Hazard Risk Analyses

Supplement to the Richmond County Joint Hazard Mitigation Plan

The Polis Center

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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 2012, the Georgia Department of Community Affairs (DCA) partnered with The Polis Center (Polis) at Indiana University Purdue University-Indianapolis (IUPUI) to develop a detailed risk assessment focused on defining hurricane, riverine flood, coastal flood risks and tornado in Richmond 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 Version 2.1 was used to perform the analyses for Richmond County. The Hazus application includes default data for every county in the US. This Hazus 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. Richmond County provided building inventory information from the county's property tax assessment system. This section describes the changes made to the default Hazus inventory and the modeling parameters used for each scenario.

County Inventory Changes

The default Hazus site-specific point inventory was updated using data compiled from the Georgia Emergency Management Agency (GEMA) in coordination with the Georgia Department of Community Affairs (DCA) 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 generates a combination of site-specific and aggregated loss estimates based on the given analysis and user input.

The GBS records for Richmond County were replaced with records provided by Richmond County with help from DCA. 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 Richmond County is close to 100%. 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.

For Richmond 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 as User-Defined Facility (UDF)[1], or site-specific points.

Table 1: GBS Building Exposure Updates by Occupancy Class*

General Occupancy	Default Count	Default Exposure	Updated Count	Updated Exposure
Agricultural	196	$26,011,000	248	$36,953,000
Commercial	4202	$2,707,355,000	4,027	$2,513,155,000
Education	145	$137,831,000	73	$241,758,000
Government	129	$96,570,000	51	$72,662,000
Industrial	961	$495,189,000	65	$89,832,000
Religious	515	$312,465,000	393	$239,650,000
Residential	71,769	$8,967,798,000	66,492	$7,836,548,000
Total	**77,917**	**$12,743,219,000**	**71,349**	**$11,030,558,000**

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

Essential Facility Updates

The default Hazus essential facility data was updated to reflect improved information available in the Georgia Mitigation Information System (GMIS), which is current as of August 30, 2012. For these risk analyses, only GMIS data for the Essential Facilities was integrated into Hazus-MH because the

Essential facilities include:

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

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

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 by Essential Facility classification of the updated data.

Table 2: Updated Essential Facilities

Classification	Updated Count	Updated Exposure
Hephzibah City		
EOC	0	0
Care	0	0
Fire	1	$228,000
Police	1	$210,000
School	4	$846,785,000
Total	6	$847,223,000
Blythe City		
EOC	0	0
Care	0	0
Fire	1	$482,000
Police	1	$386,000
School	1	$85,422,000
Total	**3**	$86,290,000
Others Facilities in Richmond County but outside of city jurisdiction boundaries		
EOC	1	$880,000
Care	17	$1,389,094,000
Fire	23	$836,333,000
Police	7	$96,818,000
School	177	$28,581,175,000
Total	225	$30,904,300,000

Assumptions and Exceptions

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

- The Richmond County analysis used Hazus Version 2.1, which was released by FEMA in February 2012.

- The population counts from the 2010 census were applied to the Hazus demographics table. Not all population counts were available, so there will be inconsistencies. For example, the sum of female and male populations (not updated) will not equal the total population (updated).

The hazard models included in this risk assessment included:

- Hurricane assessment comprised of a wind only damage assessment
- Flood assessment based on the 1% annual chance riverine flood event
- Tornado assessment based on GIS modeling

User Defined Facility and General Building Stock updates and subsequent analysis were conducted with the following assumptions:

- Assessor records are often not maintained when the parcels are not taxable. In such instances, the building replacement costs for government, religious/non-profit and education occupancy classes may be underestimated. Records for Religious, Government and/or Education occupancy classes were available in the Richmond County assessor's data and therefore this was not an issue.

- GBS updates from assessor data will skew loss calculations (see Table 2). 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 was assumed that the buildings are located at the centroid of the parcel.

- 153 out of 80,711 points fell outside of the county boundary. Some of the points belonged to parcels that did not intersect the county boundary as shown in the example below.

Some points appear to fall within the county boundary but there was not overlapping census blocks (possibly correct and possibly due to an error in the Hazus census block data) as shown in the following example.

All points were manually moved to the closest adjacent block.

- Based on a frequency analysis of the COMPNO field in the acBuildings_Failed feature class there are no structures in the acBuildings table that should be processed in Hazus-MH.
- It was determined that the county BI data does not include the land that covers Fort Gordon as shown below.

Fort Gordon is the home of US Army Signal Corps and does contain a number of buildings. The two graphics shown below show the area where these are located as well as a table with the default Hazus counts for those areas. These buildings are not represented in the updated Hazus inventory.

Table

absv_InvGbsBldgCountOccupGen

OBJECTID *	SHAPE *	CensusBlock	SHAPE_Length	SHAPE_Area	CensusBlock *	Total	Residential	Commercial	Industrial	Agriculture	Religion	Government	Education
2918	Polygon	132450107041038	0.042446	0.000007	132450107041038	7	6	1	0	0	0	0	0
3101	Polygon	132450108009000	0.136748	0.001014	132450108009000	514	499	10	0	1	1	2	1
3102	Polygon	132450108009001	0.130994	0.000651	132450108009001	119	110	5	2	0	0	0	2
3103	Polygon	132450108009002	0.027949	0.000004	132450108009002	0	0	0	0	0	0	0	0
3104	Polygon	132450108009003	0.021548	0.000021	132450108009003	5	4	1	0	0	0	0	0
3105	Polygon	132450108009004	0.03429	0.000039	132450108009004	15	15	0	0	0	0	0	0
3106	Polygon	132450108009005	0.281872	0.002225	132450108009005	122	105	8	1	0	1	7	0
3107	Polygon	132450108009006	0.389168	0.005289	132450108009006	1	0	1	0	0	0	0	0
3108	Polygon	132450108009007	0.002931	0	132450108009007	0	0	0	0	0	0	0	0
3109	Polygon	132450108009008	0.552577	0.008047	132450108009008	5	5	0	0	0	0	0	0
3110	Polygon	132450108009009	0.001971	0	132450108009009	0	0	0	0	0	0	0	0
3111	Polygon	132450108009010	0.003254	0	132450108009010	0	0	0	0	0	0	0	0
3112	Polygon	132450108009011	0.02075	0.000003	132450108009011	0	0	0	0	0	0	0	0
3113	Polygon	132450108009012	0.01316	0.000002	132450108009012	0	0	0	0	0	0	0	0
3114	Polygon	132450108009013	0.004972	0.000001	132450108009013	2	1	1	0	0	0	0	0
3115	Polygon	132450108009014	0.003433	0.000001	132450108009014	0	0	0	0	0	0	0	0
3204	Polygon	132450109014036	0.025051	0.000002	132450109014036	0	0	0	0	0	0	0	0
3206	Polygon	132450109014038	0.014158	0.000001	132450109014038	0	0	0	0	0	0	0	0
3213	Polygon	132450109014045	0.040607	0.000015	132450109014045	0	0	0	0	0	0	0	0

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 Richmond County by creating a 20-mile buffer around the county to include storms that didn't make direct landfall in Richmond County but impacted the county. Since 1863, Richmond County has had 21 tropical systems within 20 miles of its county borders (Table 4).

[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.

Table 4: Tropical Systems affecting Richmond County[3]

YEAR	MONTH	DAY	NAME	LAT	LONG	WIND KTS	PRESSURE	CAT
1851	8	24	NOTNAMED	32.5	-83	60	0	TS
1852	8	27	NOTNAMED	33.2	-82.8	40	0	TS
1877	10	4	NOTNAMED	32.8	-82.1	40	0	TS
1886	6	22	NOTNAMED	32.3	-83.2	45	0	TS
1887	10	20	NOTNAMED	33	-82.5	30	0	TD
1902	6	15	NOTNAMED	33	-81.7	35	0	TS
1915	8	3	NOTNAMED	32.9	-82.1	40	0	TS
1929	10	1	NOTNAMED	32.3	-82.9	40	0	TS
1934	5	31	NOTNAMED	33.6	-82.9	20	0	TD
1935	9	5	NOTNAMED	33	-81.7	55	0	TS
1946	10	8	NOTNAMED	31.9	-82.1	35	0	TS
1947	10	8	NOTNAMED	32.1	-82.6	20	0	TD
1949	8	28	NOTNAMED	33	-82.7	40	996	TS
1964	8	30	CLEO	32.9	-81.9	30	0	TD
1965	6	15	NOTNAMED	31.9	-84.2	40	0	TS
1968	6	7	ABBY	32.6	-82	30	0	TD
1972	6	20	AGNES	32.9	-82.8	30	992	TD
1990	10	12	MARCO	32	-83	20	1005	E
2000	9	23	HELENE	32.9	-83.5	25	1011	TD
2001	6	13	ALLISON	33.4	-81.6	25	1004	SD
2006	6	14	ALBERTO	32.8	-81.9	30	1003	TD

Category Definitions:

TS – Tropical storm

TD – Tropical depression

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

E – Extra-tropical cyclone

[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 2012-03-01.

CONTINENTAL UNITED STATES
HURRICANE STRIKES 1950-2011*
Carol (1953)
Gerda (1969)
Edna (1954)
Carol (1954)
Donna (1960)
Gloria (1985)
Edna (1954)
Bob (1991)
Belle (1976)
Isabel (2003)
Connie (1955)
Ione (1955)
Irene (2011)
Ginger (1971)
Bertha (1996)
Fran (1996)
Diana (1984)
Charley (2004)
Gaston (2004)
Carol (1954)
Emily (1993)
Alex (2004)
Gloria (1985)
Barbara (1953)
Charley (1986)
Ophelia (2005)
Donna (1960)
Diane (1955)
Floyd (1999)
Bonnie (1998)
Hazel (1954)
Cindy (1959)
Hugo (1989)
Gracie (1959)
Able (1952)
Bob (1985)
David (1979)
Dora (1964)
Baker (1950)
Ivan (2004)
Erin (1995)
Opal (1995)
Dennis (2005)
Eloise (1975)
Flossy (1956)
Florence (1953)
Agnes (1972)
Earl (1998)
Alma (1966)
Danny (1985)
Edith (1971)
Audrey (1957)
Rita (2005)
Bonnie (1986)
Humberto (2007)
Cindy (1963)
Chantal (1989)
Debra (1959)
Jerry (1989)
Alicia (1983)
Fern (1971)
Carla (1961)
Danny (1997)
Frederic (1979)
Georges (1998)
Ethel (1960)
Elena (1985)
Katrina (2005)
Kate (1985)
Camille (1969)
Flossy (1956)
Danny (1997)
Cindy (2005)
Florence (1988)
Gustav (2008)
Betsy (1965)
Bob(1979)
Carmen (1974)
Juan (1985)
Babe (1977)
Ike (2008)
Lili (2002)
Hilda (1964)
Andrew (1992)
Claudette (2003)
Celia (1970)
Bret (1999)
Dolly (2008)
Allen (1980)
Beulah (1967)
Easy (1950)
Gladys (1968)
Charley (2004)
Donna (1960)
Isbell (1964)
Wilma (2005)
Georges (1998)
Irene (1999)
David (1979)
Erin (1995)
Jeanne (2004)
Frances (2004)
Cleo (1964)
Katrina (2005)
King (1950)
Andrew (1992)
Betsy (1965)
Inez (1966)
Donna (1960)
Floyd (1987)
Saffir-Simpson Hurricane Categories (at Strike or Landfall)
Sustained Winds (MPH)
74-95 Category 1
96-110 Category 2
111-130 Category 3
131-155 Category 4
>155 Category 5
There were no hurricane strikes in the U.S. for the years 2000, 2001, 2006, 2009, and 2010.
Due to density of storms in some locations, actual strike locations are approximate.
* STRIKES- includes hurricanes that did not make direct landfall, but did produce hurricane force winds over land.
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PROBABILISTIC HURRICANE SCENARIO

Storm surge in this risk assessment is modeled using outputs from the SLOSH (Sea, Lake and Overland Surges from Hurricanes) Maximum of Maximums (MOMs) data that is calculated for each hurricane wind category. This analysis modeled a Category 1 Hurricane. This data has been revised to flood depths using the flood water elevations and elevation data from the National Elevation Dataset (NED). Each depth grid was put into Hazus-MH and damages and losses were calculated. Although the amount of rainfall from each storm can vary greatly, riverine flooding from hurricanes can have an impact inland. For this risk assessment, the damages and losses from the storm surge provide a flood risk due to hurricane landfalls.

The following probabilistic risk assessment is categorized into two sections:

1. Wind damage assessment
2. Flood (storm surge) damage assessment

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 Richmond County. Wind losses were determined from probabilistic models run for the Category 1 storm which equates to the 1% chance storm event. Figure 1 shows wind speeds for the modeled Tropical Storm.

Figure 1: Wind Speeds by Storm Category

Wind-Related Building Damages

Buildings in Richmond 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 Richmond County for the Category 1 (100 Year Event) storm. The loss ratio expresses building losses as a percentage of total building replacement cost. Figure 2 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[4]	Loss Ratio
Category 1 Storm	951	$26,148,000	$37,195,000	0.24%

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 2: Hurricane Wind Building Loss Ratios

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

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 identified the essential facilities that may be moderately or severely damaged by winds. The results are compiled in Table 6.

There are 234 essential facilities in Richmond County.

Classification	Number
EOCs	1
Fire stations	25
Hospitals	17
Police stations	9
Schools	182

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	2	0	234

Shelter Requirements

Hazus 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. The results are listed in Table 7 and mapped in Figure 3.

Table 7: Displaced Households and People

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

Figure 3: Hurricane Wind Shelter Requirements

(No shelter needs are anticipated for this event. Therefore, no map was generated.)

Debris Generated from Hurricane Wind

Hazus 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: 1) brick/wood, 2) concrete/steel, and 3) tree debris. Different material handling equipment is required for each category of debris. The results are listed in Table 8 and mapped in Figure 4. 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	4,335	0	11,988	44,562	60,885

Figure 4 shows the distribution of all wind related debris resulting from a Category 1 hurricane. Each dot represents 100 tons of debris within the census tract in which it is located. The dots do not represent the specific location of debris sites.

Figure 4: 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 Richmond County flood risk assessment analyzed at risk structures in the 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 following probabilistic risk assessment addresses only riverine flooding.

Riverine 1% Flood Scenario

Riverine losses are determined from the 1% flood boundaries found in the March 2012 DFIRM maps provided by the Georgia Department of Community Affairs. The flood boundaries were overlaid with the USGS DEM to generate riverine depth grids. The riverine flood depth grids were then imported into Hazus-MH to calculate the riverine flood loss estimates. Figure 5 illustrates the riverine boundary associated with the one-percent-annual chance.

Figure 5: Riverine 1% Flood Inundation

Riverine 1% Flood Building Damages

Buildings in Richmond County are vulnerable to flooding from the 1% Riverine Flood and the cost to rebuild may have significant consequences to the community. Table 9 shows a summary of the results of flood-related building damage in Richmond County for the Riverine 1% storm. Figure 6 reflects the loss ratios from flood damage and Figure 7 maps the buildings located in the inundation area.

Table 9: Richmond County County Riverine 1% Building Losses

Classification	Number of Buildings Damaged	Total Building Loss ($)	Loss Ratio
Augusta-Richmond County consolidated government			
Residential	1,831	$54,296,880	0.6%
Commercial	166	$6,159,415	0.2%
Industrial	3	$537,382	0.5%
Agricultural	8	$385,430	1%
Religious	8	$421,412	0.1%
Government	0	$0	0.00%
Education	1	$65,743	0.03%
Hephzibah City			
Residential	67	$3,704,390	2%
Commercial	0	$0	0.00%
Industrial	0	$0	0.00%
Agricultural	1	$21,816	0.3%
Religious	1	$139,524	0.3%
Government	0	$0	0.00%
Education	0	$0	0.00%
Blythe City			
There are no structures predicted to sustain damage from the riverine 1% flooding			

Figure 6: Richmond County Riverine Related Losses

Figure 7: Richmond County 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 the following essential facilities that were subject to damage in the Richmond County 1% probability floodplain.

Category	Facility Name
School	Westminster Schools of Augusta, Adminstr
School	C.H. Terrell Academy

Riverine 1% Flood Shelter Requirements

Hazus 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 2,921 households will be displaced due to the flood. Displacement includes households evacuated within or very near to the inundated area. Displaced households represent 8,762 individuals, of which 6,419 will require short term publicly provided shelter. The results are mapped in Figure 8.

Figure 8: Riverine 1% Flood Shelter Requirements

Riverine 1% Flood Debris

Hazus estimates the amount of debris that will be generated by the flood. The model breaks debris into three general categories: 1) Finishes (dry wall, insulation, etc.), 2) Structural (wood, brick, etc.) and 3) Foundations (concrete slab, concrete block, rebar, etc.). Different types of material handling equipment will be required for each category. Debris definitions applied in Hazus are unique to the Hazus 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 78,154 tons of debris will be generated: 1) Finishes- 25,026 tons; 2) Structures- 31,025 tons; and 3) Foundations- 22,103 tons. The results are mapped in Figure 9.

Figure 9: 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

The following example scenario is described to gauge the anticipated impacts of tornadoes in the county, in terms of numbers and types of buildings and infrastructure. GIS overlay modeling was used to determine the potential impacts of an EF4 tornado. The analysis used a historical path based upon the F4 tornado event that ran for 17.68 miles just west of City of August in April of 2009. 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	3000	100%
EF-4	2400	100%
EF-3	1800	80%
EF-2	1200	50%
EF-1	600	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 10 and Table 12 describe the zone analysis. The selected hypothetical tornado path is depicted in Figure 11, and the damage curve buffers are shown in Figure 12.

Figure 10: EF Scale Tornado Zones

An EF4 tornado has four damage zones, depicted in Table 12. Total devastation is estimated within 150 feet of the tornado path. The outer buffer is 900 feet from the tornado path, within which buildings will experience 10% damage.

Table 12: EF4 Tornado Zones and Damage Curves

Zone	Buffer (feet)	Damage Curve
1	0-150	100%
2	150-300	80%
3	300-600	50%
4	600-900	10%

Figure 11: Hypothetical EF4 Tornado Path in Richmond County

Figure 12: Modeled EF4 Tornado Damage Buffers in Richmond County

F4 Tornado Building Damages

The GIS analysis estimates that 1,721 buildings will be damaged, with estimated building losses of $95,149,510. The building losses are an estimate of building replacement costs multiplied by the percentages of damage. The overlay was performed against parcels provided by Richmond 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 Tables 13 and 14.

Table 13: Estimated Numbers of Buildings Damaged

Occupancy	Zone 1	Zone 2	Zone 3	Zone 4
Residential	290	303	519	530
Commercial	6	12	27	22
Industrial	1	0	0	0
Agriculture	0	2	1	0
Religious	2	3	1	1
Government	0	0	0	0
Education	1	0	0	0
Total	300	320	548	553

Table 14: Estimated Building Losses

Occupancy	Zone 1	Zone 2	Zone 3	Zone 4
Residential	$30,901,732	$23,482,202	$27,829,563	$5,446,233
Commercial	$590,410	$718,254	$1,175,857	$417,016
Industrial	$613,471	$0	$0	$0
Agriculture	$0	$184,080	$128,150	$0
Religious	$661,225	$1,651,753	$86,569	$132,998
Government	$0	$0	$0	$0
Education	$1,130,000	$0	$0	$0
Total	$33,896,838.00	$26,036,289.00	$29,220,139.00	$5,996,247.00

Tornado Essential Facility Damage

There are three essential facilities located within 900 feet of the historical tornado path. The model predicts three schools would experience damage. The affected facilities are identified in Table 15, and their geographic locations are shown in Figure 13.

Table 15: Estimated Essential Facilities Affected

Name
Augusta Seventh Day Adventist (closed)
Bungalow Road Elementary School
Jenkins Elementary School (Former)

Figure 13: Essential Facilities within Tornado Path