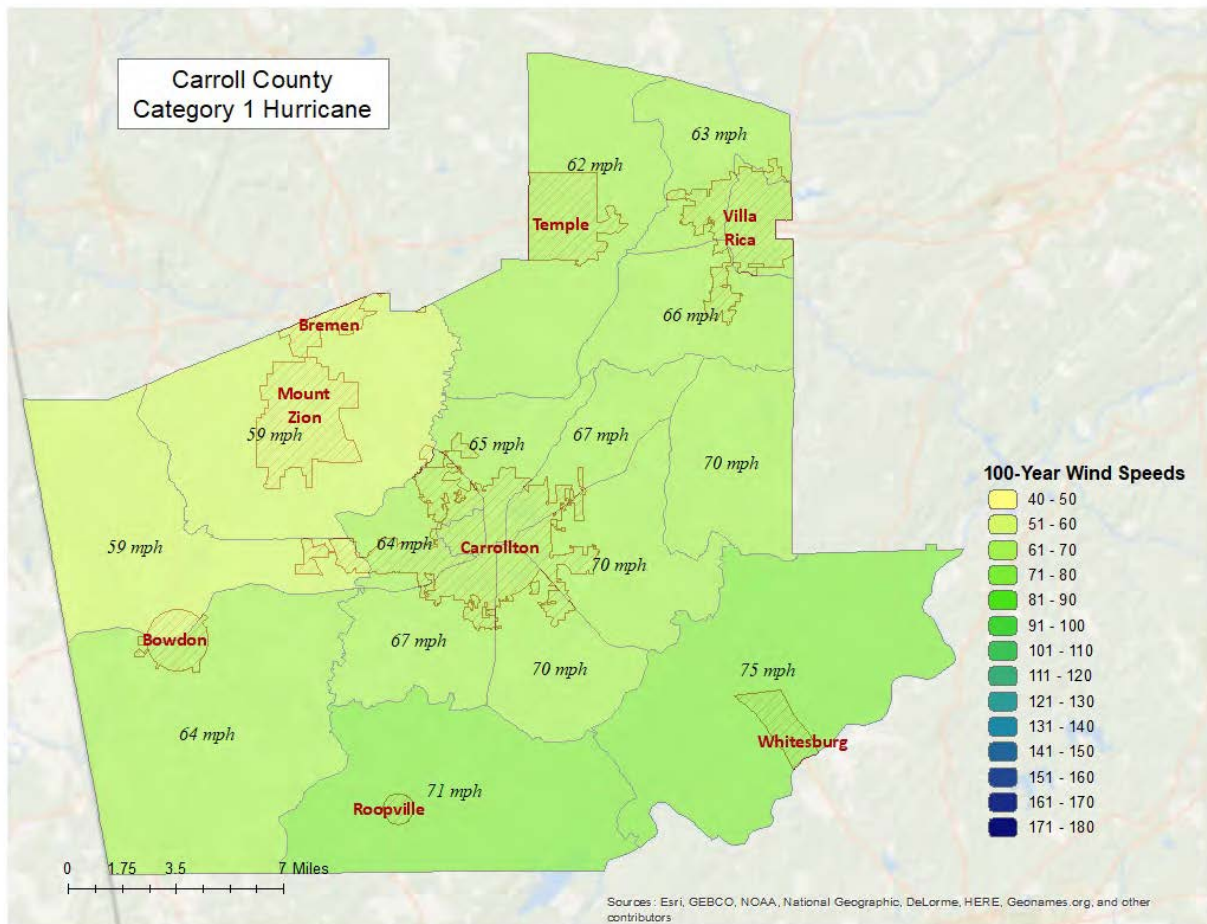
Figure 3: Wind Speeds by Storm Category

Wind-Related Building Damages

Buildings in Carroll County are vulnerable to storm events, and the cost to rebuild may have significant consequences to the community. The following table shows a summary of the results of wind-related building damage in Carroll County for the Category 1 (100 Year Event) storm. The loss ratio expresses building losses as a percentage of total building replacement cost in the county. Figure 4 illustrates the building loss ratios of the modeled Category 1 storm.

Table 5: Hurricane Wind Building Damage

Classification	Number of Buildings Damaged	Total Building Damage	Total Economic Loss[5]	Loss Ratio
Category 1	69	$5,441,700	$7,006,960	0.07%

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[5] Includes property damage (infrastructure, contents, and inventory) as well as business interruption losses.

Note that wind damaged buildings are not reported by jurisdiction. This is due to the fact that census tract boundaries – upon which hurricane building losses are based – do not closely coincide with jurisdiction boundaries.
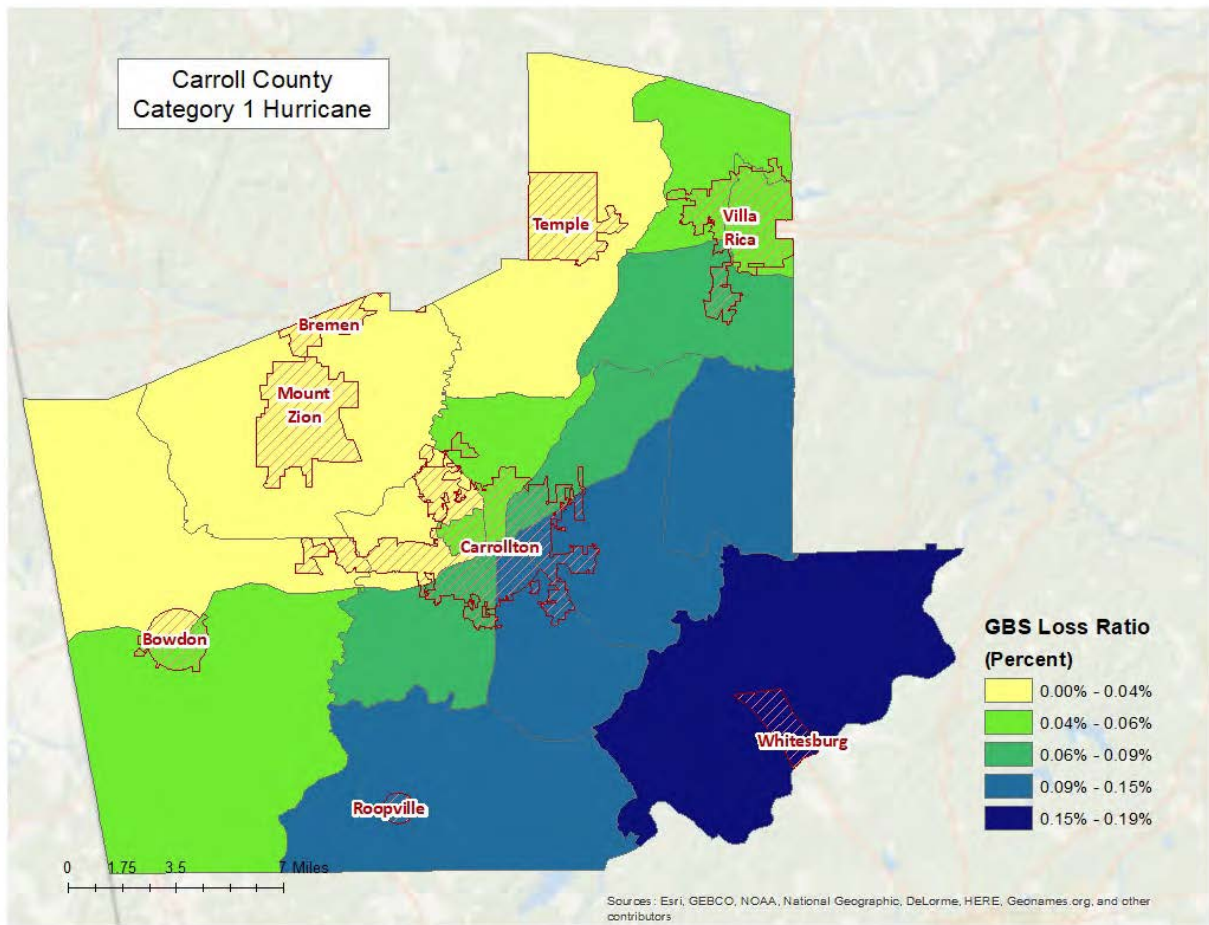
Figure 4: Hurricane Wind Building Loss Ratios

Essential Facility Losses

Essential facilities are also vulnerable to storm events, and the potential loss of functionality may have significant consequences to the community. Hazus-MH identified the essential facilities that may be moderately or severely damaged by winds. The results are compiled in Table 6.

There are 114 essential facilities in Carroll County.

Classification	Number
EOCs	1
Fire Stations	19
Care Facilities	5
Police Stations	12
Schools	77

Table 6: Wind-Damaged Essential Facility Losses

Classification	Facilities At Least Moderately Damaged > 50%	Facilities Completely Damaged > 50%	Facilities with Expected Loss of Use (< 1 day)
Category 1	1	0	114

Shelter Requirements

Hazus-MH estimates the number of households evacuated from buildings with severe damage from high velocity winds as well as the number of people who will require short-term sheltering. Since the 1% chance storm event for Carroll County is a Category 1 storm, the resulting damage is not enough to displace Households or require temporary shelters as shown in the results listed in Table 7.

Table 7: Displaced Households and People

Classification	# of Displaced Households	# of People Needing Short-Term Shelter
Category 1	0	0

Debris Generated from Hurricane Wind

Hazus-MH estimates the amount of debris that will be generated by high velocity hurricane winds and quantifies it into three broad categories to determine the material handling equipment needed:

- Reinforced Concrete and Steel Debris
- Brick and Wood and Other Building Debris
- Tree Debris

Different material handling equipment is required for each category of debris. The estimates of debris for this scenario are listed in Table 8. The amount of hurricane wind related tree debris that is estimated to require pick up at the public's expense is listed in the eligible tree debris column.

Table 8: Wind-Related Debris Weight (Tons)

Classification	Brick, Wood, and Other	Reinforced Concrete and Steel	Eligible Tree Debris	Other Tree Debris	Total
Category 1	331	0	2,131	18,883	21,345

Figure 5 shows the distribution of all wind related debris resulting from a Category 1 storm. Each dot represents 20 tons of debris within the census tract in which it is located. The dots are randomly distributed within each census tract and therefore do not represent the specific location of debris sites.
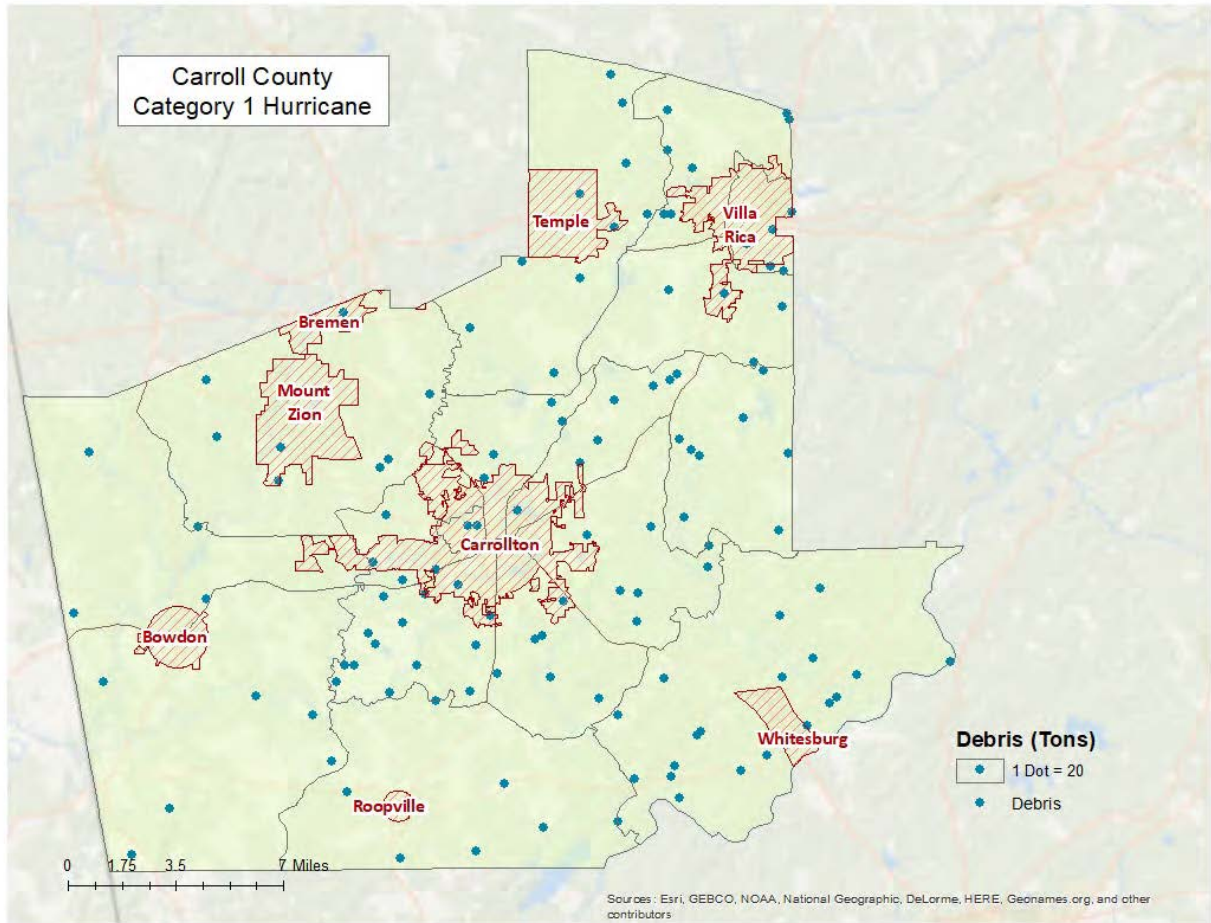
Figure 5: Wind-Related Debris Weight (Tons)

Flood Risk Assessment

Hazard Definition

Flooding is a significant natural hazard throughout the United States. The type, magnitude, and severity of flooding are functions of the amount and distribution of precipitation over a given area, the rate at which precipitation infiltrates the ground, the geometry and hydrology of the catchment, and flow dynamics and conditions in and along the river channel. Floods can be classified as one of three types: upstream floods, downstream floods, or coastal floods.

Upstream floods, also called flash floods, occur in the upper parts of drainage basins and are generally characterized by periods of intense rainfall over a short duration. These floods arise with very little warning and often result in locally intense damage, and sometimes loss of life, due to the high energy of the flowing water. Flood waters can snap trees, topple buildings, and easily move large boulders or other structures. Six inches of rushing water can upend a person; another 18 inches might carry off a car. Generally, upstream floods cause damage over relatively localized areas, but they can be quite severe in the local areas in which they occur. Urban flooding is a type of upstream flood. Urban flooding involves the overflow of storm drain systems and can be the result of inadequate drainage combined with heavy rainfall or rapid snowmelt. Upstream or flash floods can occur at any time of the year in Georgia, but they are most common in the spring and summer months.

Downstream floods, also called riverine floods, refer to floods on large rivers at locations with large upstream catchments. Downstream floods are typically associated with precipitation events that are of relatively long duration and occur over large areas. Flooding on small tributary streams may be limited, but the contribution of increased runoff may result in a large flood downstream. The lag time between precipitation and time of the flood peak is much longer for downstream floods than for upstream floods, generally providing ample warning for people to move to safe locations and, to some extent, secure some property against damage.

Coastal floods occurring on the Atlantic and Gulf coasts may be related to hurricanes or other combined offshore, nearshore, and shoreline processes. The effects of these complex interrelationships vary significantly across coastal settings, leading to challenges in the determination of the base (1-percent-annual-chance) flood for hazard mapping purposes. Land area covered by floodwaters of the base flood is identified as a Special Flood Hazard Area (SFHA).

> The SFHA is the area where the National Flood Insurance Program's (NFIP) floodplain management regulations must be enforced and the area where the mandatory purchase of flood insurance applies. The owner of a structure in a high-risk area must carry flood insurance, if the owner carries a mortgage from a federally regulated or insured lender or servicer.

The Carroll County flood risk assessment analyzed at risk structures in the SFHA.

The following probabilistic risk assessment involves an analysis of a 1% annual chance riverine flood event (100-Year Flood) and a 1% annual chance coastal flood.

Riverine 1% Flood Scenario

Riverine losses were determined from the 1% flood boundaries downloaded from the FEMA Flood Map Service Center in April 2019.   The flood boundaries were overlaid with the USGS 10 meter DEM using

the Hazus-MH Enhanced Quick Look tool to generate riverine depth grids. The riverine flood depth grid was then imported into Hazus-MH to calculate the riverine flood loss estimates. Figure 6 illustrates the riverine inundation boundary associated with the 1% annual chance.
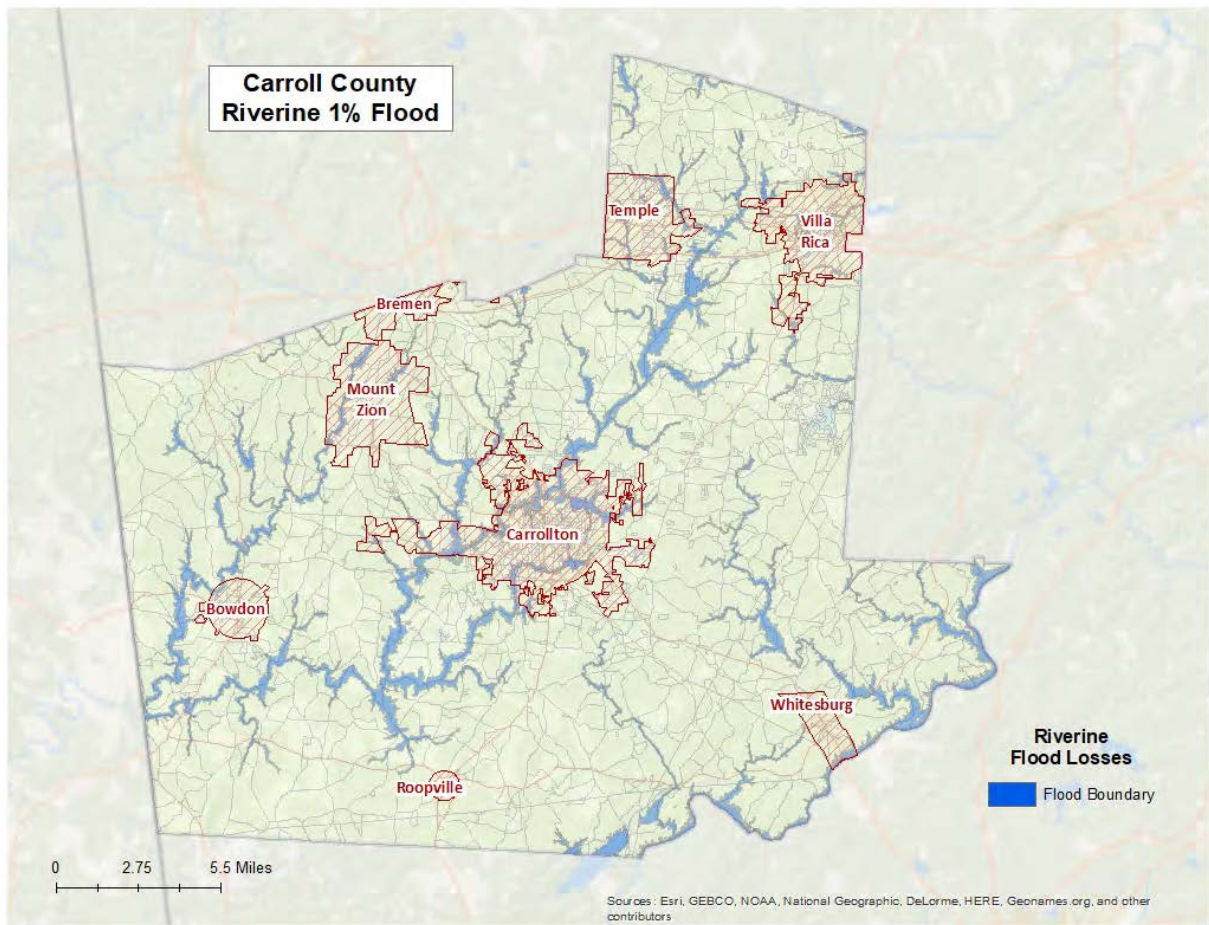

Figure 6: Riverine 1% Flood Inundation

Riverine 1% Flood Building Damages

Buildings in Carroll County are vulnerable to flooding from events equivalent to the 1% riverine flood. The economic and social impacts from a flood of this magnitude can be significant. Table 9 provides a summary of the potential flood-related building damage in Carroll County by jurisdiction that might be experienced from the 1% flood. Figure 7 maps the potential loss ratios of total building exposure to losses sustained to buildings from the 1% flood by 2010 census block and Figure 8 illustrates the relationship of building locations to the 1% flood inundation boundary.

Table 9: Carroll County Riverine 1% Building Losses

Occupancy	Total Buildings in the Jurisdiction	Total Buildings Damaged in the Jurisdiction	Total Building Exposure in the Jurisdiction	Total Losses to Buildings in the Jurisdiction	Loss Ratio of Exposed Buildings to Damaged Buildings in the Jurisdiction
Bowdon					
Residential	752	5	$115,110,092	$409,911	0.36%
Carrollton					
Government	14	2	$12,029,602	$16,201	0.13%
Commercial	1,013	25	$315,689,004	$2,071,620	0.66%
Industrial	311	16	$105,918,199	$3,616,272	3.41%
Agricultural	29	2	$908,081	$47,903	5.28%
Religious	52	2	$11,312,856	$49,997	0.44%
Residential	6,071	115	$1,262,562,014	$17,679,465	1.40%
Mount Zion					
Residential	573	15	$76,323,238	$683,414	0.90%
Temple					
Residential	1,694	45	$272,475,572	$2,507,428	0.92%
Commercial	77	1	$9,282,629	$992	0.01%
Industrial	24	2	$9,239,558	$60,596	0.66%
Occupancy	Total Buildings in	Total Buildings	Total Building Exposure in the	Total Losses to Buildings in	Loss Ratio of Exposed

|	the Jurisdiction	Damaged in the Jurisdiction	Jurisdiction	the Jurisdiction	Buildings to Damaged Buildings in the Jurisdiction
Unincorporated					
Agricultural	41	2	$995,180	$13,729	1.38%
Commercial	461	11	$52,153,508	$82,548	0.16%
Residential	26,151	399	$4,256,897,944	$19,560,971	0.46%
Industrial	319	4	$41,600,075	$78,616	0.19%
Villa Rica					
Industrial	114	2	$60,201,896	$873,031	1.45%
Commercial	352	5	$78,076,237	$417,219	0.53%
Residential	2,865	85	$538,825,448	$6,335,581	1.18%
County Total					
	40,913	**738**	**$7,219,601,133**	**$54,505,494**	
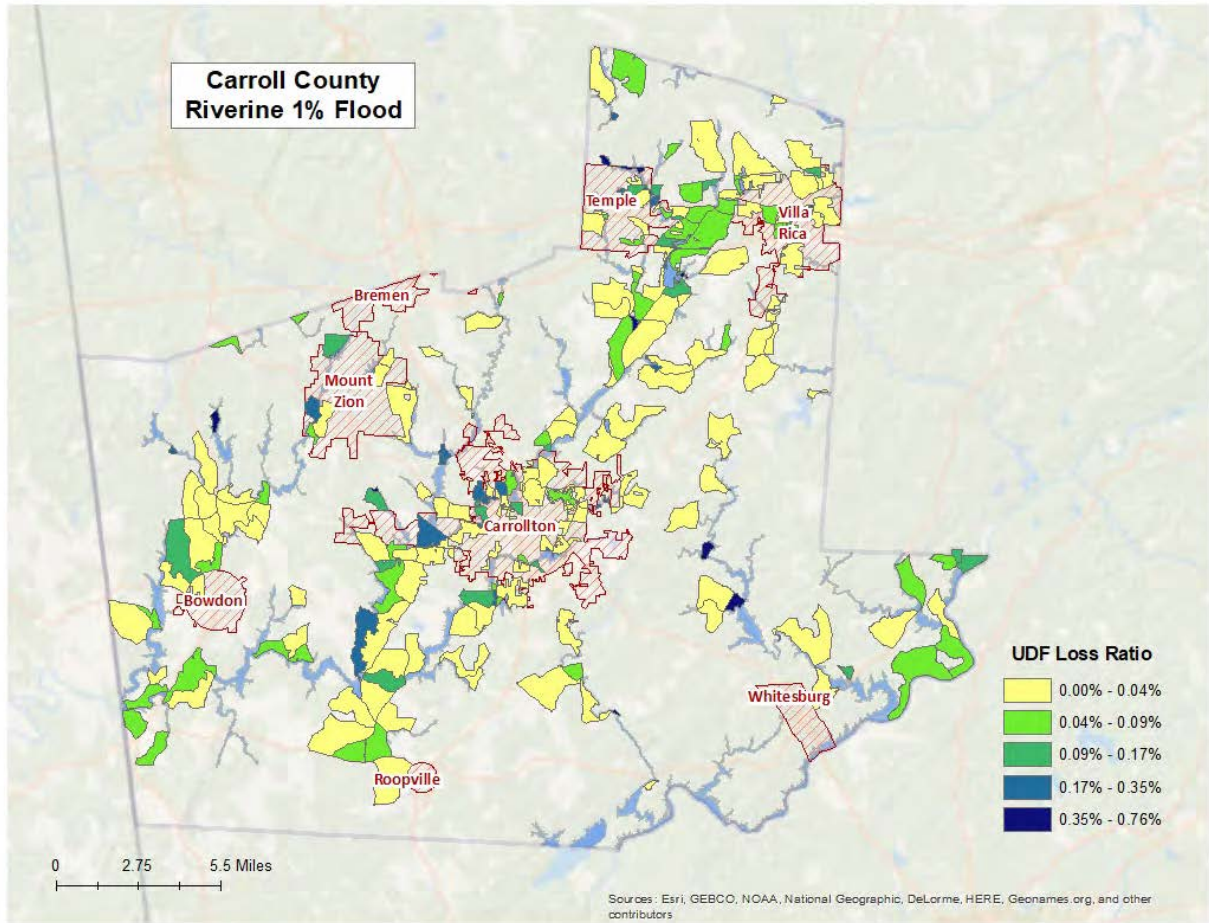
Figure 7: Carroll County Potential Loss Ratios of Total Building Exposure to Losses Sustained to Buildings from the 1% Riverine Flood by 2010 Census Block
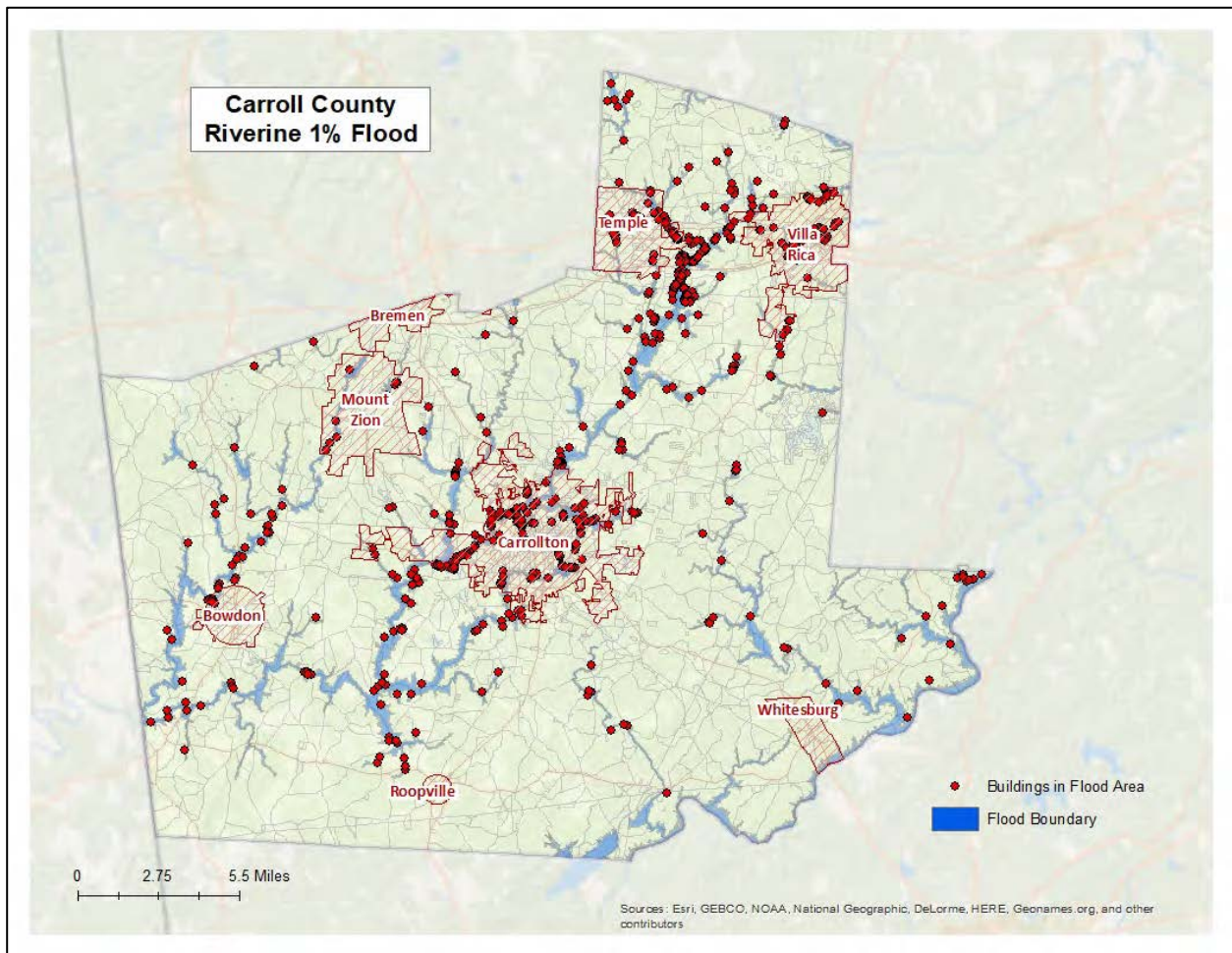
Figure 8: Carroll County Damaged Buildings in Riverine Floodplain (1% Flood)

Riverine 1% Flood Essential Facility Losses

An essential facility may encounter many of the same impacts as other buildings within the flood boundary. These impacts can include structural failure, extensive water damage to the facility and loss of facility functionality (e.g. a damaged police station will no longer be able to serve the community). The analysis identified no essential facility that were subject to damage in the Carroll County riverine 1% probability floodplain.

Riverine 1% Flood Shelter Requirements

Hazus-MH estimates that the number of households that are expected to be displaced from their homes due to riverine flooding and the associated potential evacuation. The model estimates 2,100 households might be displaced due to the flood. Displacement includes households evacuated within or very near to the inundated area. Displaced households represent 6,301 individuals, of which 3,923 may require short term publicly provided shelter. The results are mapped in Figure 9.
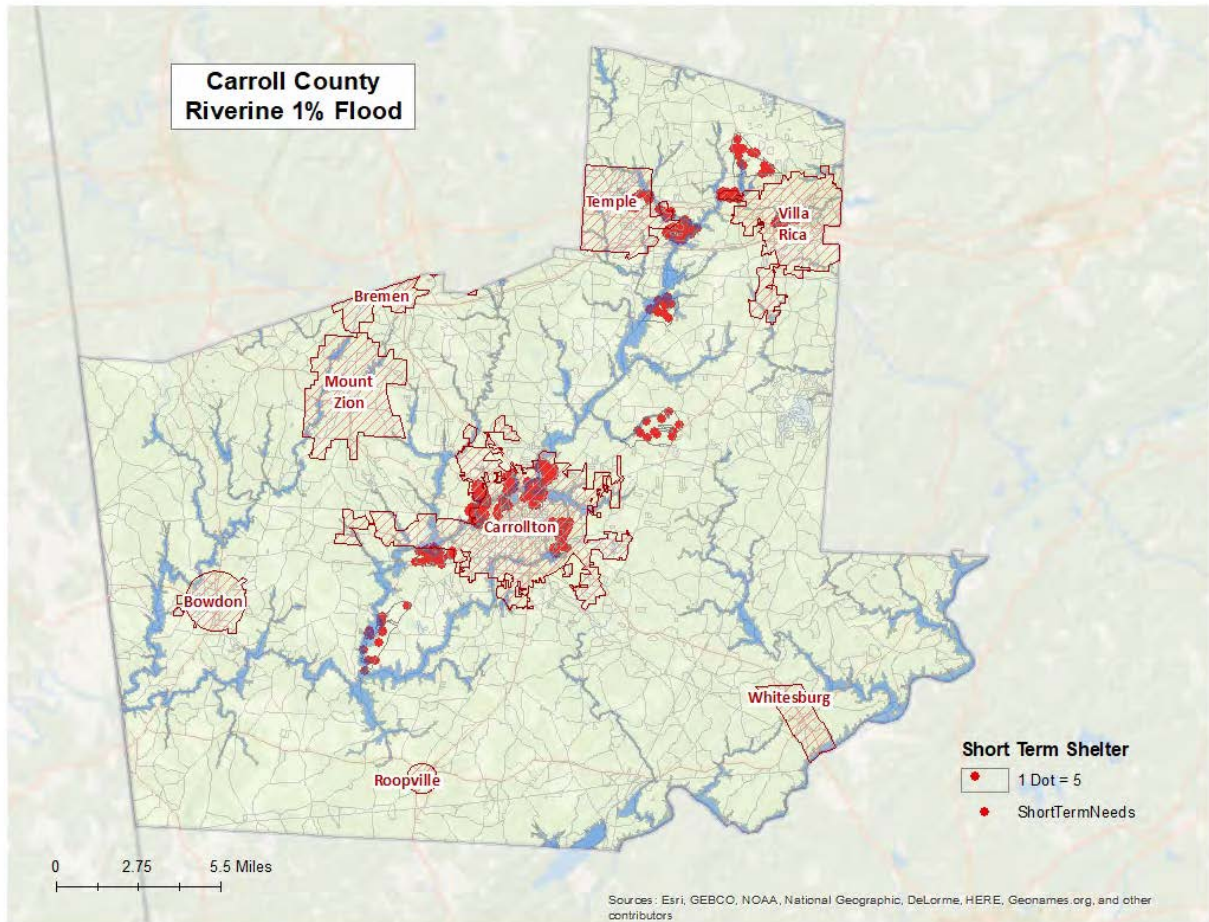

Figure 9: Riverine 1% Estimated Flood Shelter Requirements

Riverine 1% Flood Debris

Hazus-MH estimates the amount of debris that will be generated by the flood. The model breaks debris into three general categories:

- Finishes (dry wall, insulation, etc.)
- Structural (wood, brick, etc.)
- Foundations (concrete slab, concrete block, rebar, etc.)

Different types of material handling equipment will be required for each category. Debris definitions applied in Hazus-MH are unique to the Hazus-MH model and so do not necessarily conform to other definitions that may be employed in other models or guidelines.

The analysis estimates that an approximate total of 26,188 tons of debris might be generated: 1) Finishes- 8,631 tons; 2) Structural – 8,509 tons; and 3) Foundations- 9,047 tons. The results are mapped in Figure 10.
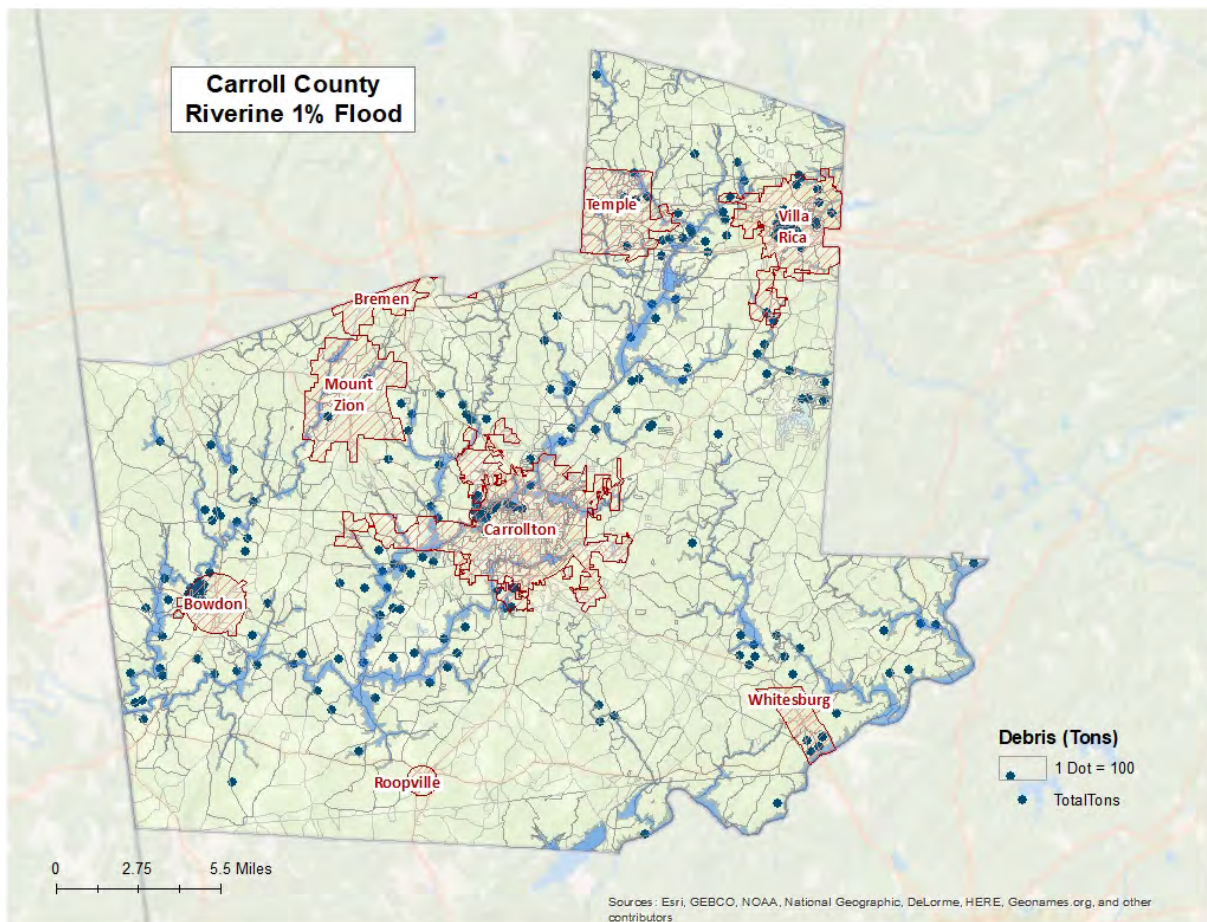

Figure 10: Riverine 1% Flood Debris Weight (Tons)

Tornado Risk Assessment

Hazard Definition

Tornadoes pose a great risk to the state of Georgia and its citizens. Tornadoes can occur at any time during the day or night. They can also happen during any month of the year. The unpredictability of tornadoes makes them one of Georgia's most dangerous hazards. Their extreme winds are violently destructive when they touch down in the region's developed and populated areas. Current estimates place the maximum velocity at about 300 miles per hour, but higher and lower values can occur. A wind velocity of 200 miles per hour will result in a wind pressure of 102.4 pounds per square foot of surface area—a load that exceeds the tolerance limits of most buildings. Considering these factors, it is easy to understand why tornadoes can be so devastating for the communities they hit.

Tornadoes are defined as violently-rotating columns of air extending from thunderstorms and cyclonic events. Funnel clouds are rotating columns of air not in contact with the ground; however, the violently-rotating column of air can reach the ground very quickly and become a tornado. If the funnel cloud picks up and blows debris, it has reached the ground and is a tornado.

Tornadoes are classified according to the Fujita tornado intensity scale. Originally introduced in 1971, the scale was modified in 2006 to better define the damage and estimated wind scale. The Enhanced Fujita Scale ranges from low intensity EF0 with effective wind speeds of 65 to 85 miles per hour, to EF5 tornadoes with effective wind speeds of over 200 miles per hour. The Enhanced Fujita intensity scale is included in Table 10.

Table 10: Enhanced Fujita Tornado Rating

Fujita Number	Estimated Wind Speed	Path Width	Path Length	Description of Destruction
EF0 *Gale*	65-85 mph	6-17 yards	0.3-0.9 miles	Light damage, some damage to chimneys, branches broken, sign boards damaged, shallow-rooted trees blown over.
EF1 Moderate	86-110 mph	18-55 yards	1.0-3.1 miles	Moderate damage, roof surfaces peeled off, mobile homes pushed off foundations, attached garages damaged.
EF2 Significant	111-135 mph	56-175 yards	3.2-9.9 miles	Considerable damage, entire roofs torn from frame houses, mobile homes demolished, boxcars pushed over, large trees snapped or uprooted.
EF3 Severe	136-165 mph	176-566 yards	10-31 miles	Severe damage, walls torn from well-constructed houses, trains overturned, most trees in forests uprooted, heavy cars thrown about.
EF4 Devastating	166-200 mph	0.3-0.9 miles	32-99 miles	Complete damage, well-constructed houses leveled, structures with weak foundations blown off for some distance, large missiles generated.
EF5 Incredible	> 200 mph	1.0-3.1 miles	100-315 miles	Foundations swept clean, automobiles become missiles and thrown for 100 yards or more, steel-reinforced concrete structures badly damaged.

Source: http://www.srh.noaa.gov

Hypothetical Tornado Scenario

For this report, an EF3 tornado was modeled to illustrate the potential impacts of tornadoes of this magnitude in the county. The analysis used a hypothetical path based upon an EF3 tornado event running along the predominant direction of historical tornados (southeast to northwest). The tornado path was placed to travel through Carrollton. The selected widths were modeled after a re-creation of the Fujita-Scale guidelines based on conceptual wind speeds, path widths, and path lengths. There is no guarantee that every tornado will fit exactly into one of these categories. Table 11 depicts tornado path widths and expected damage.

Table 11: Tornado Path Widths and Damage Curves

Fujita Scale	Path Width (feet)	Maximum Expected Damage
EF-5	2,400	100%
EF-4	1,800	100%
EF-3	1,200	80%
EF-2	600	50%
EF-1	300	10%
EF-0	300	0%

Within any given tornado path there are degrees of damage. The most intense damage occurs within the center of the damage path, with decreasing amounts of damage away from the center. After the hypothetical path is digitized on a map, the process is modeled in GIS by adding buffers (damage zones) around the tornado path. Figure 11 describes the zone analysis.
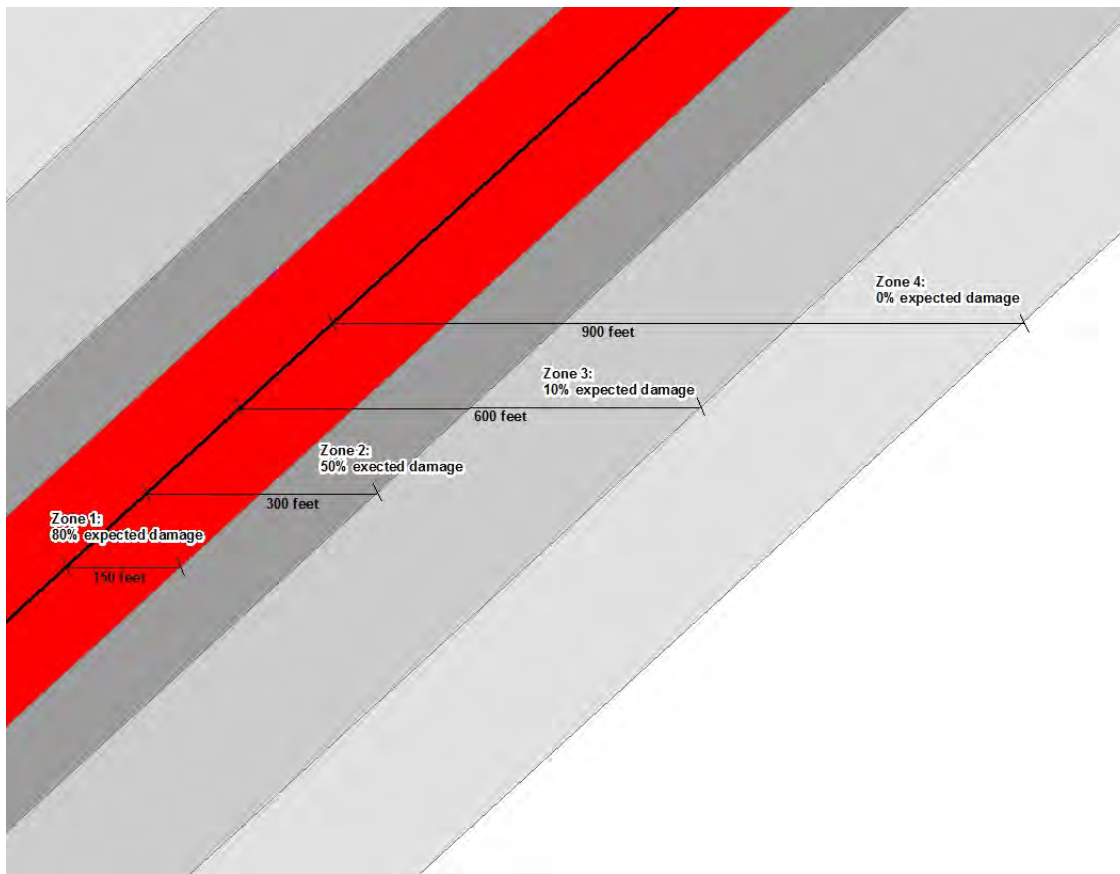
Figure 11: EF Scale Tornado Zones

An EF3 tornado has four damage zones, depicted in Table 12. Major damage is estimated within 150 feet of the tornado path. The outer buffer is 900 feet from the tornado path, within which buildings will not experience any damage. The selected hypothetical tornado path is depicted in Figure 12 and the damage curve buffer zones are shown in Figure 13.

Table 12: EF3 Tornado Zones and Damage Curves

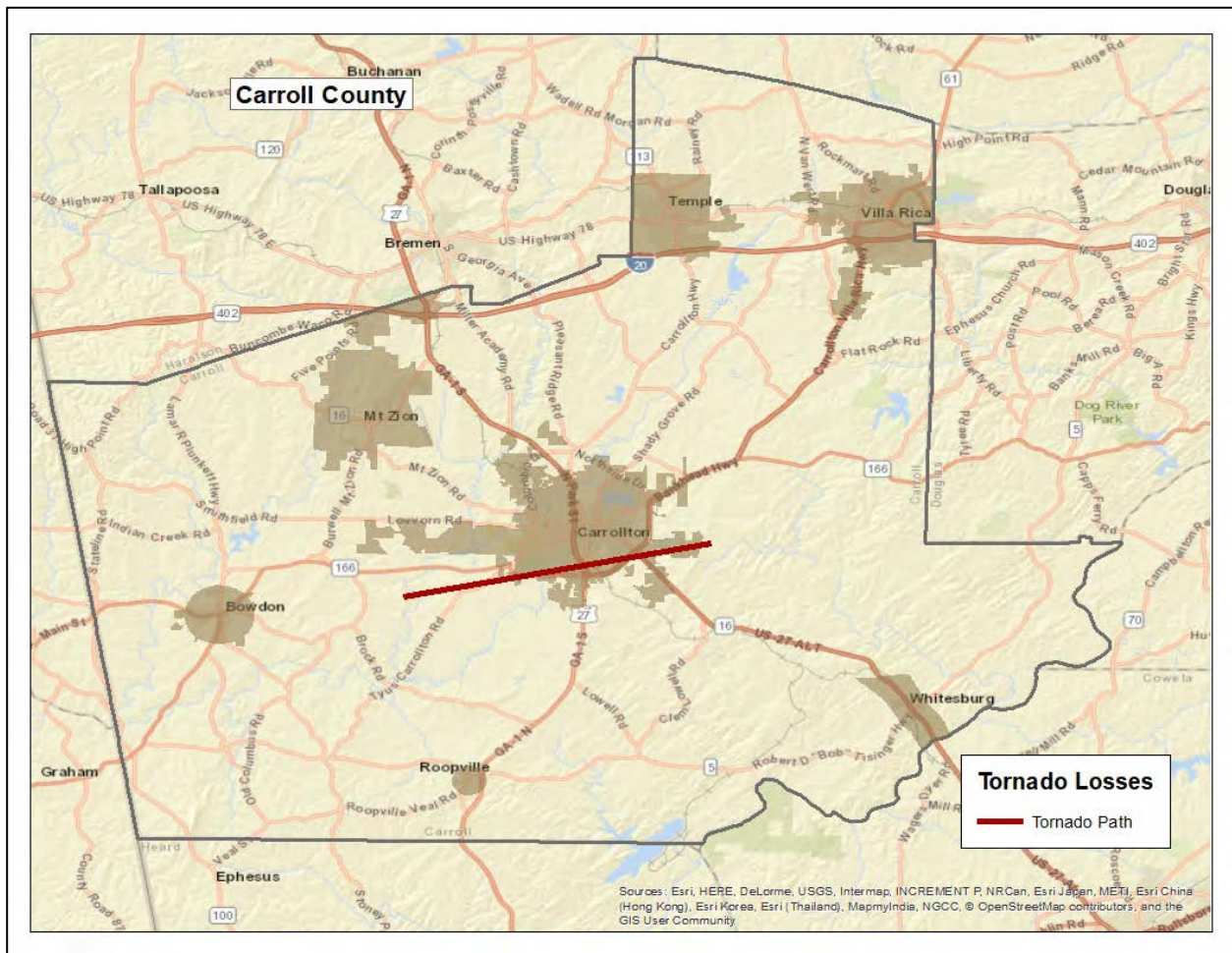| Zone	Buffer (feet)	Damage Curve
1	0-150	80%
2	150-300	50%
3	300-600	10%
4	600-900	0%

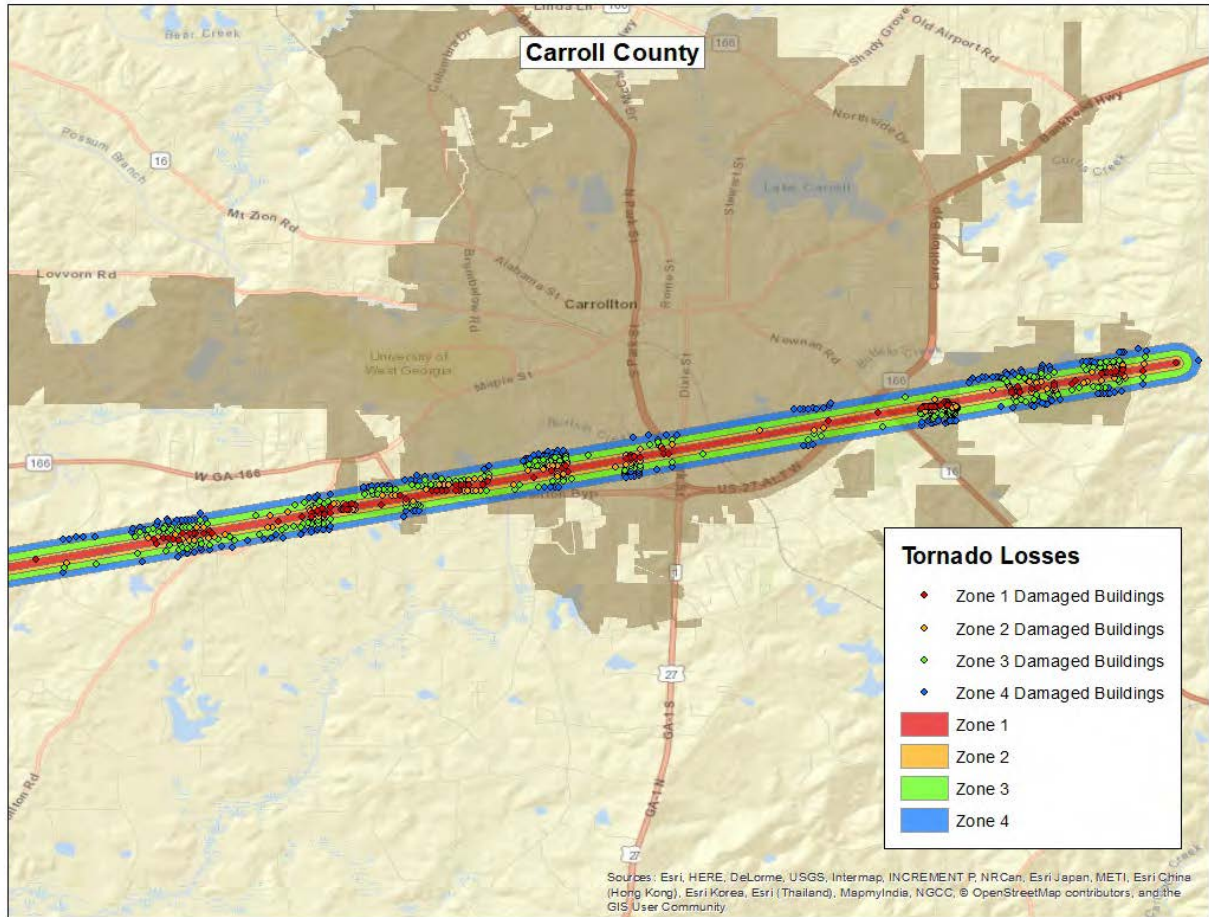Figure 12: Hypothetical EF3 Tornado Path in Carroll County

Figure 13: Modeled EF3 Tornado Damage Buffers in Carroll County

EF3 Tornado Building Damages

The analysis estimated that approximately 695 buildings could be damaged, with estimated building losses of $61 million. The building losses are an estimate of building replacement costs multiplied by the percentages of damage. The overlay was performed against parcels provided by Carroll County that were joined with Assessor records showing estimated property replacement costs. The Assessor records often do not distinguish parcels by occupancy class if the parcels are not taxable and thus the number of buildings and replacement costs may be underestimated. The results of the analysis are depicted in Table 13.

Table 13: Estimated Building Losses by Occupancy Type

Occupancy	Buildings Damaged	Building Losses
Residential	621	$40,012,870
Commercial	51	$13,730,821
Industrial	15	$2,088,797
Agricultural	1	$475
Education	5	$4,702,232
Government	2	$19,699
Total	695	$60,554,894

EF3 Tornado Essential Facility Damage

There were five essential facilities located in the tornado path - three schools and two police stations. Table 14 outlines the specific facility and the amount of damage under the scenario.

Table 14: Estimated Essential Facilities Damaged

Facility	Amount of Damage
West Central Tech	Major Damage
Carroll County Sheriff's Department	Major Damage
Carroll County Jail	Minor Damage
Carrollton Junior High	Minor Damage
Carrollton Elementary School	Minor Damage

According to the Georgia Department of Education, Carrollton Elementary School's enrollment was approximately 1,709 students and Carrollton Junior High's enrollment was approximately 812 students as of March 2019. West Georgia Technical College's enrollment was approximately 1,905 students as of January 2018. Depending on the time of day, a tornado strike as depicted in this scenario could result in significant injury and loss of life. In addition, arrangements would have to be made for the continued education of the students in another location.

The location of the damaged Essential Facility is mapped in Figure 14.
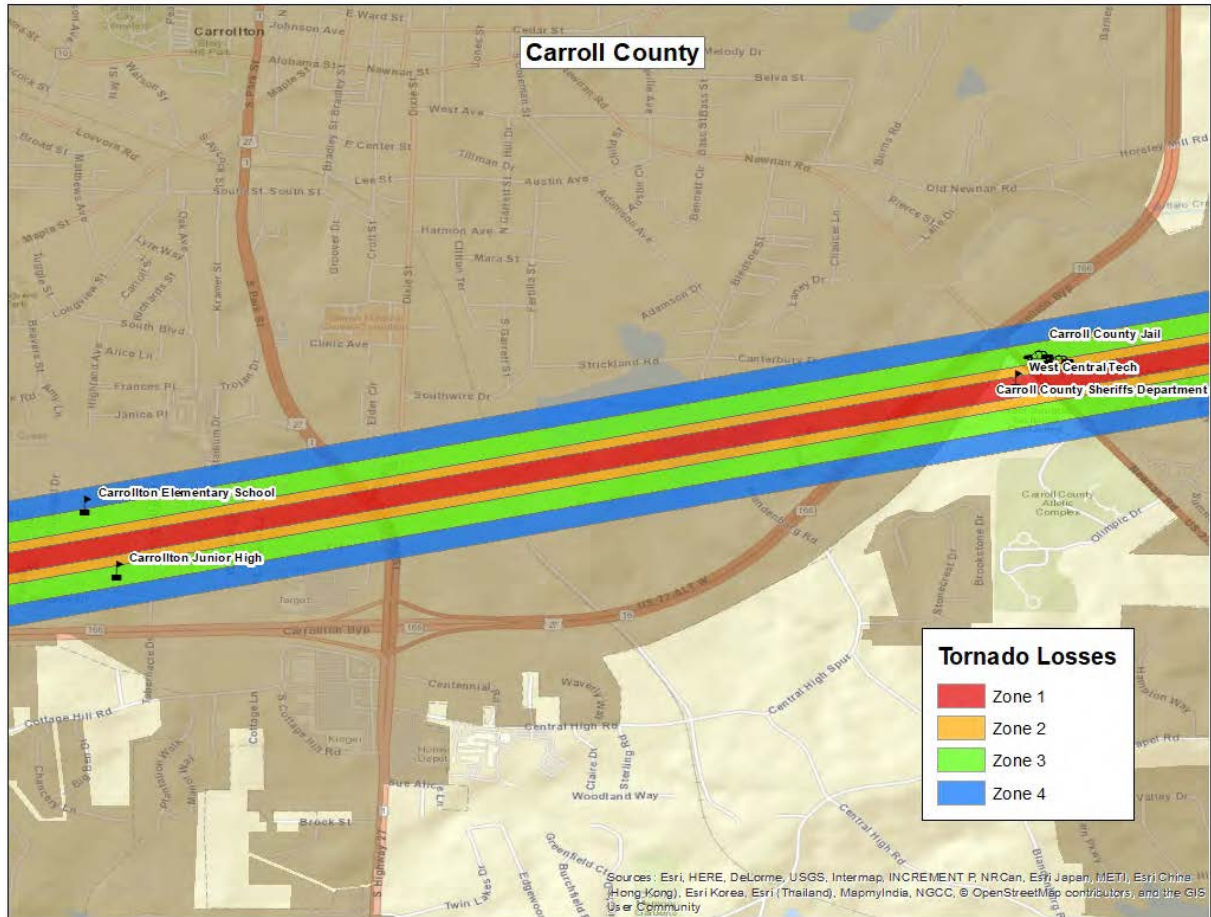
Figure 14: Modeled Essential Facility Damage in Carroll County

Exceptions Report

Hazus Version 2.2 SP1 was used to perform the loss estimates for Carroll County, Georgia. Changes made to the default Hazus-MH inventory and the modeling parameters used to setup the hazard scenarios are described within this document.

Reported losses reflect the updated data sets. Steps, algorithms and assumptions used during the data update process are documented in the project workflow named PDM_GA_Workflow.doc.

Statewide Inventory Changes

The default Hazus-MH Essential Facility inventory was updated for the entire state prior to running the hazard scenarios for Carroll County.

Updates to the Critical Facility data used in GMIS were provided by Carroll County in March 2019. These updates were applied by The Carl Vinson Institute of Government at the University of Georgia. Table 15 summarizes the difference between the original Hazus-MH default data and the updated data for Carroll County.

Table 15: Essential Facility Updates

Site Class	Feature Class	Default Replacement Cost	Default Count	Updated Replacement Cost	Updated Count
EF	Care	$159,571,000	5	$159,571,000	5
EF	EOC	$880,000	1	$267,000	1
EF	Fire	$4,365,000	17	$8,725,000	19
EF	Police	$8,374,000	7	$18,329,000	12
EF	School	$309,986,000	82	$305,630,000	77

County Inventory Changes

The GBS records for Carroll County were replaced with data derived from parcel and property assessment data obtained from Carroll County. The county provided property assessment data was current as of August 2018 and the parcel data current as of August 2018.

General Building Stock Updates

The parcel boundaries and assessor records were obtained from Carroll County. Records without improvements were deleted. The parcel boundaries were converted to parcel points located in the centroids of each parcel boundary. Each parcel point was linked to an assessor record based upon matching parcel numbers. The generated Building Inventory represents the approximate locations (within a parcel) of building exposure. The Building Inventory was aggregated by Census Block and

imported into Hazus-MH using the Hazus-MH Comprehensive Data Management System (CDMS). Both the 2010 Census Tract and Census Block tables were updated.

The match between parcel records and assessor records was based upon a common Parcel ID. For this type of project, unless the hit rate is better than 85%, the records are not used to update the default aggregate inventory in Hazus-MH. The Parcel-Assessor hit rate for Carroll County was 99.8%.

Adjustments were made to records when primary fields did not have a value. In these cases, default values were applied to the fields. Table 16 outlines the adjustments made to Carroll County records.

Table 16: Building Inventory Default Adjustment Rates

Type of Adjustment	Building Count	Percentage
Area Unknown	1,589	4%
Construction Unknown	2,925	7%
Condition Unknown	595	1%
Foundation Unknown	2,927	7%
Year Built Unknown	9	0%
Total Buildings	41,690	4%

Approximately 4% of the CAMA values were either missing (<Null> or '0'), did not match CAMA domains or were unusable ('Unknown', 'Other', 'Pending'). These were replaced with 'best available' values. Missing YearBuilt values were populated from average values per Census Block. Missing Condition, Construction and Foundation values were populated with the highest-frequency CAMA values per Occupancy Class. Missing Area values were populated with the average CAMA values per Occupancy Class.

The resulting Building Inventory was used to populate the Hazus-MH General Building Stock and User Defined Facility tables. The updated General Building Stock was used to calculate flood and tornado losses. Changes to the building counts and exposure that were modeled in Carroll County are sorted by General Occupancy in Table 1 at the beginning of this report. If replacements cost or building value were not present for a given record in the Assessor data, replacement costs were calculated from the Building Area (sqft) multiplied by the Hazus-MH RS Means ($/sqft) values for each Occupancy Class.

Differences between the default and updated data are due to various factors. The Assessor records often do not distinguish parcels by occupancy class when the parcels are not taxable; therefore, the total number of buildings and the building replacement costs for government, religious/non-profit, and education may be underestimated.

User Defined Facilities

Building Inventory was used to create Hazus-MH User Defined Facility (UDF) inventory for flood modeling. Hazus-MH flood loss estimates are based upon the UDF point data. Buildings within the flood boundary were imported into Hazus-MH as User Defined Facilities and modeled as points.

Table 17: User Defined Facility Exposure

Class	Hazus-MH Feature	Counts	Exposure
BI	Building Exposure	41,690	$7,418,815,166
Riverine UDF	Structures Inside 1% Annual Chance Riverine Flood Area	797	$210,790,441

Assumptions

- Flood analysis was performed on Building Inventory. Building Inventory within the flood boundary was imported as User Defined Facilities. The point locations are parcel centroid accuracy.
- The analysis is restricted to the county boundary. Events that occur near the county boundary do not contain loss estimates from adjacent counties.
- The following attributes were defaulted or calculated:
    First Floor Height was set from Foundation Type
    Content Cost was calculated from Building Cost