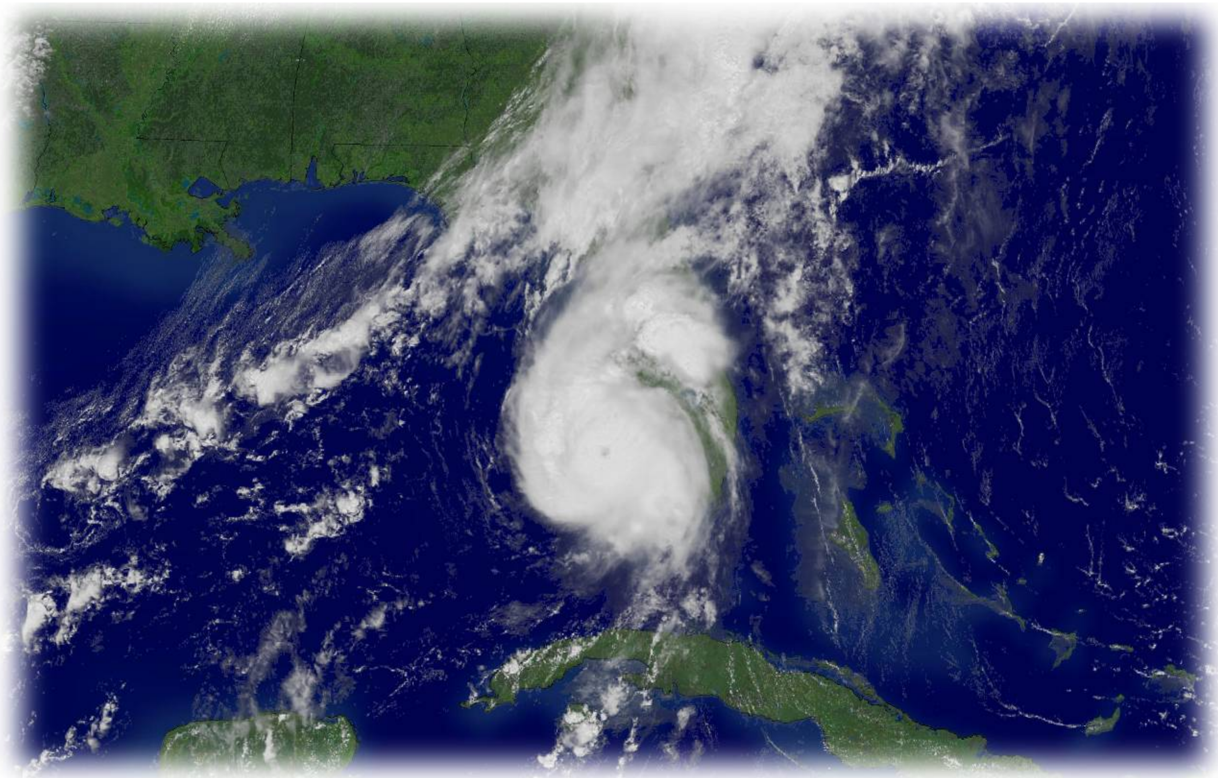

HAZUS-MH® Hurricane Wind Model Validation Study – Florida

Hurricanes Charley and Ivan

HAZUS-MH® MR-2

April 2007

FEMA

HAZUS MH

FEMA HMTAP 440

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ABBREVIATIONS

ARC – American Red Cross

CECBL – Concrete, Engineered Commercial Building, Low-Rise

CECBM – Concrete, Engineered Commercial Building, Mid-Rise

FDEM – Florida Division of Emergency Management

FDOIR – Florida Department of Insurance Regulation

FDOT – Florida Department of Transportation

FEMA – Federal Emergency Management Agency

FHA – Florida Hospital Association

GIS – Geographic Information System

HAZUS-MH – Hazards United States-Multi-Hazard

HMTAP – Hazard Mitigation Technical Assistance Program

JFO – Joint Field Office

MECBL – Masonry, Engineered Commercial Building, Low-Rise

MECBM – Masonry, Engineered Commercial Building, Mid-Rise

MLR1 – Masonry, Low-Rise, Industrial/Warehouse/Factory Buildings

NCDC – National Climatic Data Center

NEMIS – National Emergency Management Information System

NOAA – National Oceanic and Atmospheric Administration

PA – Public Assistance

PDA – Preliminary Damage Assessment

PW – Project Worksheet

SBA – Small Business Administration

SECBL – Steel, Engineered Commercial Building, Low-Rise

SECBM – Steel, Engineered Commercial Building, Mid-Rise

SECBH – Steel, Engineered Commercial Building, High-Rise

TO – Task Order

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EXECUTIVE SUMMARY

This study was performed for FEMA by URS Corporation and PBS&J, as Task Order 440, under HMTAP contract EMW-2000-CO-0247. This report presents the findings of a FEMA validation study of the HAZUS-MH MR-2 (Build 45) Hurricane Wind Model. The validation study involved the comparison of HAZUS-MH modeled results with observed hurricane wind hazards and impact data. To make comparisons to the HAZUS-MH modeled results from observed data, data collection activities were conducted from November 2005 (more than a year after the storms) through August 2006. Data were collected from local, state, and federal agencies and the private sector after Hurricane Charley in Charlotte, DeSoto, Hardee, Lee, Orange, Osceola, and Polk Counties; and Hurricane Ivan in Escambia County in the State of Florida. In addition, data were also used from prior HAZUS validation studies conducted in 2004 for Hurricanes Charley (HMTAP TO – 332) and Ivan (HMTAP TO – 348).

The purpose of this project was to benchmark the best modeled runs of HAZUS-MH (MR2 version) for wind and compare those runs to the observed and recorded damage and loss in various counties and jurisdictions in Florida. A primary goal was to test run HAZUS-MH's functionality and utility against "real world" historical field data to support disaster operations. A secondary goal was to develop standardized data collection process and analysis for HAZUS-MH for long-term recovery operations. This report describes data collection, modeling improvement, and software functionality enhancement recommendations for future HAZUS-MH applications, including validation studies.

This validation study was intended to help provide a systematic assessment of how well the model performed in several categories compared with readily available observed data from these specific events. However, some comparisons could not be made due to limitations with existing data or a lack of data. For example, some readily available observed data sets did not distinguish damage caused by wind versus flood; and commercial, industrial and most critical facility qualitative damage count data are not collected.

HAZUS-MH modeled results for residential, commercial, and industrial occupancy classes compared well with the observed data for the Hurricane Charley study region. Overall, HAZUS-MH modeled results were in good agreement with observed data for residential qualitative damage and economic loss. This good agreement can be attributed to the updated and improved residential building stock in the MR2 version HAZUS-MH default inventory. Even with the uncertainties and limitations with the national default inventory for commercial and industrial occupancy classes, HAZUS-MH economic loss estimates compared well with the observed data from both insurance data sources -- FDOIR and ISO -- for the Hurricane Charley study region. Also, HAZUS-MH estimates for shelter demand were in good agreement for southwest Florida.

Prior validation studies conducted for FEMA by Applied Research Associates (ARA) indicated that HAZUS-MH estimates compared well with preliminary ISO losses for Hurricanes Charley, and Jeanne.

HAZUS-MH consistently and significantly underestimated economic loss for public and critical facilities. However, this may be attributed to the age and source of the critical facilities default inventory in HAZUS-MH, which is not as current as the general building stock, specifically the

residential building stock. The general building stock square footage for schools (EDU1-2) and government essential facilities (GOV1-2) are not well-represented in the commercial real estate datasets purchased for HAZUS. The residential building stock valuations are current as of 2005, while the square footage information is based on the 2000 census, and the critical facilities data is current as of 2001. The critical facilities default data were collected from national and state data providers and most likely do not reflect the most current data (i.e., number and location of facilities) that are available from local governments.

The level of agreement between HAZUS-MH and observed data for site specific critical facilities varied. HAZUS-MH estimates for critical facility damage states were in good agreement with more than half of the observed data for site specific facilities. The HAZUS-MH wind damage curve more accurately predicted the type of damage, the closer the facility was located to the hurricane track in nearly all cases for Hurricane Charley. However, the accuracy of the damage curve varied for facilities that were located farther away from the hurricane path, as seen for Hurricane Ivan. The wind damage curve estimates were in good agreement for more than half of the sites for Hurricane Charley, but underestimated the damage for Hurricane Ivan for all but one site. The HAZUS-MH wind loss curve underestimated economic loss and loss ratio for all four of the site specific critical facilities in Escambia County for Hurricane Ivan.

The summary of the comparisons of HAZUS-MH modeled results and observed data and observations about these comparisons are listed in **Table 1**. Overall, there was better agreement in the Hurricane Charley study region than there was in the Hurricane Ivan study region. This is to be expected, as HAZUS-MH estimates are most accurate when used at a multi-county regional level such as Hurricane Charley. The accuracy decreases when the HAZUS-MH modeled results are compared with observed data at a smaller geographic region, such as the one county study region of Escambia County for Hurricane Ivan. Additionally, HAZUS-MH estimates compared the best with observed data for the Hurricane Charley study region, as Charley caused predominantly wind damage and loss. Therefore hurricane wind modeled results generated by HAZUS-MH could be more accurately compared with observed data for predominantly a wind event. This correlation was not as strong for Hurricane Ivan since it was both a wind and flood event. Based on a comparison of the economic loss data received for Ivan, it appears that 35 percent was attributed to flood damage.

Table 1a. HAZUS-MH and Observed Data Agreement by Hurricane, County, and Category

Hurricane	County	Agreement of HAZUS-MH Estimate With Observed Data
Charley (Residential Damage)	Hurricane Charley Study Region	Agreement at low end
Ivan (Residential Damage)	Escambia	HAZUS appears to underestimate damage. However, this is not the case since Ivan caused flood damage that is not accounted for in the Hurricane Model. Therefore, direct comparisons were not able to be made as the observed data included both wind and flood damage.
Charley (Shelter Demand)	Hurricane Charley Study Region	Good agreement
Ivan (Shelter Demand)	Escambia	Underestimates
Charley (Residential Economic Loss) – FDOIR data	Hurricane Charley Study Region	Good agreement
Ivan (Residential Economic Loss) – FDOIR data	Escambia	Underestimates wind loss
Charley (Residential Economic Loss) – ISO data	Hurricane Charley Study Region	Good agreement
Ivan (Residential Economic Loss) – ISO data	Escambia	Agreement at the high end
Charley (Commercial and Industrial Economic Loss) – ISO data	Hurricane Charley Study Region	Good agreement
Ivan (Commercial and Industrial Economic Loss) – ISO data	Escambia	Underestimates wind loss
Charley (Public Facilities Economic Loss)	Hurricane Charley Study Region	HAZUS underestimates wind loss. This is likely due to the generalizations made about the building inventory, size (sf), and replacement value for these types of facilities.
Ivan (Public Facilities Economic Loss)	Escambia	
Charley (Hospital Economic Loss)	Charlotte, DeSoto, and Orange	
Ivan (Hospital Economic Loss)	Escambia	
Ivan (School Economic Loss)	Escambia	
Charley (Site Specific Critical Facility Damage)	Hardee, Osceola, and Polk	80% of Sites in Good Agreement or Agreement at Low End
Ivan (Site Specific Critical Facility Damage)	Escambia	50% of Sites in Good Agreement
Charley (Wind Damage Curve)	Hardee, Osceola, and Polk	60% of Sites in Agreement at Low End
Ivan (Wind Damage Curve)	Escambia	88% of Sites were Underestimated
Ivan (Wind Loss Curve)	Escambia	Underestimates

Previous research has shown that the HAZUS-MH Wind Model results have compared well with observed data. A prior validation study of the HAZUS-MH Wind Model was conducted in November 2004 by ARA for FEMA. Initial estimates of industry-wide insured losses released by ISO for Hurricanes Charley, Frances, Ivan, and Jeanne were used in comparison with HAZUS-MH modeled economic loss estimates. ARA performed hurricane wind field modeling and hurricane wind loss estimates before, during, and after each of the four hurricanes.

The modeled results compared well with insurance economic loss data for Hurricanes Charley and Jeanne, but there were significant differences in the estimates for Hurricanes Frances and Ivan. More recent runs for Hurricane Frances have produced results between $3.0B and $5.8B, through updates in wind model parameters brought about model updates that accounted for FCMP tower wind speeds for terrain effects. The comparison of the modeled results and the observed data is shown in **Table 1b** and **Appendix C**.

Table 1b. Prior Validation Study - Summary of Initial ISO Insured Loss Estimates

Hurricane	Landfall Date	ISO Press Release Date	Initial ISO Insured Loss Estimate ($B)	HAZUS-MH Estimate Based on Final ARA Tracks from Tables 3-6 ($B)	States Included
Charley	8/13/04	8/25/04	6.7	7.1	FL
Frances*	9/5/04	9/23/04	4.1	1.8	FL
Ivan	9/16/04	10/14/04	5.3	1.6	FL, AL, GA
Jeanne	9/26/04	10/26/04	2.8	2.8	FL
2004 Total	--	--	18.9	13.3	--

Source: ARA

* More recent runs for Hurricane Frances have produced results between $3.0B and $5.8B, through updates in wind model parameters brought about through correction of the FCMP tower wind speeds for terrain effects

The specific conclusions from this report include:

- The observed data for the Hurricane Charley study region compared well with HAZUS-MH (1) residential qualitative damage; (2) residential, commercial, and industrial economic loss; and (3) short-term shelter demand estimates. There was better agreement at the regional level, as seen in the Hurricane Charley study region versus the results for one county, Escambia County, in the Hurricane Ivan study region. Hurricane Charley was predominantly a wind event. Therefore, it is more appropriate to compare HAZUS-MH wind results with observed wind data for Charley, than it is for Ivan that was both a wind and flood event.
- HAZUS-MH public and critical facilities qualitative damage (i.e., for schools) and economic loss estimates did not compare well with observed data. HAZUS-MH consistently and significantly underestimated economic loss for public and critical facilities. This is most likely because the HAZUS-MH default inventory for public and critical facilities was collected at the national level in 2001, and does not include the most current number and location of facilities.

- HAZUS-MH site specific qualitative damage estimates were in good agreement for 80 percent of the sites for Hurricane Charley and 50 percent of the sites for Hurricane Ivan. Considering that HAZUS-MH was designed to be used at a larger scale (i.e., region, county), it appears that the analysis showed that HAZUS-MH estimates compared reasonably well with the observed damage at the site specific level. However, site specific economic loss estimates were underestimated by HAZUS-MH.
- HAZUS-MH wind damage curve estimates were in good agreement at the low end for 60 percent of the sites for Hurricane Charley, but underestimated 88 percent of the sites for Hurricane Ivan.
- HAZUS-MH wind loss curve estimates underestimated for all sites for Hurricane Ivan.
- HAZUS-MH hospital loss of functionality estimates did not compare well with the observed data. The model significantly overestimated the loss of functionality (i.e., number of days). However, it is important to consider that HAZUS-MH estimates loss of functionality based on building damage. It is possible that a facility can be operational, if key parts of the building are not damaged.

The lessons learned and next steps for FEMA include understanding the challenges, and recommendations and benefits for HAZUS-MH. This information is organized by: (1) data collection, (2) modeling capabilities, and (3) software functionality. Some of the lessons learned and next steps are listed below. All lessons learned and next steps are included in Section 4.

HAZUS-MH Data Collection

Challenges:

- Modeled estimates for a variety of categories such as: displaced households; debris; damage and loss at the jurisdictional level; damage to site specific facilities; and vulnerability reduction measures through mitigation options were not compared with observed data because the observed data was incomplete, unavailable, or incomparable.
- Data for comparison with HAZUS-MH estimates are not always separated by hazard; and damage data are not collected for commercial, industrial, public, and critical facilities.
- Currently there is no coordination with counties prior to hurricane season to determine what data are already being collected that are useful for future HAZUS-MH validation studies and to determine which additional data are required for the local level. There is limited staff available to collect detailed HAZUS-MH data after an event.

Recommendations and Benefits:

- It is recommended that FEMA convene a focus group to determine the appropriate data to collect to enhance the default inventory and to document observed disaster impacts. The focus group should develop a pre-disaster local data gap analysis and data gathering coordination groups for enhanced planning and mitigation efforts.

- It is recommended that FEMA encourage state and local jurisdictions to use the data collection template (refer to Appendix A) developed for this project to help consistently collect data. This data collection template should be examined by the focus group to ensure that all necessary data are being requested.
- It is recommended that future validation studies should be conducted at a regional level for counties that only experienced wind damage, and should include data for only wind impacts. Focused data collection efforts enhance the value, and usefulness of HAZUS-MH validation.
- It is recommended that FEMA prepare prewritten rapid response HMTAP task orders for the types of HAZUS-MH data needed to be collected so deployment to collect the data is executed shortly after the event.
- It is recommended that coordination occur with counties to determine which data sets are available for comparison with HAZUS-MH, and which data sets need to be collected. It might be necessary to provide assistance to counties to collect data that is not typically collected (e.g., commercial, industrial and public facilities damage).

HAZUS-MH Modeling Capabilities

Challenges:

- When the study regions were exported, all of the results were not automatically exported with the study region. As such, sharing the results between HAZUS-MH users involved exporting individual results tables.
- The damaged building count is generated from the general building stock for general occupancy classes, but not specific occupancy classes. Damage counts are not provided for critical facilities in HAZUS-MH.
- The default general building stock for the grade school occupancy class (i.e., EDU1) does not include all of the schools that are in the critical facilities default inventory.

Recommendations and Benefits:

- Develop the capability to retain the results that have been run in HAZUS-MH when it is exported to allow for user sharing.
- Develop the capability to provide damage counts for critical facilities.
- Develop a process to permit local governments to submit updated building stock inventory for use with HAZUS-MH.

Software Functionality

Challenges:

- Damage and loss estimates are not provided at the zip code, jurisdictional, or site specific levels by HAZUS-MH; this would improve the usefulness of the model for comparative analysis.

- HAZUS-MH analysis parameters revert to the default parameters after an analysis is run. Therefore, it can not determine which parameters were selected for analysis after the analysis has been run. Also, when all parameters are not selected for analysis, HAZUS-MH does not always generate all the results specified.
- Damaged building counts are not provided for specific occupancy classes or critical facilities.

Recommendations and Benefits:

- Develop the capability in HAZUS-MH to produce results at the zip code, jurisdictional, and site specific levels. Develop capability to select zip code or jurisdiction level data attributes from the map view. This functionality will allow for more detailed comparisons and validations of results.
- Develop the capability in HAZUS-MH to identify which analysis parameters have been run, instead of the analysis screen reverting back to default analysis parameter settings. Also, develop the capability within HAZUS-MH to run individual analysis parameters. Although it appears that this can be done, sometimes the results are not provided consistently.
- Develop the functionality to provide the damaged building count for specific occupancy classes and critical facilities in the wind model. This functionality will allow for more detailed comparisons and validations of results.

INTRODUCTION

This validation study examines the impacts caused by Hurricane Charley in Charlotte, DeSoto, Hardee, Lee, Orange, Osceola, and Polk Counties, and Hurricane Ivan in Escambia County using HAZUS-MH. These two devastating hurricanes provided an unprecedented opportunity to validate the HAZUS-MH Hurricane Wind Model. According to the National Climatic Data Center (NCDC), the general impacts caused by Hurricanes Charley and Ivan are as follows:

- Hurricane Charley made landfall in Southwest Florida on August 13, 2004, as a Category 4 storm, causing over $15 billion in losses and at least 34 deaths in Florida, South Carolina, and North Carolina.
- Hurricane Ivan made landfall near Gulf Shores, Alabama, on September 16, 2004, as a Category 3 storm, causing over $14 billion in losses and at least 57 deaths in the eastern United States. Ivan was the most destructive hurricane to impact the area in over 100 years.

Two other significantly damaging hurricanes occurred in Florida during 2004 and 2005:

- Hurricane Jeanne made landfall in East-Central Florida on September 26, 2004, as a Category 3 storm, causing over $6.9 billion in losses and at least 28 deaths in the Eastern U.S. and Puerto Rico.
- Hurricane Dennis made landfall near Pensacola, Florida on July 10, 2005, also as a Category 3 storm, causing $2 billion in losses and at least 12 deaths in the Florida Panhandle and eastern United States. Losses from Hurricane Dennis were substantially less than Ivan, even though both were Category 3 hurricanes. This difference was due to four factors: intensity, size, speed and location. Hurricane Dennis made landfall east of Pensacola, Florida where there was less property than the area that was impacted by Hurricane Ivan.

A prior validation study that was conducted for FEMA by ARA in November 2004 showed that the HAZUS-MH Wind Model results compared well with economic loss data for Hurricanes Charley, and Jeanne; as shown in full copy in **Appendix C**.

HAZUS-MH is a risk assessment model developed by FEMA to estimate damage and loss from natural and man-made hazards. Readily available as public domain software on FEMA's website, HAZUS-MH software is the most frequently downloaded content on the website. The analyses and results are used to help make decisions for disaster preparedness, response, recovery, and mitigation. HAZUS-MH is used to estimate affected populations and infrastructure damage and economic loss, to target response resources, and to evaluate the savings from implementing hazard mitigation measures to reduce impacts from natural hazards. These measures include but are not limited to land use planning, zoning, structural projects, and building code enhancements.

In this study, damage is defined as qualitative damage (e.g., minor) and economic loss is defined as the cost to repair or replace structures and contents. The results of this report will be used to understand how well HAZUS-MH estimates impacts for a given event. This understanding will provide a foundation to potentially improve the HAZUS-MH model, and to enhance future data collection efforts for future validation studies. These efforts will support communities who use this loss estimation tool to help identify and prioritize mitigation measures, and perform more accurate analyses of avoided damages resulting from the implementation of mitigation techniques.

Validation Study Objectives

The objectives of the validation study were to:

- Compare HAZUS-MH-modeled estimates of wind damage and loss with actual damage and loss for the general building stock and critical facilities at the county level.
- Compare HAZUS-MH-modeled estimates of wind impacts such as displaced populations and debris generated at the county level with observed data.
- Compare HAZUS-MH-modeled damage and loss estimates for critical facilities at the site level with observed data.
- Compare HAZUS-MH-modeled damage states and resultant loss of functionality (loss of use in days) of hospitals at the site level with actual impacts.
- Explore documented vulnerability reduction measures and the potential to mitigate these measures in HAZUS-MH.
- Validate the existing HAZUS-MH damage and wind loss curves.
- Provide recommendations, as appropriate, to improve the HAZUS-MH Hurricane Wind Model.
- Provide recommendations to enhance data collection for future HAZUS-MH validations.

Overview of HAZUS-MH

HAZUS-MH is a standardized loss estimation software program built upon an integrated Geographic Information System (GIS) platform. HAZUS-MH includes a wide range of inventory data (e.g., demographics, building stock, critical facility, transportation, and utility lifelines) and three models to estimate potential losses from earthquakes, hurricanes, and floods. The system was developed by the Department of Homeland Security's FEMA to support improved risk assessments to address mitigation, emergency planning, and response.

The HAZUS-MH Hurricane Wind Model provides users the ability to estimate potential economic damage and loss to residential, commercial, and industrial buildings. It also allows users to estimate direct economic loss, post-storm shelter needs, and building debris. The model addresses wind pressure, windborne debris, surge and waves, atmospheric pressure change, duration or fatigue, and rain. HAZUS-MH is flexible and can be used in conjunction with third-party models and other hazard and building inventory data to support a range of hazard-related analyses, such as. The results are displayed in a series of tabular reports and maps.

It includes the following features:

- A building classification system that depends on the characteristics of the building envelope and building frame.
- The capability to compute damage based on building classes and the effects of rain and progressive failure.
- The capability to compute damage to contents and building interior.
- The capability to estimate tree blow-down and structure debris quantities.
- Loss estimates that include direct and indirect economic loss, shelter requirements, and casualties.
- Modules that facilitate future assessment of mitigation, benefit-cost, and building code issues.

Model Releases MR-1 and MR-2

Initially, MR-1 was to be used to run the analyses as it was available at the onset of this project. However, MR-2 was ultimately used, since this version of the model had enhanced functionality as it included the latest modifications to the data and methodology. The following updates have been incorporated in MR-2:

- The default inventory data has been updated with 2005 valuation data for all occupancy classes.
- Valuation data for single-family residential housing and manufactured housing has been updated and validated based on comparisons with other national databases.
- Zeros have been substituted for any negative values calculated for the daytime, nighttime, working commercial, working industrial and commuting populations.

1.0 METHODOLOGY

The methodology for this comparative validation study includes conducting two analyses:

- Macro-analyses by county of observed data versus HAZUS-MH estimates
  - Building damage count for residential structures and critical facilities
  - Shelter population requirements
  - Economic loss to residential, commercial, industrial, public, and critical facilities
  - Wind speed sensitivity analysis

- Micro-analysis by jurisdiction of observed data versus HAZUS-MH estimates
  - Critical facilities (only damage)
  - Hospital loss of functionality
  - Comparison of observed data for site specific critical facilities damage and economic loss with HAZUS wind damage and wind loss curves
  - Wind speed sensitivity analysis

Hurricane wind study regions were created for Hurricane Charley for Charlotte, DeSoto, Hardee, Lee, Orange, Osceola, and Polk Counties, and for Hurricane Ivan hurricane for Escambia County. These two study regions are provided in **Figure 1** and **Figure 2**, respectively.

Figure 1. Hurricane Charley Study Region

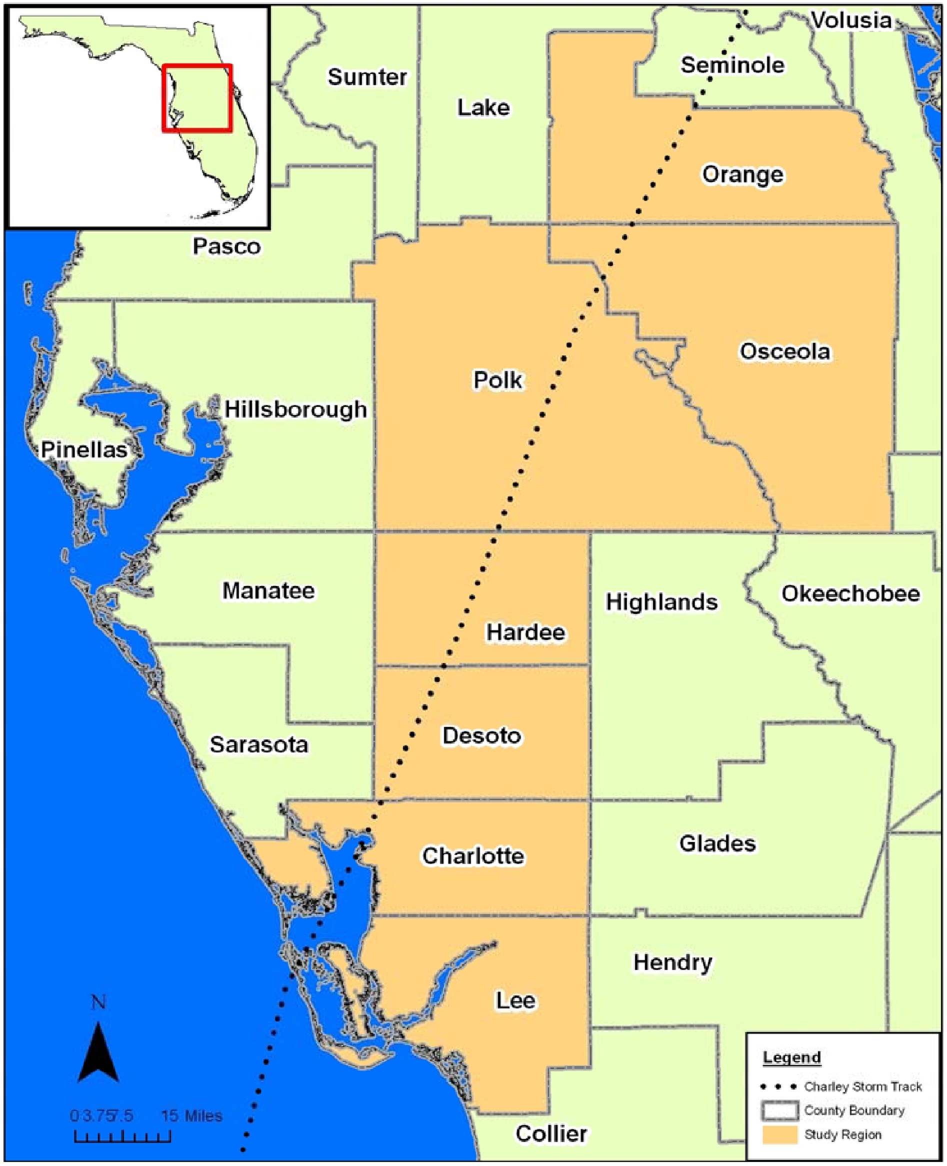
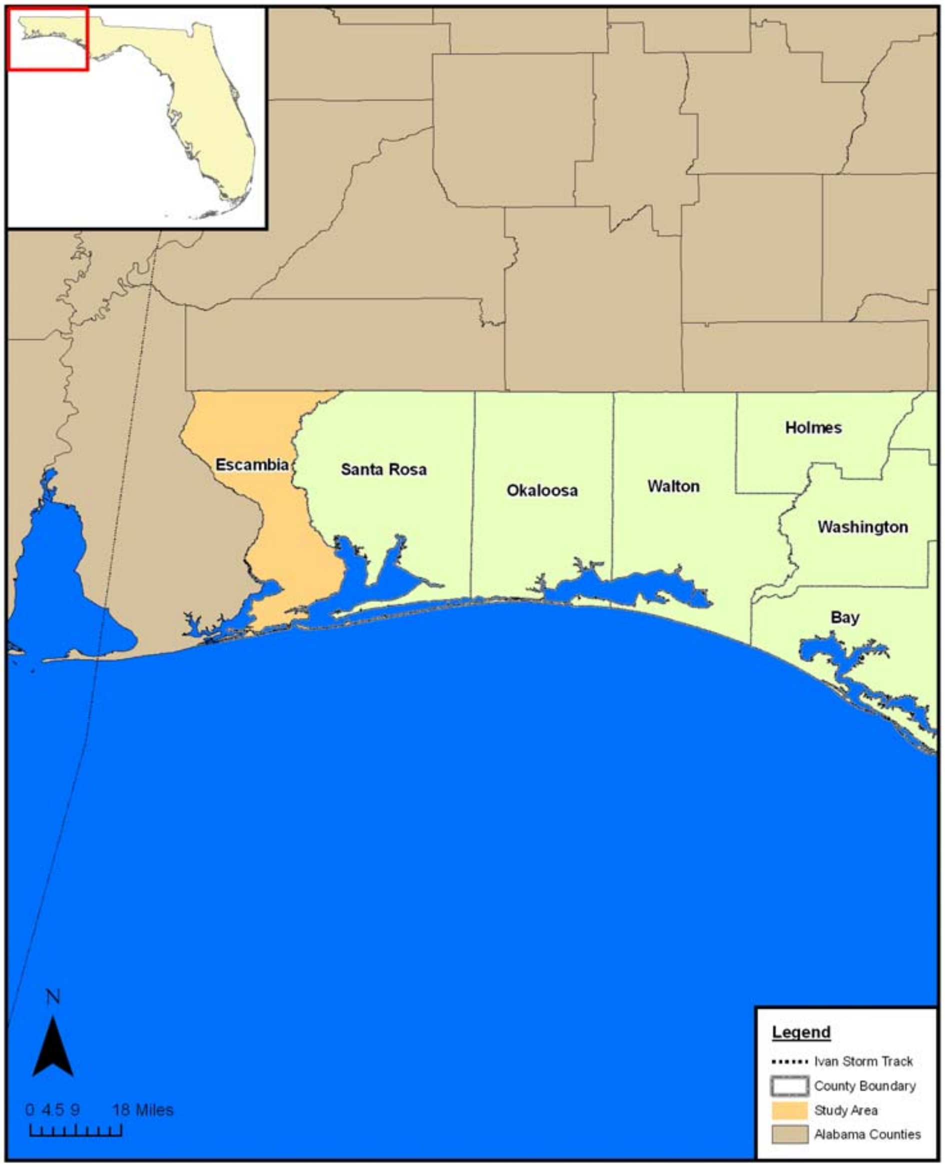


Figure 2. Hurricane Ivan Study Region



Hazard Modeling

Landfall conditions for Hurricanes Charley and Ivan that were considered in this study are summarized in **Table 2**. Two types of data were obtained for these hurricanes: (1) Applied Research Associate's (ARA) best estimate of the hurricane intensity parameters based on data from the following sources: (i) National Hurricane Center (NHC) forecast advisories, (ii) H*Wind surface wind analysis output provided by Hurricane Research Division (HRD), and (iii) surface level wind and pressure observations to determine the values of the profile parameter and radius of maximum winds; and (2) H*Wind swaths which were downloaded directly from the Internet. Comparisons were made for sustained wind because H*Wind data and ARA windfield data both included sustained wind speeds. However, sustained winds were converted to peak gust wind speeds for HAZUS-MH modeling purposes.

Table 2. List of Hurricanes Considered in TO 440

Hurricane	Landfall Conditions			
	Location	Date	NHC Saffir-Simpson Category	NHC 1-minute Sustained Wind Speed (mph)
Charley	Charlotte County, FL	8/13/04	4	145
Ivan	Baldwin County, AL	9/16/04	3	130

Figures 3a and **3b** shows the resulting peak gust wind speeds at the census tract level using the ARA modeled tracks in HAZUS MR-2 for the two hurricanes included in this study.

Figure 3a. Hurricane Charley HAZUS-MR2 Peak Gust Wind Speeds

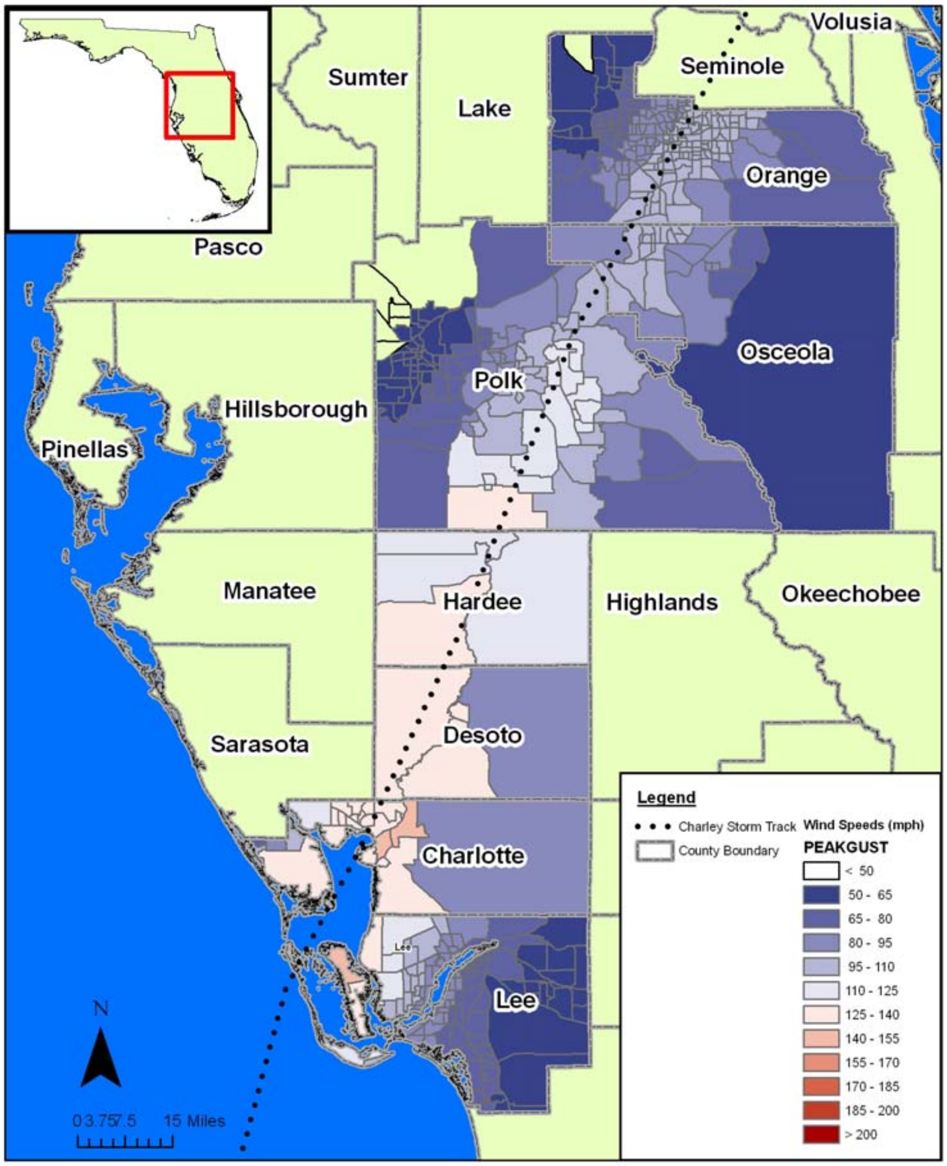
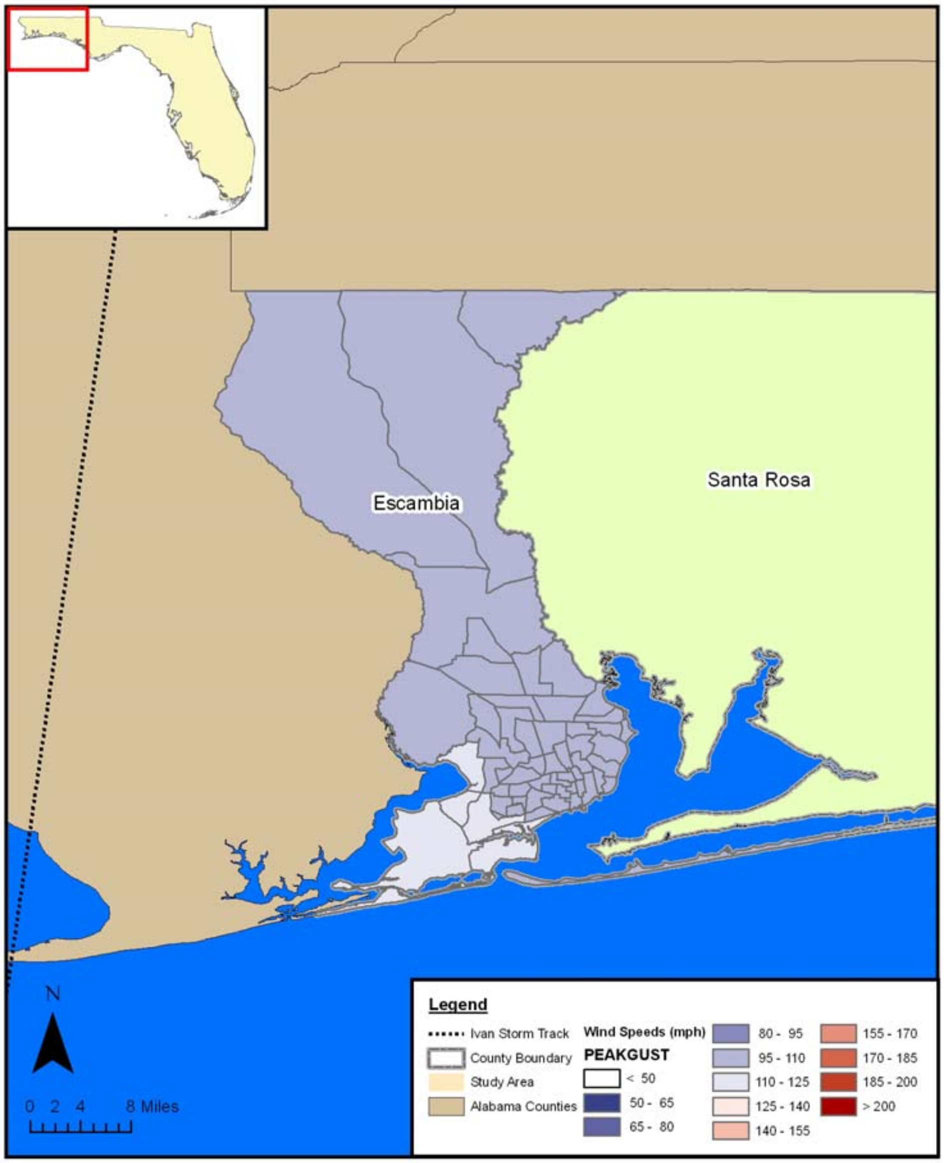


Figure 3b. Hurricane Ivan HAZUS-MR2 Peak Gust Wind Speeds



Figures 4 and **5** illustrate the comparison of the sustained wind speeds between ARA and H*Wind data for all the jurisdictions within the counties considered in this study, and **Appendix E** lists this comparison in tabular format. This comparison shows in general small variations in the predicted wind speeds between the two data sources. It seems from the plot of both storms that right along the track the ARA data was very consistent with H wind, but less accurate away from the track. In comparison to ARA windfield data, H*Wind sustained wind speeds were:

- 10 percent lower for Charley
- 10 percent higher for Ivan

Due to the 10-percent difference in the wind speeds, three hazard scenarios were created to account for a 10-percent margin of error for the wind speeds:

1) Default HAZUS-MH using ARA windfield data, which is referred to in the results section as the Optimum HAZUS Results.

2) HAZUS-MH using ARA windfield data decreased by 10 percent, which is referred to in the results section as the Lower End Results.

3) HAZUS-MH using ARA Windfield data increased by 10 percent, which is referred to in the results section as the Higher End Results.

Figure 4. Hurricane Charley Windfield

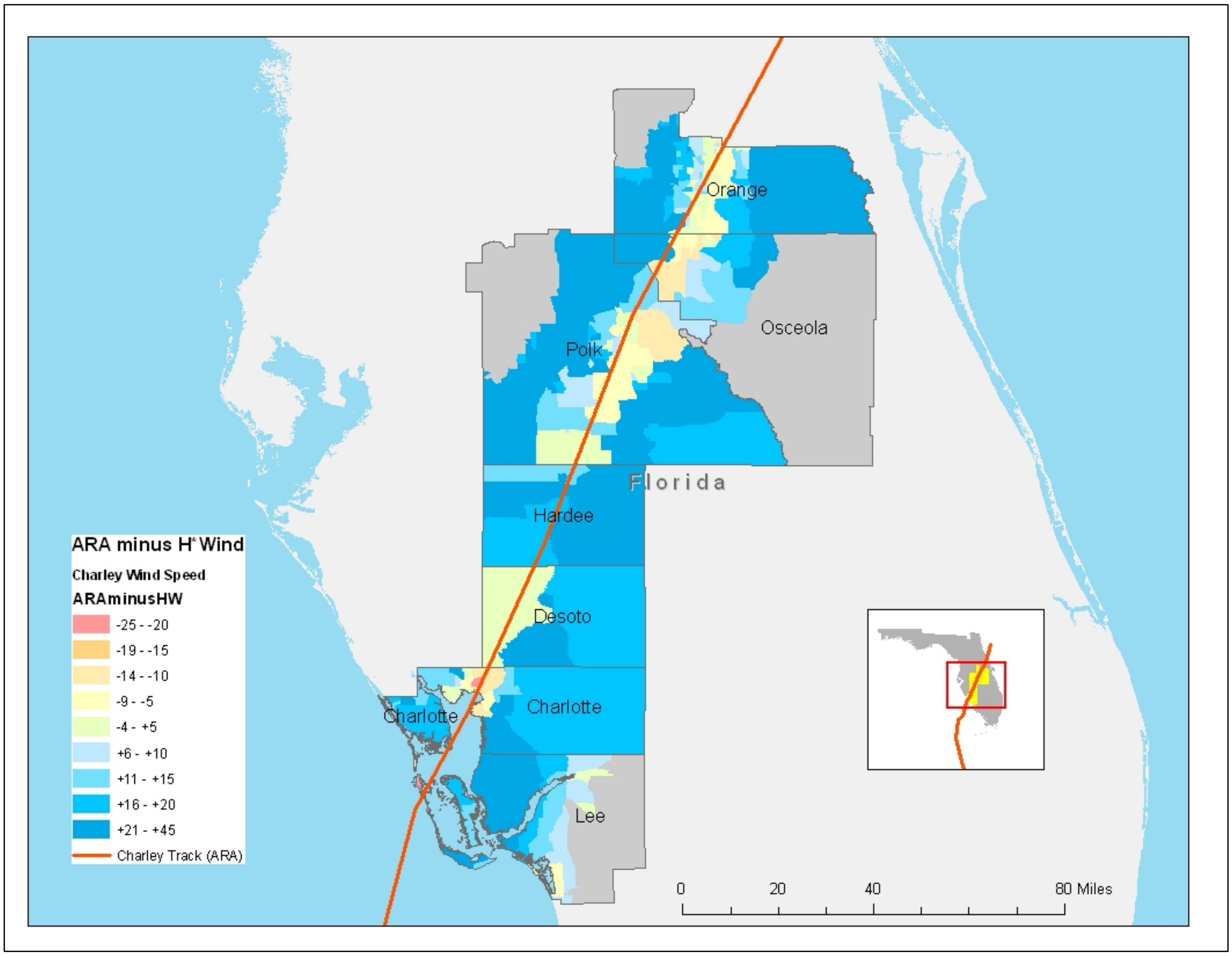
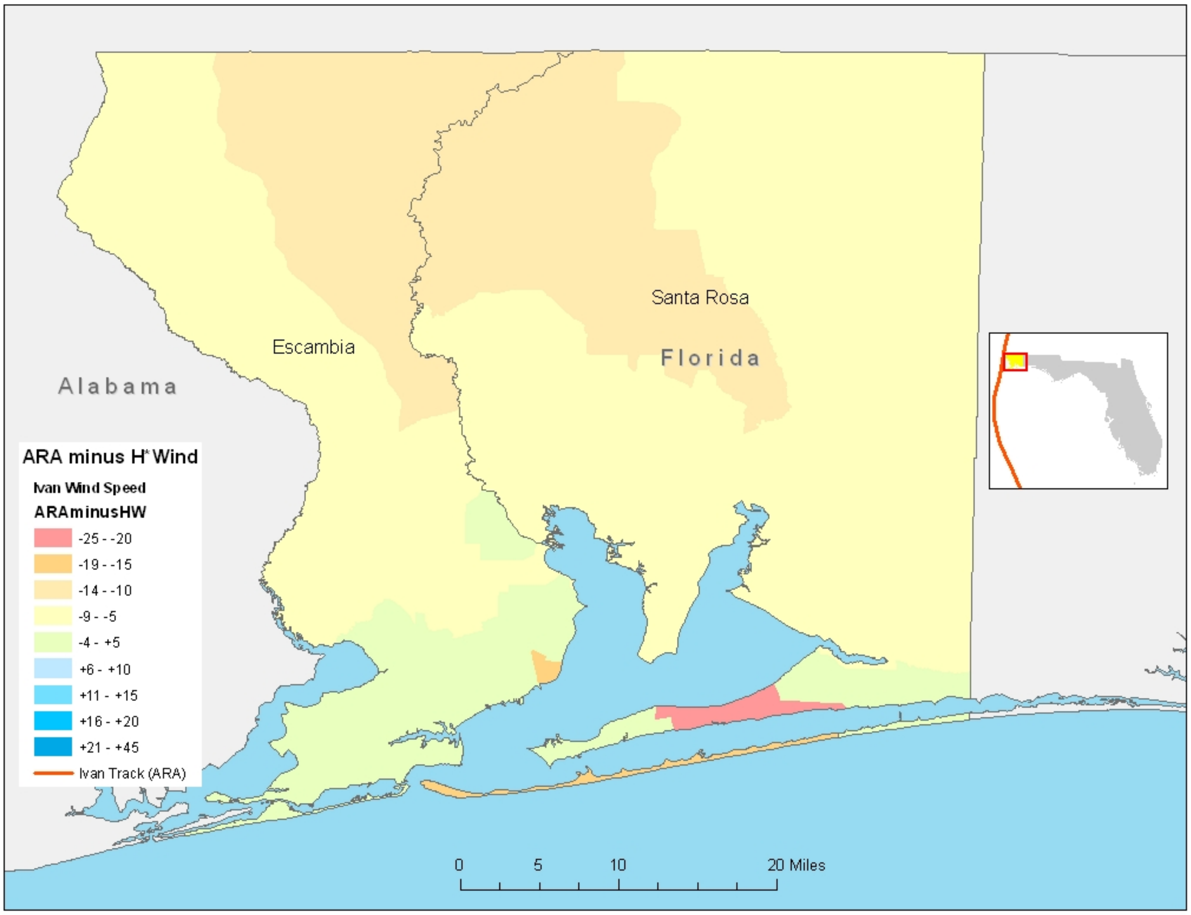


Figure 5. Hurricane Ivan Windfield



Hazard Modeling Assumptions and Limitations

This analysis used the best available wind speed data. As is the case with all models, there are modeling uncertainties that result from incomplete scientific knowledge about hurricanes and their effects on structures. For example, it is difficult to predict all types of flying debris that could damage a structure.

HAZUS-MH modeled peak gust wind speeds were converted from sustained wind speeds for the analysis. However, it is always likely that micro-bursts could occur, which would not be represented in the peak gust wind speeds. Or, the location of large buildings in an area could reduce wind speeds in a given area. These wind speed anomalies would not be accounted for and cause uncertainty in modeling the hazard.

Study Approach

Observed damage and loss data were compared with HAZUS-MH modeled estimates at the county-level, and observed damage data were compared at the site-specific level. Hospital loss-of-functionality-observed data were also compared with HAZUS-MH estimates. HAZUS-MH estimates were generated using three hazard scenarios for the purpose of a sensitivity analysis, which is described in greater detail following this study approach section. These three scenarios included running HAZUS-MH with a hazard scenario using wind speeds provided by ARA, and running two scenarios to account for a +/-10 percent variance in wind speed. HAZUS-MH estimates were compared with the observed data that were collected from a variety of sources that are summarized in Section 2.0, and discussed in detail and provided in tabular format in **Appendix B**.

A county-level (**macro-level**) analysis was performed to compare HAZUS-MH estimates of the following with observed data:

- The number of people requiring short-term shelter.
- Qualitative damage (i.e., minor and moderate damage, severe and destroyed) counts for the residential building stock, and public and critical facilities.
- Economic loss to the residential building stock, and public and critical facilities.

Debris quantities were not received for either county; consequently, debris estimates could not be compared with observed data.

Damage and economic loss to structures were modeled in HAZUS-MH based on the vulnerability of the structure. This vulnerability was based on building characteristics such as the type of building materials and roof type. Short-term shelter demand was modeled in HAZUS-MH based on a percentage of the population that would require sheltering because their homes were damaged.

A detailed (**micro-level**) analysis was performed to compare HAZUS-MH of the following with observed data:

- Qualitative damage (i.e., minor and moderate damage, severe and destroyed) for site specific critical facilities.
- Economic loss to the site specific critical facilities (Escambia only).
- Wind damage curve for site specific critical facilities.
- Wind loss curve for site specific critical facilities.

A micro level analysis was intended to be performed at the jurisdictional level to compare HAZUS-MH damage and loss estimates with observed data. However, this could not be completed because observed data were not available for this analysis at the jurisdictional level. Data received were aggregated at the county level.

An analysis was also performed using HAZUS-MH to estimate hospital loss of functionality (i.e., loss of use in days). Observed data were compared with HAZUS-MH estimates.

Approach Assumptions and Limitations

Most of the observed data included damage and economic loss from both wind and flood hazard for Escambia County, and could not be separated. As such, comparing HAZUS-MH results with these data sets did not usually result in good agreement.

Comparisons were attempted for the damaged building count for critical facilities such as schools, fires stations, and shelters. The damaged building count is generated from the general building stock for general occupancy classes, but not specific occupancy classes. Damage counts are not provided for critical facilities in HAZUS-MH

<u>Sensitivity Analysis</u>

Given the nature of uncertainty in HAZUS, it is more practical to compare observed data with a range of HAZUS-MH results instead of simply comparing the observed data with just HAZUS results. This uncertainty may be due to uncertainty in the hazard modeling, the way the inventory is modeled, the valuation in the damage model, or a combination of some or all three of these parameters. The comparison to ARA windfield data with the H*Wind sustained wind speeds were 10 percent lower for Charley and 10 percent higher for Ivan.

A range of +/- 10 percent of wind speeds is believed to have the highest impact on results and would cover the valuation in results if the other parameters are varied. The scale shown in **Figure 6** provides a consistent and statistically based scale for deriving quantitatively based conclusions as to how well HAZUS-MH estimates compared with observed data. The scale consists of five categories:

HAZUS-MH underestimates impacts in comparison with observed data. The observed data are greater than the upper-end results.

Observed data agrees with HAZUS low-end results. The range includes numbers that fall within the bounds between the low-end results, and the midpoint of the low-end results and the optimum results.

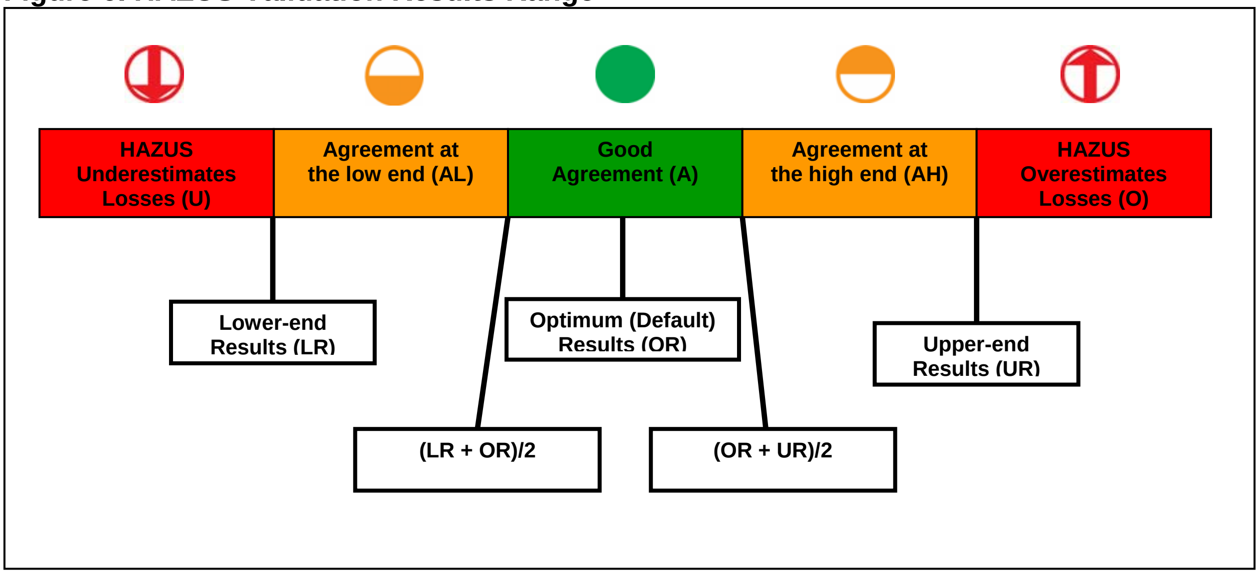
Observed data has good agreement. The range includes numbers that fall within the bounds between the midpoint of the low-end results and the optimum results, and the midpoint of the optimum results and the upper-end results.

Observed data agrees with HAZUS upper-end results. This data includes the numbers that fall within the bounds between the midpoint of the optimum results and the high-end results, and the upper-end results.

HAZUS-MH overestimates impacts in comparison with observed data. The observed data are less than the lower-end results.

These icons, as illustrated, are used as a visual guide to represent the level of agreement in the Results and Observation Section of this report. These icons are correlated with the levels of agreement in **Figure 6**.

Figure 6. HAZUS Validation Results Range



<u>Inventory</u>

HAZUS-MH MR-2 Build 45 default inventory obtained from national level sources was used for this study. There are five general building types (e.g., wood, masonry, concrete, steel, and manufactured homes). The general building stock data are in aggregate form, and percentages of building types are assumed for each census tract or block based on average characteristics of the geographic region.

The HAZUS-MH default building inventory is based on U.S. Census (2000) and Dun & Bradstreet (D&B) (2002) data. The Census and D&B data provide a range of the year of construction at the census block , beginning with pre-1939 structures and includes each decade up to 1990, as well as structures built during 1998 to 2002 (these are referred to in HAZUS-MH as post-1998 construction). The default general building stock data are further classified into 39 specific building types and 33 occupancy classes, which includes building square footage and building value. General building stock data are grouped by occupancy class (e.g., residential, commercial, industrial, and governmental facilities), critical facilities data (e.g., emergency operation centers, hospitals, police and fire departments, and schools), and population characteristics. Buildings are further categorized by characteristics such as roof shape, roof covering, and opening protection.

Default inventory data were used, meaning that no data modifications were made to the general building stock percentage distribution to reflect local building inventory characteristics (e.g., building count, replacement value, building type, roof type). Local building inventory was considered, though none was received for this validation study that was applicable for modifying the general building stock exposure, occupancy class, or detailed building characteristics.

Table 3a lists the building exposure values for counties within the Hurricane Charley study region, and **Table 3b** lists the building exposure for the county within the Hurricane Ivan study region, for HAZUS-MH MR-1 and MR-2. Building valuations for MR-2 are current as of 2005. These tables are provided to illustrate the difference in building valuation between MR-1 and MR-2.

Table 3a. Hurricane Charley Study Region - County Building Exposure

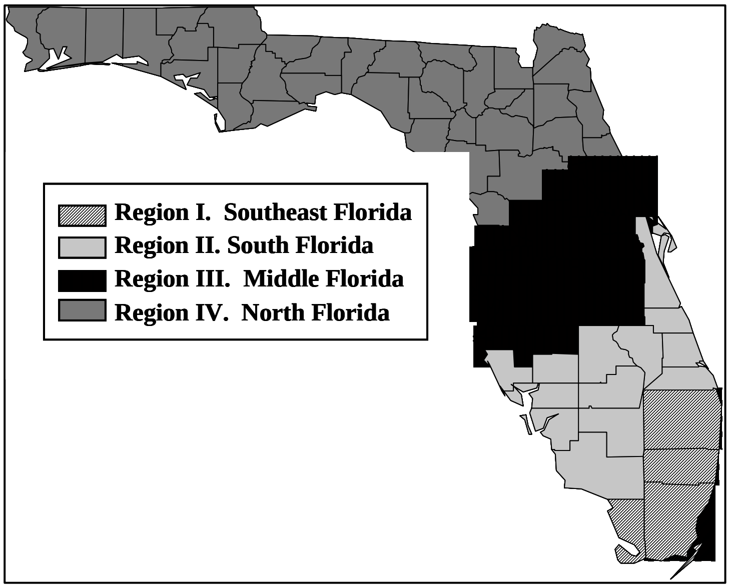
Counties	Residential ($B)	Commercial ($B)	Industrial ($B)	Other Occupancies ($B)	Total HAZUS-MR2 ($B)	Total HAZUS-MH MR1 ($B)
Charlotte	8.9	0.8	0.1	0.1	9.8	8.7
Desoto	1.1	0.1	0	0	1.3	1.3
Hardee	0.9	0.1	0	0	1	0.9
Lee	26.9	3.2	0.5	0.3	30.9	26.4
Orange	47	8.9	1.4	1.3	58.6	51.1
Osceola	8.3	1.1	0.1	0.2	9.7	8.3
Polk	22.3	3	0.9	0.6	26.8	22.9
Total for Region	115.4	17.2	3	2.5	138.1	119.6

Table 3b. Hurricane Ivan Study Region - County Building Exposure

Counties Affected	Residential ($ Billion)	Commercial ($ Billion)	Industrial ($ Billion)	Other Occupancies ($ Billion)	Total HAZUS-MR2 ($ Billion)	Total HAZUS-MR1 ($ Billion)
Escambia	13.4	2.1	0.3	0.4	16.2	15.9

The distribution of the exposure data, building count, and square footage into hurricane-specific building types was done using the default mapping schemes of the hurricane model. **Figure 7** illustrates the allocation of these default schemes for the different areas in Florida.

Figure 7. Default Mapping Schemes in HAZUS-MH



These schemes generally reflect the different building codes requirements where southeast Florida has historically stronger wind provisions while the northern portion of the state reflects more wood frame construction. Southeast Florida is typically exposed to higher wind speeds and buildings are designed to higher wind pressures.

Default Inventory Assumptions and Limitations

General building stock data are in aggregate form by census block and tract. The percentages of building types are assumed for each census tract or block based on average characteristics of the geographic region. As noted in the *HAZUS-MH MR-2 User Manual*, the model can be used to estimate losses for a group of similar buildings. However, nominally similar buildings have experienced greatly different damages and losses during a hurricane. This could be due to factors such as the structural quality of construction, enforcement of building codes, and lack of maintenance. Where construction quality is known to be different from the defined norms in the HAZUS-MH model, larger uncertainties in loss projections can occur.

Default data were obtained at the national level, and did not include recently constructed building stock and critical facilities after 2000, or contain actual replacement cost values for the building stock. Estimates used are based on a replacement value established with R.S. Means, per the *HAZUS-MH Hurricane Wind Technical Manual*. This does not reflect actual repair costs that can fluctuate with the economy at the time of the disaster.

Local Inventory Data

Local inventory data were considered to update the general building stock and critical facilities databases, but minimal data were received. Sample general building stock characteristics and damage data were collected in prior validation studies for Hurricanes Charley (TO – 332) and Ivan (TO – 348) for residential and commercial structures and public and critical facilities.

Local Inventory Data Assumptions and Limitations

Sufficient data were not received to update the general building stock or critical facilities inventory. Prior validation study site assessments did not represent statistically significant samples, for which general building stock conditions could be extrapolated at the jurisdictional or county level. There were not enough building characteristic data to fully update the site specific critical facilities for the micro analysis. No critical facilities data were collected for Charlotte County after Hurricane Charley.

There is subjectivity in characterizing damage during field observations. Efforts were made to reduce this subjectivity, by providing descriptions of damage states to field inspectors. However, uncertainty is always possible.

2.0 DATA COLLECTED

Per the scope of work, this validation study was to include Hurricane Ivan for Escambia County and Hurricane Charley for Charlotte County. To illustrate the regional comparison of HAZUS-MH estimates with observed data for Hurricane Charley, results were included for these additional six counties: DeSoto, Hardee, Lee, Polk, Orange, and Osceola Counties.

Data were also collected but not presented in this report include six additional counties for Hurricane Frances (i.e., Brevard, Indian River, Martin, Okeechobee, Palm Beach, and St. Lucie Counties), and two counties for Hurricane Jeanne (i.e., Martin and St. Lucie Counties), and one county for Hurricane Ivan (i.e., Santa Rosa).

Data were collected for Hurricane Dennis for Escambia County, per the scope of work. Data collected for Hurricane Dennis was not useable as much of the structures were damaged during Ivan and not all had been repaired when Dennis impacted these same counties. Therefore, the default HAZUS-MH building stock inventory would still include the structures as they were initially constructed. Nor, would the default HAZUS-MH building stock inventory have been updated to include structural repairs or reconstruction to current code. Therefore, it was prudent to compare the HAZUS-MH results with observed data in Escambia County for Hurricane Ivan to reduce the margin of error.

Data aggregated to the county, jurisdictional, and site levels were requested from various sources for this study for Hurricanes Charley and Ivan. Data were requested from local, state, and federal agencies and organizations during November 2005 through March 2006. Readily available data were received by August 2006. Data collected included hazards data, physical damage to structures and contents, social impacts, and economic loss. Data were also retrieved from prior HAZUS validation studies conducted in 2004 for Hurricanes Charley (TO – 332) and Ivan (TO – 348). The data collection form that was sent to local governments is provided in **Appendix A**.

At the local level, data were provided by DeSoto, Escambia, and Hardee Counties. At the state level, data were provided by the Florida Department of Insurance Regulation (FDOIR) and the Florida Hospital Association (FHA). At the federal level, data were compiled from the American Red Cross (ARC), FEMA HMTAP task orders such as local and regional HAZUS validations, and from the FEMA Public Assistance (PA) program. Private sector level data for the hurricane windfield were provided by ARA.

Data used in this validation study includes Charlotte, DeSoto, Hardee, Lee, Polk, Orange, and Osceola Counties for Hurricane Charley, and Escambia County for Hurricane Ivan. **Table 4** summarizes which data have been received, its source, identifies the gaps, and summarizes the usefulness of the data for this validation study. Therefore, only the categories with green cells would allow any comparisons. **Appendix B** includes all data that were collected, and describes the observed data, data source(s), limitations, and modeling usefulness of data that was collected for this study, as summarized in **Table 5**.

Table 4. Summary of Data Received and Used for Validation Study

Data Received and Source	Charley							Ivan	Usefulness for Validation
	Charlotte	DeSoto	Hardee	Lee	Orange	Osceola	Polk	Escambia	
Residential Qualitative Damage:									
American Red Cross (ARC) Preliminary Damage Assessment (PDA)									Yes, but includes flood damage for Ivan.
County Damage Assessment	-		-	-	-	-	-	-	No, data are very similar to ARC data, which is used instead.
Critical Facility Damage:									
County Damage Assessment	-		-	-	-	-	-		Yes for schools.
Post-disaster Short-term Shelter Population									
ARC									Yes.
Residential Economic Loss:									
Florida Department of Insurance Regulation claims (FDOIR)									Yes.
Residential, Commercial, and Industrial Economic Loss:									
Insurance Services Office, Inc. (ISO)									Yes.
Public Building Economic Loss:									
FEMA Public Assistance (PA)									No,includes flood damage for Ivan.
Hospital Economic Loss:									
Florida Hospital Association (FHA)			-	-		-	-		Yes.
School Economic Loss:									
County	-	-	-	-	-	-	-		Yes.
Debris Generated									
County Estimate	-			-	-	-	-	-	No, estimates are not final.
FEMA PA	-	-	-	-	-	-	-	-	Not available.
Site Specific Damage:									
HAZUS Validations	-	-		-	-				Yes.
Site Specific Economic Loss:									
Escambia County School Board	-	-		-	-				Yes.
Hospital Loss of Functionality:									
FHA				-		-	-		Yes.

= Data Received

Table 5. Summary of Data Received for Validation Study

Data Received and Source	Charley							Dennis		Frances						Ivan		Jeanne	
	Charlotte	DeSoto	Hardee	Lee	Orange	Osceola	Polk	Escambia	Santa Rosa	Brevard	Indian River	Martin	Okeechobee	Palm Beach	St. Lucie	Escambia	Santa Rosa	Martin	St. Lucie
Residential Qualitative Damage																			
ARC PDA	■	■	■	■	■	■	■	-	-	-	-	-	-	-	-	■	■	■	■
County	-	■	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Commercial Qualitative Damage	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Industrial Qualitative Damage	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Critical Facility Qualitative Damage																			
Medical Care Facilities	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Schools (County)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	■	-	-	-
Fire Stations (County)	-	■	-	-	-	-	-	-	-	-	-	-	-	-	-	■	-	-	-
Police Stations	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-
Shelters (County)	-	■	-	-	-	-	-	-	-	-	-	-	-	-	-	■	-	-	-
Critical Facility Site Damage (Prior HAZUS Validations)	-	-	■	-	-	■	■	■	■	-	-	-	-	-	-	■	■	-	-
Critical Facility Loss of Function																			
Medical Care Facilities (FHA)	■	■	■	-	■	-	-	-	-	-	-	-	-	-	-	■	■	-	-
Schools	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fire Stations	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Police Stations	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Shelters	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Displaced Households (ARC)	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Residential Economic Loss																			
Wind (FL DOIR claims)	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Commercial and Industrial Economic Loss (ISO)	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Critical Facility Economic Loss																			
Medical Care Facilities (FHA)	■	■	■	-	■	-	-	-	-	-	-	-	-	-	-	■	■	-	-
Schools (county)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	■	-	-	-
Fire Stations	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Police Stations	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Shelters (county)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	■	-	-	-
Public Building Economic Loss (FEMA PA)	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Debris Generated (County)	-	■	■	-	-	-	-	-	■	-	-	-	-	-	-	-	-	-	-
Injuries and Deaths (County)	-	■	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Road Damage (FDOT)	-	-	-	-	-	-	-	■	-	-	-	-	-	-	-	■	-	-	-

■ = Data Collected

3.0 ANALYSES RESULTS AND OBSERVATIONS

HAZUS-MH results for the macro level are presented by:

1. residential damage
2. critical facilities damage
3. shelter populations
4. residential, commercial, and industrial economic loss
5. public and critical facilities economic loss

HAZUS-MH results for the micro level are provided for:

1. Site specific critical facilities damage
2. Site specific critical facilities economic loss
3. Wind damage curve for site specific critical facilities.
4. Wind loss curve for site specific critical facilities.

HAZUS-MH results are also provided for hospital loss of functionality.

Each of these categories of results presents observations about the level of agreement between the HAZUS-MH results and the observed data.

Observed data were compared with three HAZUS-MH estimates.

1. The ARA wind speeds were decreased by 10 percent to model the lower-end HAZUS estimate.
2. The ARA wind speeds were used to model the optimum HAZUS estimate.
3. The ARA wind speeds were increased by 10 percent to model the upper-end HAZUS estimate.

The icons below are used as a visual guide to represent the level of agreement in this section.

HAZUS-MH underestimates impacts in comparison with observed data. The observed data are greater than the upper-end results.

Observed data agrees with HAZUS low-end results. The range includes numbers that fall within the bounds between the low-end results, and the midpoint of the low-end results and the optimum results.

Observed data has good agreement. The range includes numbers that fall within the bounds between the midpoint of the low-end results and the optimum results, and the midpoint of the optimum results and the upper-end results.

Observed data agrees with HAZUS upper-end results. This data includes the numbers that fall within the bounds between the midpoint of the optimum results and the high-end results, and the upper-end results.

HAZUS-MH overestimates impacts in comparison with observed data. The observed data are less than the lower-end results.

3.1 HAZUS-MH Macro Level Results for Aggregate Inventory at the County Level

Hurricane Charley and Ivan Results and Observations

Residential Damage

HAZUS-MH was used to obtain wind-damaged building-count estimates for residential structures (i.e., all residential general building stock occupancy classes in HAZUS-MH). HAZUS-MH results were compared with ARC (American Red Cross) Preliminary Damage Assessment (PDA) data, as this data set included qualitative damage estimates. HAZUS-MH estimated damage counts for each qualitative damage state (e.g., minor, moderate, severe, and destroyed) and were compared with ARC data. ARC data were the best available data that was received for the study region. ARC PDAs are collected by windshield survey performed by Red Cross volunteers for the purpose of estimating shelter needs and are not detailed site inspections. PDA data might under- or over-estimate the damage counts for Hurricanes Charley and Ivan. Ivan damage was due to hurricane wind and coastal flooding, which is not differentiated in the PDA data. The following number of structures was inaccessible during the PDA data collection process: Charlotte – 200, Escambia – 684, Hardee – 461, and Polk – 5,000. Residential damage comparisons are provided in **Table 6a** for the Hurricane Charley Counties and **Table 6b** for Escambia County. In addition, not all County ARC estimates included estimates for buildings that had minor damage; therefore, the total damaged structures for those Counties will not be readily comparable for the minor damage state or total damage. In HAZUS-MH, lower wind speeds resulted in more minor damage and fewer moderate, severe, and destroyed structures. Higher wind speeds resulted in fewer structures estimated to have minor damage and more moderate, severe, and destroyed structures.

ARC PDA qualitative damage definitions are very comparable to those in HAZUS-MH. Detailed ARC PDA qualitative damage definitions are included in **Appendix B**. For reporting purposes, the following correlation between damage states has been established for comparison of HAZUS-MH estimates with observed ARC PDA data:

ARC PDA		**HAZUS-MH Damage State**
Affected	=	Minor Damage
Minor Damage	=	Moderate Damage
Major Damage	=	Severe Damage
Destroyed	=	Destruction

Table 6a. Hurricane Charley Residential Damage - HAZUS-MH Wind Results

County	HAZUS Damage				ARC PDA (wind and flood)	HAZUS-MH Validation				
	Damage State	Lower-End	Optimum HAZUS Estimate	Upper-End						
Charlotte	Minor	20,499*	19,027*	12,963*	8,373					x
	Moderate	10,128	17,478	18,240	12,457		x			
	Severe	2,031	7,644	15,004	12,006				x	
	Destroyed	722	3,109	8,274	5,013			x		
	Total	33,380	47,258	54,481	37,849		x			
DeSoto	Minor	2,922	2,792	2,024	0**					x
	Moderate	1,578	2,826	2,999	2,020		x			
	Severe	262	1,108	2,213	2671	x				
	Destroyed	130	593	1,489	3644	x				
	Total	4,892	7,319	8,725	8,335				x	
Hardee	Minor	1,627	2,424	2,473	1,578					x
	Moderate	493	1,305	2,093	2,488	x				
	Severe	63	331	877	1,052	x				
	Destroyed	40	225	682	367			x		
	Total	2,223	4,285	6,125	5,485				x	
Lee	Minor	8,174	14,067	21,187	9,648		x			
	Moderate	2,898	5,634	9,111	6,817			x		
	Severe	691	2,090	4,017	654					x
	Destroyed	230	908	2,377	331		x			
	Total	11,993	22,699	36,692	17,450			x		
Orange	Minor	9,593	26,495	48,698	0**					x
	Moderate	1,185	5,096	14,366	2,036		x			
	Severe	23	197	1,268	177			x		
	Destroyed	4	80	501	2		x			
	Total	10,805	31,868	64,833	2,215					x
Osceola	Minor	2,840	7,435	12,923	0**					x
	Moderate	361	1,549	4,158	149					x
	Severe	9	85	491	487				x	
	Destroyed	3	46	250	137			x		
	Total	3,213	9,115	**17822**	773					x
Polk	Minor	7,209	15,136	22,223	0**					x
	Moderate	1,393	4,825	10,454	1,700		x			
	Severe	102	681	2,401	1,782				x	
	Destroyed	146	751	2,380	2,012				x	
	Total	8,850	21,393	37,458	5,494					x
Total for Region	Minor	52,864	87,376	122,491	19,599					x
	Moderate	18,036	38,713	61,421	27,667		x			
	Severe	3,181	12,136	26,271	18,829			x		
	Destroyed	1,275	5,712	15,953	11,506				x	
	Total	75,356	143,937	226,136	77,601		x			

*Lower wind speeds resulted in more minor damage and fewer moderate, severe, and destroyed structures. Higher wind speeds resulted in fewer minor damage and more moderate, severe, and destroyed structures.

**DeSoto, Orange, Osceola, and Polk County ARC estimates did not include estimates for buildings that had minor damage.

Figure 8 illustrates the geographic trend of the comparison of the modeled and observed results. HAZUS-MH predicted the damage type that actually occurred, more accurately in counties that were located closer to the point of the landfalling hurricane.

Figure 8. Hurricane Charley Residential Damage (Total Damaged Building Count) - HAZUS-MH Wind Results

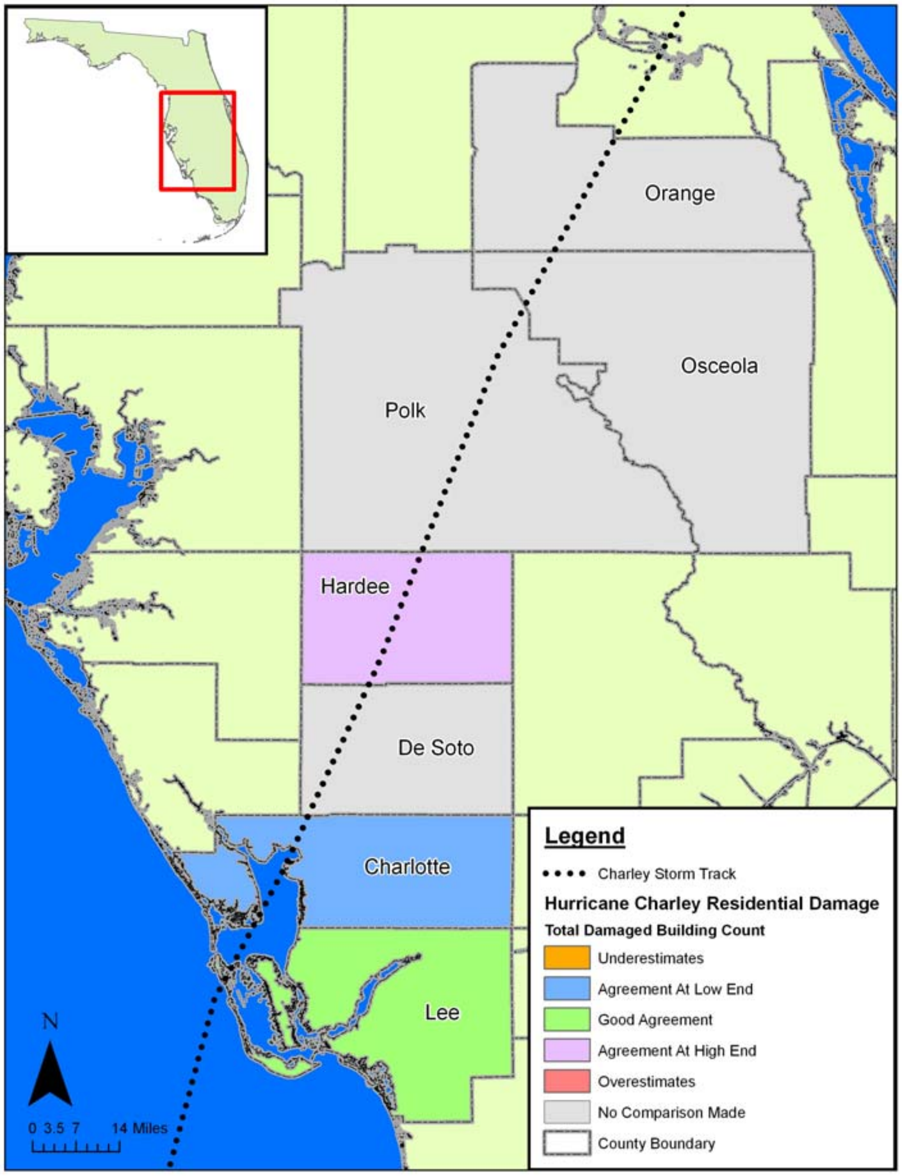


Table 6b. Hurricane Ivan Residential Damage - HAZUS-MH Wind Results

County	HAZUS Wind Damage				ARC PDA (wind and flood damage)	HAZUS-MH Validation				
	Damage State	Lower-End	Optimum HAZUS Estimate	Upper-End						
Escambia	Minor	8,702	21,131	33,765	29,898				x	
	Moderate	1,073	4,385	11,539	22,926	x				
	Severe	22	196	1,204	9,385	x				
	Destroyed	2	50	336	5,224	x				
	Total	9,799	25,762	46,844	67,433	x				

Observations:

- Minor damage data was not collected for DeSoto, Orange, Osceola, and Polk Counties. The HAZUS-MH estimates were in good agreement for Charlotte, Hardee, and Lee Counties.

- The observed damage data, which are based on windshield surveys performed by Red Cross volunteers, might under- or overestimate the damage states through study region.

- There were 5,000 inaccessible structures in Polk County, which is nearly equal to the number of structures that were reported to be damaged. It is likely that this data limitation tainted the comparison for Polk County, but it did not seem to affect the level of agreement for the study region. The study region level of agreement was computed without Polk County and there was still a 60 percent level of good agreement.

- It appears that HAZUS-MH significantly underestimated damage in Escambia County. This is due to the fact that Hurricane Ivan caused coastal flood damage, and this model only estimates wind damage. Based on a comparison of ARC PDA data and National Flood Insurance Program (NFIP) data, it appears that about 10 percent of the damage was attributed to flood damage. However, NFIP data only includes claims for insured properties.

- It looks like HAZUS also did a better job of predicting losses when the damage is severe or destroyed and was not as good at damage predicting when the loss was minor. However, it is important to consider that not all County ARC estimates included estimates for buildings that had minor damage. Therefore, it is not appropriate to directly compare the HAZUS-MH estimated number of structures with minor damage with the ARC data for minor damage.

- It appears that the model did a better job closer to the landfall spot then it did inland as the windfield decays.

Critical Facility Damage

HAZUS-MH was used to obtain hurricane wind damage building count estimates for Escambia County schools. Comparisons were attempted for damage for Escambia County schools, fires stations, and shelters. However, HAZUS-MH does not provide damaged building counts by qualitative damage state for critical facilities. The damaged building count is generated from the general building stock for general occupancy classes, but not specific occupancy classes. For that reason, results could not be generated for fire stations and shelters.

Results were provided for the damaged building count for schools, using the estimates provided for the general occupancy for schools (EDU). It was determined that the schools included in the EDU general occupancy class only contained grade schools (EDU1). Therefore the observed data, which was of the same occupancy class, was suitable for comparison.

Observations:

- The HAZUS-MH model consistently and significantly underestimated the damage to the schools. This underestimate is due to the underestimated educational (EDU) building stock. The HAZUS-MH default inventory contains 25 schools in Escambia County. There were 72 schools for which damage was reported for by the county. The total number of schools in the county was not reported.

Shelter Population

HAZUS-MH was used to obtain hurricane wind estimates for short term post-landfall shelter population and compared with ARC data collected at the hurricane shelters. Pre-landfall shelter population is included to show the perception of the evacuees needs to evacuate. Post-landfall shelter population comparisons are provided in **Table 7a** for the Hurricane Charley Counties and **Table 7b** for Escambia County.

Table 7a. Hurricane Charley Shelter Demand - HAZUS-MH Wind Results

County	HAZUS Short Term Shelter Needs			ARC Pre-landfall Shelter Population	ARC Post-landfall Shelter Population	Shelter Capacity	HAZUS-MH Validation				
	Lower-End	Optimum HAZUS Estimate	Upper-End								
Charlotte	652	2,475	5,617	425	425	1,500					x
DeSoto	102	453	1,081	1,374	1,400	4,245	x				
Hardee	26	140	415	537	537	1,267	x				
Lee	142	474	1,044	8,129	1,191	17,768	x				
Orange	104	406	1,112	727	727	6,320			x		
Osceola	29	109	321	1,714	102	10,284			x		
Polk	64	327	1,072	3,390	14	11,172					x
Total for Region	1,055	4,057	9,590	12,906	4,382	41,384			x		

Figure 9 illustrates the geographic trend of the comparison of the modeled and observed results. HAZUS-MH predicted the shelter requirements more accurately for the inland counties.

Figure 9. Hurricane Charley Shelter Demand - HAZUS-MH Wind Results

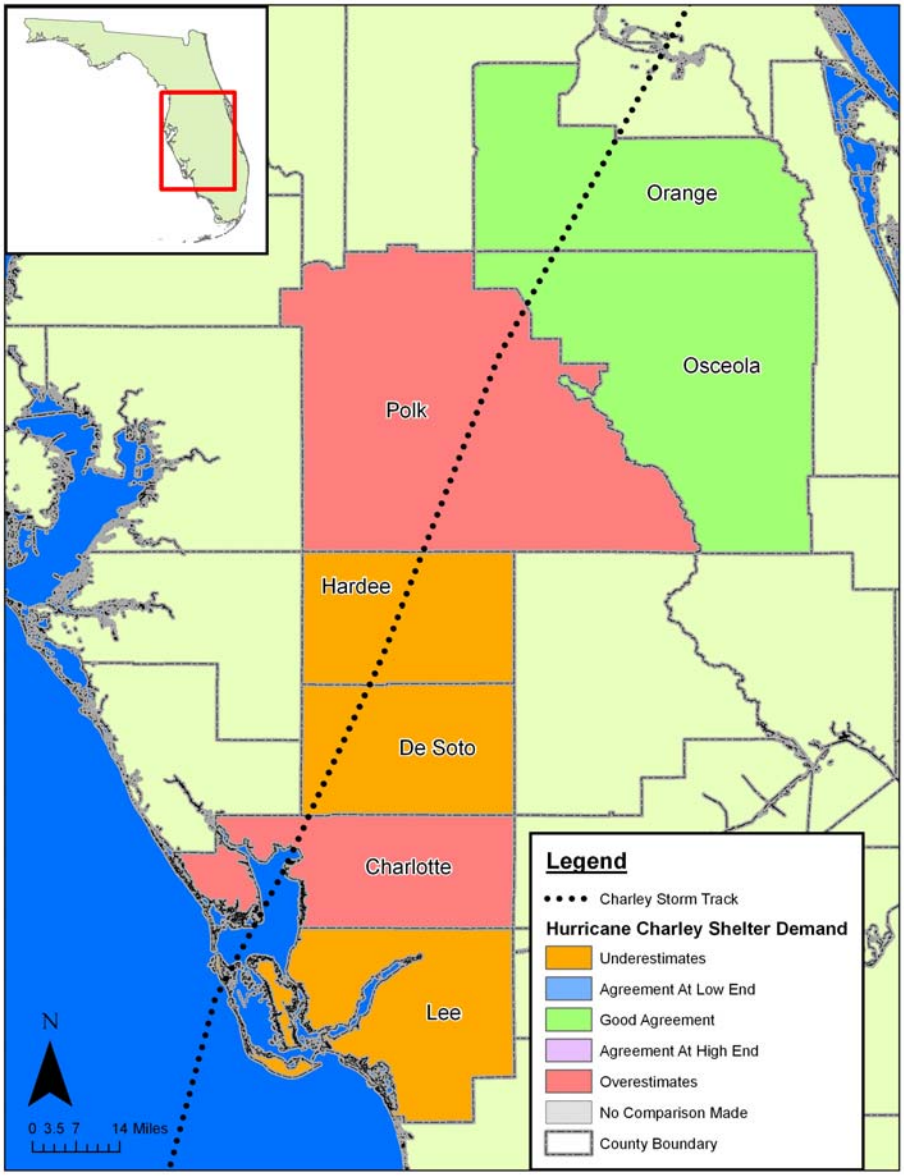


Table 7b. Hurricane Ivan Shelter Demand - HAZUS-MH Wind Results

County	HAZUS Short Term Shelter Needs			ARC Pre-landfall Shelter Population	ARC Post-landfall Shelter Population	Shelter Capacity	HAZUS-MH Validation				
	Lower-End	Optimum HAZUS Estimate	Upper-End								
Escambia	72	252	698	6,707	978	16,827	x				

Observations:

- HAZUS-MH short-term shelter estimates were in very good agreement at the regional level and for Orange and Osceola Counties in the Hurricane Charley Study region. Shelter needs were underestimated for DeSoto, Hardee, and Lee Counties, and overestimated for Charlotte and Polk Counties. It is possible that people evacuated away from Charlotte County to DeSoto, Hardee, and Lee because they were located farther away from where Charley was predicted to make impact.

- The pre-landfall and the post-landfall population for Charlotte County are the same, and the shelter was operating at less than 30 percent of its capacity. It is important to note that the observed data for shelter use was low in comparison to shelter estimates developed in the Hurricane Evacuation Studies (HES). As stated in the FEMA *2004 Hurricane Assessments Executive Summary*, low shelter use was due to low evacuation participation. It is also likely that people needing shelter in one county may have sought shelter in adjacent counties, or stayed with family or friends, or at a hotel.

- It appears that HAZUS-MH underestimated the short term shelter needs in Escambia County. Observed shelter data could include transient or tourist populations, which are not reflected in the HAZUS-MH default inventory, although they can be added where the data are available. People may have stayed in shelters after landfall because they could not return to their homes due to electric, water, and sewage outages. This could explain why HAZUS-MH underestimated the shelter need for Escambia County. This could also be related to the fact that Ivan was also a coastal flood event.

- HAZUS-MH estimates short term shelter needs based on damaged building stock. It is also possible that the estimates did not agree well with the observed data due to uncertainties in the default building characteristic data.

- The behavior of whether people who chose to evacuate could have been caused by their perception of the need to evacuate based on experience with prior hurricanes. For example, people in Escambia County had possibly experienced hurricane impacts during the 1990’s (i.e., Erin and Opal), and were more likely to evacuate.

Residential Economic Loss

HAZUS-MH was used to obtain wind economic loss estimates for residential structures found in the general building stock occupancy classes given in HAZUS-MH. HAZUS-MH estimated economic loss was compared with FDOIR as well as ISO wind insurance claim data. These insured-loss estimates provide a useful benchmark for the HAZUS-MH wind loss estimate comparisons.

However, FDOIR and ISO data cannot be directly compared with HAZUS-MH estimates. FDOIR and ISO insurance claims data includes losses for automobiles, boats, and appurtenant structures, and additional living expenses, yet do not include deductibles or uninsured properties. The FDOIR and ISO data includes fewer inventories (i.e., fewer structures) than HAZUS, as it only includes insured properties. However, FDOIR and ISO data include more property (e.g., automobiles and boats) than is included in HAZUS. In addition, the ISO claims data do not include manufactured housing. As such, the total economic loss for the residential building stock less the manufactured housing loss was compared with the ISO data.

Raw FDOIR data were compared with HAZUS-MH estimates, as the penetration rate (i.e., the percent of structures that are insured) was not provided. However, since the penetration rate was provided for ISO data, the ISO raw data were converted for comparison. The penetration rate for the ISO data was 45 percent. Therefore the ISO losses were converted to 100 percent by multiplying the ISO raw losses by 2.22.

Residential loss comparisons using FDOIR data are provided in **Table 8a** for the Hurricane Charley Counties and **Table 8b** for Escambia County. Residential loss comparisons using ISO data are provided in **Table 8c** for the Hurricane Charley Counties and **Table 8d** for Escambia County.

Table 8a. Hurricane Charley Residential Economic Loss (FDOIR) - HAZUS-MH Wind Results

County	HAZUS Residential Loss ($M)			FDOIR Data ($M)	HAZUS-MH Validation				
	Lower-End	Optimum HAZUS Estimate	Upper-End						
Charlotte	884	2,322	4,317	2,561			x		
DeSoto	109	300	555	283			x		
Hardee	42	130	285	138			x		
Lee	362	874	1657	1,014			x		
Orange	311	716	1597	991			x		
Osceola	77	183	425	560	x				
Polk	150	430	1045	554			x		
Total for Region	1,935	4,955	9,881	6,101			x		

Note: HAZUS-MH inventory includes more buildings. FDOIR claims include fewer buildings, but also include losses for automobiles, boats and appurtenant structures, and additional living expenses.

Figure 10 illustrates the geographic trend of the comparison of the modeled and observed results. HAZUS-MH modeled residential economic loss results were in good agreement with FLDOIR observed data for six of the seven counties.

Figure 10. Hurricane Charley Residential Economic Loss (FLDOIR) - HAZUS-MH Wind Results

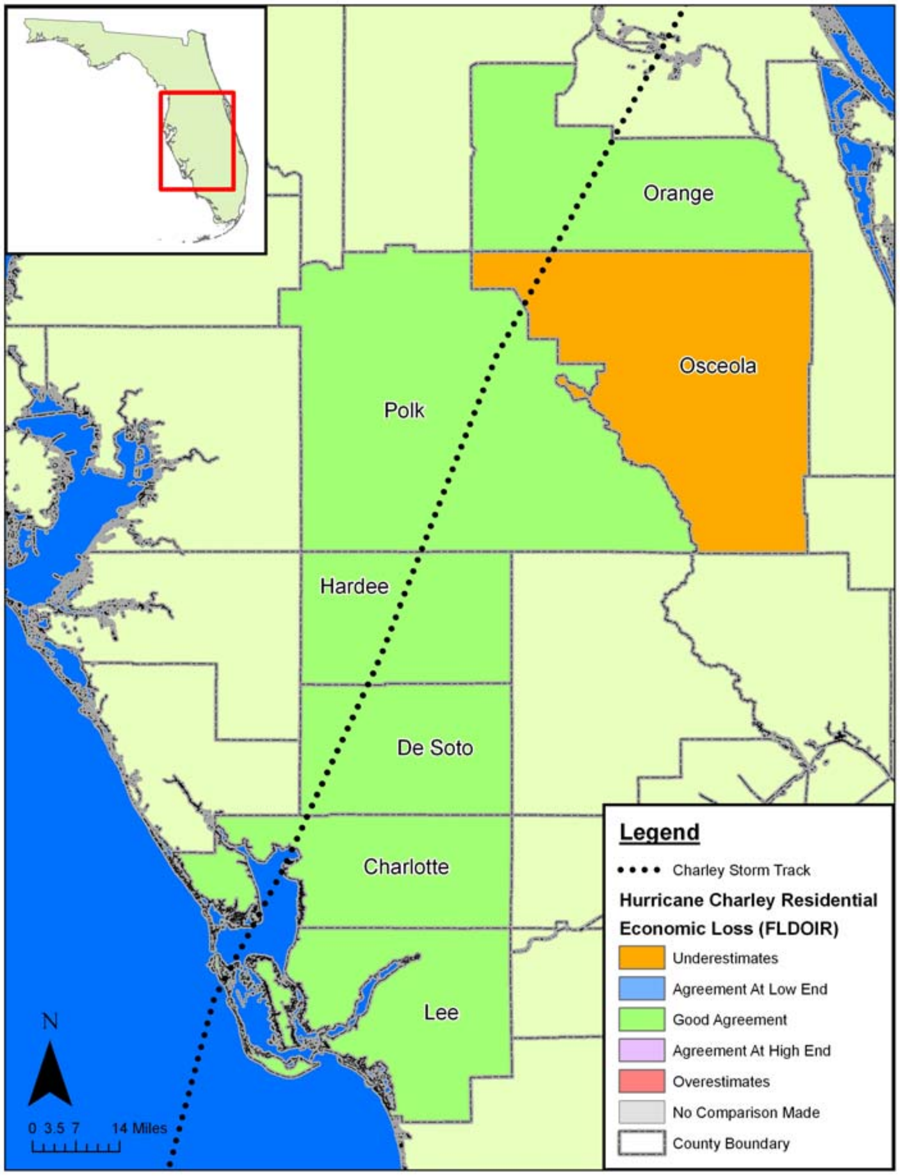


Table 8b. Hurricane Ivan Residential Economic Loss (FDOIR) – HAZUS-MH Wind Results

County	HAZUS Residential Loss ($M)			FDOIR Data ($M)	HAZUS-MH Validation				
	Lower-End	Optimum HAZUS Estimate	Upper-End						
Escambia	205	448	968	1,698	x				

Note: HAZUS-MH inventory includes more buildings than insurance data. FDOIR claims include fewer buildings, but also include losses for automobiles, boats and appurtenant structures, and additional living expenses.

Table 8c. Hurricane Charley Residential Economic Loss (ISO) – HAZUS-MH Wind Results

County	HAZUS Residential Loss ($M)			ISO Data ($M)	HAZUS-MH Validation				
	Lower-End	Optimum HAZUS Estimate	Upper-End						
Charlotte	809	2,139	4,020	1,763			x		
DeSoto	88	239	448	87					x
Hardee	37	113	244	53		x			
Lee	340	823	1,562	384		x			
Orange	308	709	1,579	591			x		
Osceola	74	174	401	226			x		
Polk	121	341	835	226		x			
Total for Region	1,777	4,538	9,089	3,330			x		

Note: HAZUS-MH inventory includes more buildings. ISO claims include fewer buildings, but also include losses for automobiles, boats and appurtenant structures, and additional living expenses.

Figure 11 illustrates the geographic trend of the comparison of the modeled and observed results. HAZUS-MH modeled residential economic loss results were in good agreement with ISO observed data for six of the seven counties.

Figure 11. Hurricane Charley Residential Economic Loss (ISO) - HAZUS-MH Wind Results

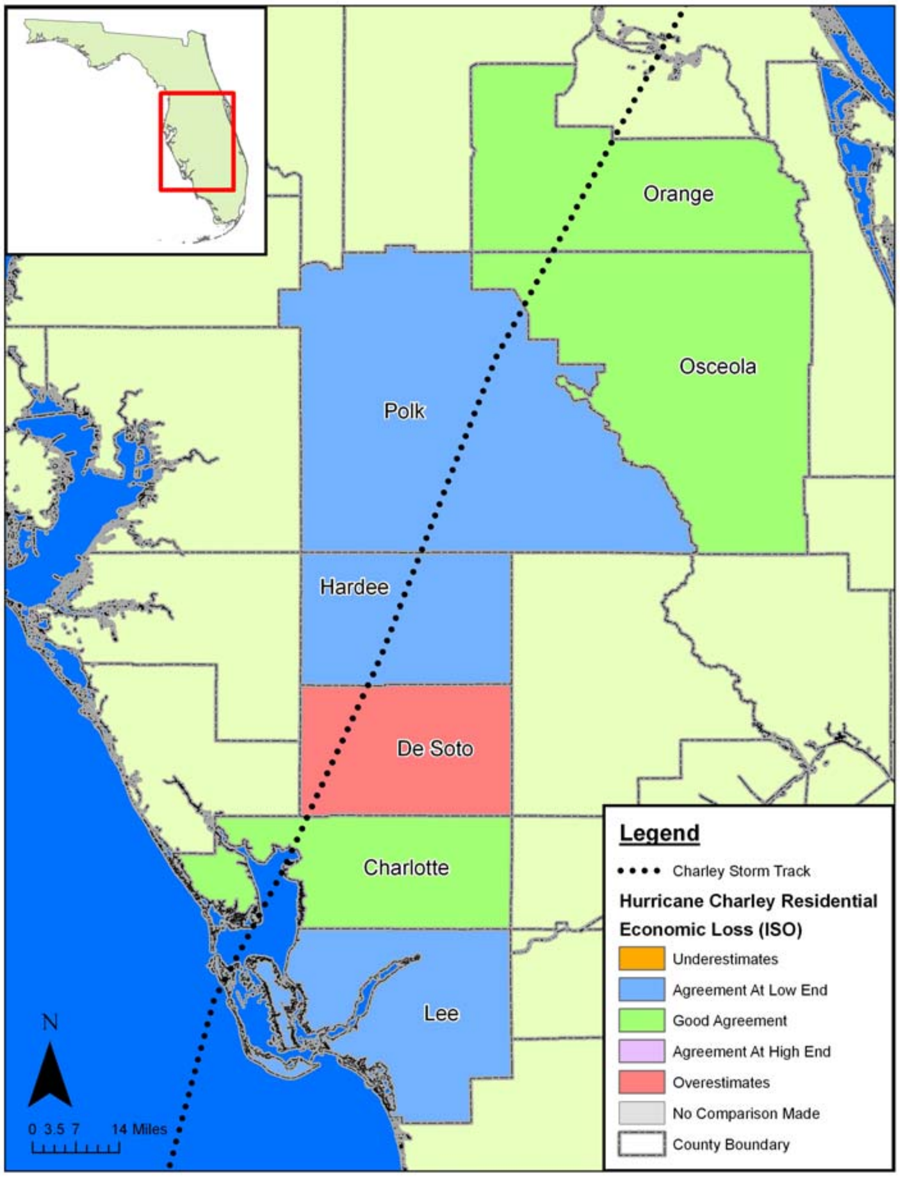


Table 8d. Hurricane Ivan Residential Economic Loss (ISO) – HAZUS-MH Wind Results

County	HAZUS Residential Loss ($M)			ISO Data ($M)	HAZUS-MH Validation				
	Lower-End	Optimum HAZUS Estimate	Upper-End						
Escambia	200	435	933	895				x	

Note: HAZUS-MH inventory includes more buildings. ISO claims include fewer buildings, but also include losses for automobiles, boats and appurtenant structures, and additional living expenses.

Observations:

- It appears that HAZUS-MH estimates were in very good agreement with the observed residential economic loss data for Charlotte County.

- It appears that HAZUS-MH significantly underestimated residential economic loss for Escambia County. It is likely that the underestimation occurred, because Escambia County experienced economic loss from both hurricane wind and coastal flood. It is also possible that the estimates did not agree well with the observed data due to uncertainties in the default inventory and building characteristic data.

Commercial and Industrial Economic Loss

HAZUS-MH was used to obtain wind economic loss estimates for commercial and industrial structures found in the general building stock occupancy classes in HAZUS-MH. HAZUS-MH estimated economic loss was compared with ISO wind insurance claim data. These insured-loss estimates provide a useful benchmark for the HAZUS-MH wind loss estimates. The commercial and industrial losses are combined for comparison with ISO data, as provided in **Table 9a** for the Hurricane Charley Counties and **Table 9b** for Escambia County**.**

Table 9a. Hurricane Charley Commercial and Industrial Economic Loss (ISO) - HAZUS-MH Wind Results

County	HAZUS Commercial and Industrial Loss ($M)			ISO Data ($M)	HAZUS-MH Validation				
	Lower-End	Optimum HAZUS Estimate	Upper-End						
Charlotte	118	340	609	202		x			
DeSoto	20	60	107	24		x			
Hardee	6	20	42	18			x		
Lee	25	71	145	64			x		
Orange	26	115	367	131			x		
Osceola	6	23	78	47			x		
Polk	18	75	208	67			x		
Total for Region	219	704	1,556	553			x		

Figure 12 illustrates the geographic trend of the comparison of the modeled and observed results. HAZUS-MH modeled commercial and industrial economic loss results were in good agreement with ISO observed data for all seven counties.

Figure 12. Hurricane Charley Commercial and Industrial Economic Loss (ISO) - HAZUS-MH Wind Results

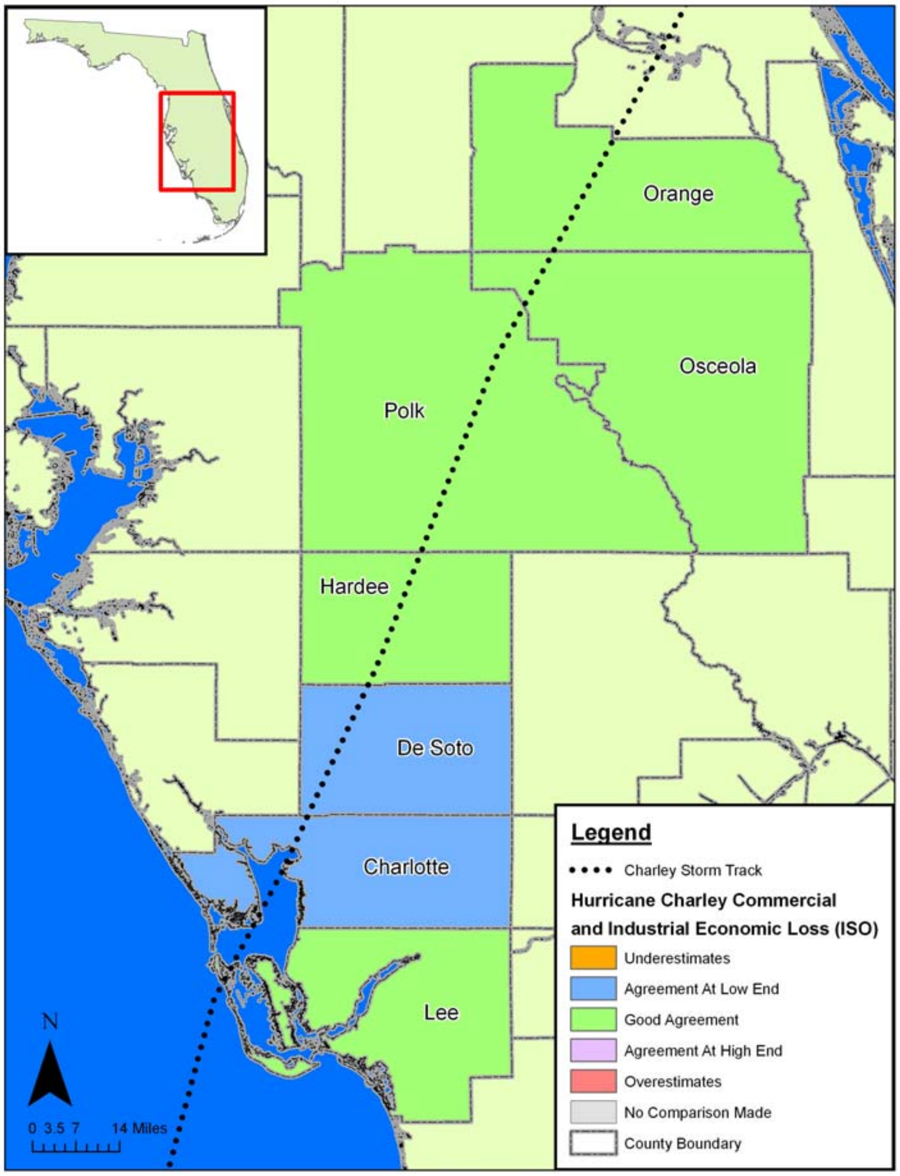


Table 9b. Hurricane Ivan Commercial and Industrial Economic Loss (ISO) - HAZUS-MH Wind Results

County	HAZUS Commercial and Industrial Loss ($M)			ISO Data ($M)	HAZUS-MH Validation				
	Lower-End	Optimum HAZUS Estimate	Upper-End						
Escambia	13	53	163	311	x				

Observations:

- HAZUS-MH is in good agreement for every county in the Hurricane Charley study region. However, HAZUS-MH underestimated loss for Escambia County.
- Perhaps the reason the model appears to underestimate the results for Escambia County is that the building inventory is not as accurate as it is in southwest Florida.

Public and Critical Facilities Economic Loss

<u>Public Facilities Economic Loss</u>

HAZUS-MH was used to obtain economic loss estimates for public and critical facilities. HAZUS-MH results for government buildings, hospitals, and schools (i.e., GOV1, GOV2, COM6, and EDU1 in the general building stock) were compared with a summary of PA funds that were aggregated at the county level. PA funding was generated from NEMIS for Category "E" Public Facilities for structure and content loss.

Category E covers uninsurable losses to repair or restore publicly owned and maintained structures, equipment (e.g., electrical, mechanical, telecommunications, etc.), and contents (e.g., furniture, books, computers, etc.). PA loss amounts could be overestimated or underestimated, as insurance claims were still being settled by local governments at the time that this report was prepared. PA loss amounts might also include associated debris removal and mold remediation costs, or costs for code and standard upgrades.

Observations:

- It appears that HAZUS-MH underestimated the economic loss of public and critical facilities in comparison to the PA data for most of the Hurricane Charley study region and for Escambia County.
- This underestimation appears to be due to the fact that Hurricane Ivan caused both hurricane wind and coastal flood economic loss. In comparing the optimum HAZUS-MH results with the observed PA data, the Hurricane Charley study region results were underestimated by 62 percent, whereas, Escambia County results were underestimated by 800 percent.

- This underestimation appears to be caused by the fact that the default general building stock is incomplete. For example, the grade school occupancy class (i.e., EDU1) does not include all of the schools that are in the critical facilities default inventory. It is assumed that the default inventory is also inaccurate for the governmental and hospital structures.

- It is also plausible that the underestimation occurred because of an underestimation of content value. For example, hospitals are considered commercial structures, for which HAZUS-MH estimates the content value to be between 100 to 150 percent of the replacement value of the structure. As such, if the default inventory is not accurate for replacement value for commercial structures, HAZUS-MH would not be able to accurately calculate the content replacement cost.

Hospital Economic Loss

HAZUS-MH was used to obtain hurricane wind economic loss estimates for hospitals. HAZUS-MH results for hospitals (i.e., COM6 in the general building stock) were compared with losses that were reported by the FHA, which included loss to structures, equipment, contents, and "other damages" as listed in the following observations.

Observations:

- It appears that HAZUS-MH underestimated economic loss for hospitals for both Charlotte and Escambia Counties.

- It is possible that the estimates did not agree well with the observed data, as it included losses for items not modeled in HAZUS-MH. The FHA-observed data included costs for non-structural damage, referred to as "other damages" (e.g., debris removal, signage, landscaping, fencing, screens, canopies and awnings, and compressors). FHA reported that of $67.4 million in losses for all 2004 hurricanes, $10.9 million or 16 percent of economic loss was attributed to other damages.

- It is possible that the estimates did not agree well with the observed data due to uncertainties associated with missing facilities or the assumptions made for the default building characteristic data in the general building stock for commercial structures.

- It is also plausible that the underestimation occurred because of an underestimation of content value. Hospitals are considered commercial structures, for which HAZUS-MH estimates the content value to be between 100 to 150 percent. As such, if the default inventory is not accurate for commercial structures, HAZUS-MH would not be able to accurately calculate the content replacement cost.

School Economic Loss

HAZUS-MH was used to obtain hurricane wind economic loss estimates for schools. HAZUS-MH results for schools (i.e., EDU1 in the general building stock) were compared with losses that were reported by Escambia County. No data were received for southwestern counties that were impacted by Hurricane Charley.

Observations:

- It appears that HAZUS-MH significantly underestimated economic loss for schools for Escambia County.

- It is possible that the estimates did not agree well with the observed data due to uncertainties associated with missing facilities or the assumptions made for the default building characteristic data in the general building stock.

3.2 HAZUS-MH Micro Level Results for Site Specific Critical Facilities

Site Specific Damage

HAZUS-MH was used to obtain hurricane wind damage estimates for site specific critical facilities in Escambia County. Data were not received for critical facility damage in Charlotte County. Site specific comparisons are provided in **Table 10a** for Hardee, Osceola and Polk Counties, and **Table 10b** for Escambia County.

Table 10a. Hurricane Charley Damage - HAZUS-MH Site Specific Hurricane Wind Results

County	Type of Facility	Facility Name	Damage State			Observed Wind Damage	HAZUS-MH Validation				
			Lower-End	Optimum HAZUS Estimate	Upper-End						
Hardee	School	Hardee High School	Minor	Severe	Severe	Minor		x			
Hardee	School	Wauchula Elementary	Minor	Severe	Severe	Minor		x			
Osceola	School	Poinciana High School	Minor	Minor	Minor	Moderate	x				
Osceola	School	Thacker Elementary	Minor	Minor	Minor	Minor			x		
Polk	Fire Station	Haines City Fire Dept.	Minor	Minor	Moderate	Minor			x		

Table 10b. Hurricane Ivan Damage - HAZUS-MH Site Specific Hurricane Wind Results

County	Type of Facility	Facility Name	Damage State			Observed Wind Damage	HAZUS-MH Validation				
			Lower-End	Optimum HAZUS Estimate	Upper-End						
Escambia	Hospital	Baptist Hospital	Minor	Minor	Minor	Minor			x		
Escambia	Hospital	Naval Hospital Pensacola	Minor	Minor	Minor	Minor			x		
Escambia	Hospital	Sacred Heart Health System	Minor	Minor	Minor	Minor			x		
Escambia	Hospital	West Florida Hospital	Minor	Minor	Minor	Severe	x				
Escambia	School	Bellview Elementary School	Minor	Minor	Minor	Minor			x		
Escambia	School	Longleaf Elementary	Minor	Minor	Minor	Severe	x				
Escambia	School	Pine Forest High School	Minor	Minor	Minor	Moderate	x				
Escambia	School	West FL High School/Beggs Educational Center	Minor	Minor	Minor	Moderate	x				

Figures 13 and **14** illustrates the geographic trend of the comparison of the modeled and observed results for the Hurricane Charley and Hurricane Ivan study regions, respectively. The maps show the levels of agreement of HAZUS-MH damage estimates with the observed damage estimates for the site specific critical facilities.

Figure 13. Hurricane Charley Damage - HAZUS-MH Site Specific Wind Results

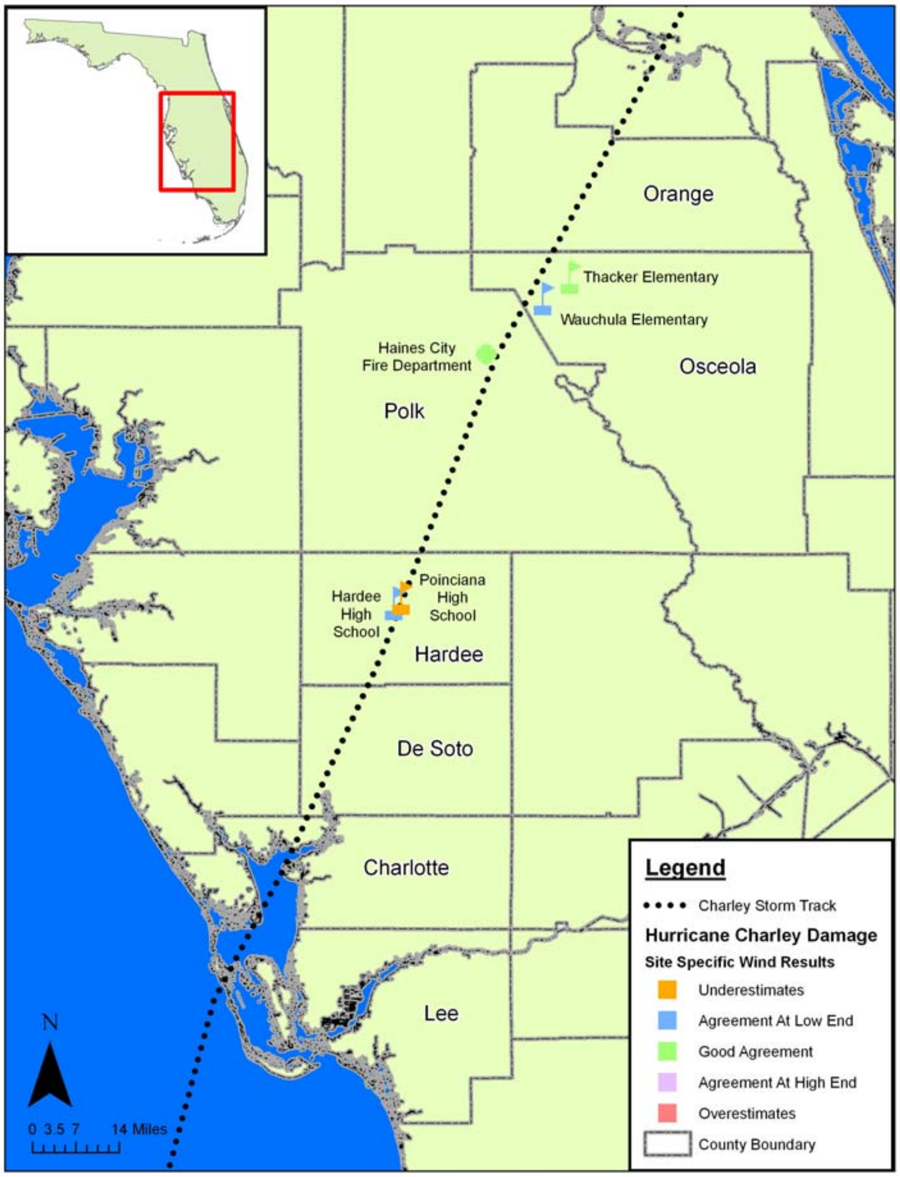
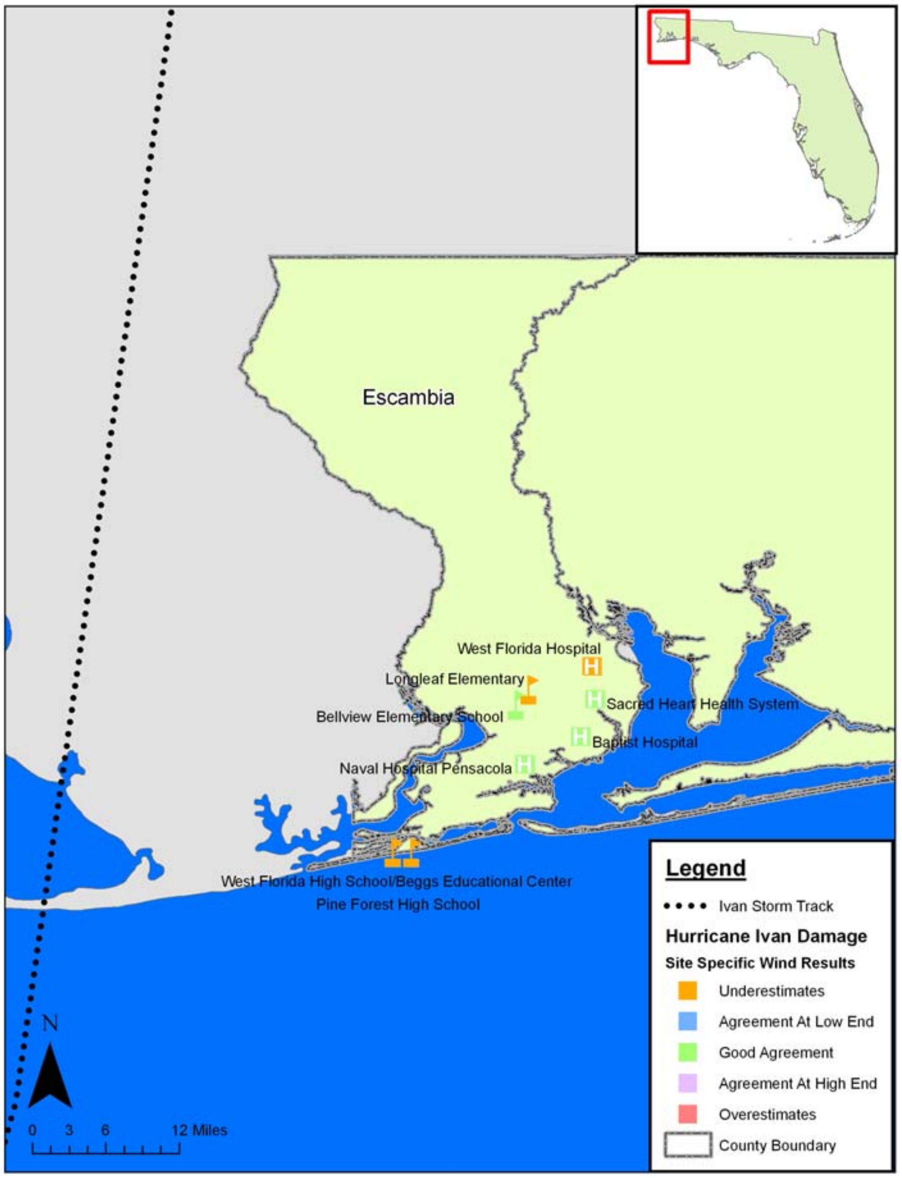


Figure 14. Hurricane Ivan Damage - HAZUS-MH Site Specific Wind Results



Observations:

- HAZUS-MH estimates were in good agreement with 80 percent of the observed damage states for the counties in the Hurricane Charley study region, and were in good agreement with 50 percent of the observed damage to the critical facilities in Escambia County even though, HAZUS-MH was not intended to be used for site-specific assessments.

- HAZUS-MH modeled damage results were generally in good agreement with the observed damage for critical facility sites that were located along the path of the hurricane track. However, damage to facilities that were located farther away from the hurricane track were also compared for Hurricane Ivan to determine if there is any fluctuation in the modeling accuracy, depending on the proximity of the facilities to the hurricane track. There was a lot more variance in the agreement of the HAZUS-MH estimates in comparison with the observed data for the Hurricane Ivan study region, than there was for the Hurricane Charley study region.

- All three hazard scenarios produced the same level of damage for all sites in Escambia County. It appears that varying the wind speed did not have an effect on the damage states at the site-level, as it did at the aggregate level. As such, it does not appear that HAZUS-MH is valid for site-specific analysis.

Wind Damage Curve Comparison for Site Specific Critical Facilities

The type of observed critical facility damage (e.g., minor, moderate, etc.) provided by the Escambia County School Board was compared with the probability of that same of type of damage predicted by the HAZUS-MH wind damage curve. The damage curve shows the likelihood of the type of qualitative damage (e.g., minor) associated with a particular wind speed for each model building type, expressed as a percentage. These model building types are spelled out in the Abbreviations List at the beginning of this report.

Tables 11a and **11b** show the observed damage compared with the probability of that predicted type of damage for 13 critical facilities in Hardee, Osceola, Polk, and Escambia Counties. For example, the first data record in Table 12a shows that HAZUS-MH estimated there to be a 60 percent chance that Hardee High School would experience minor damage.

Table 11a. Hurricane Charley Damage - Comparison of Observed Site Specific Critical Facility Damage and HAZUS-MH Wind Damage Curve

County	Type of Facility	Facility Name	HAZUS-MH Wind Class	Peak Gust	Observed Wind Damage	HAZUS-MH Wind Damage Curve Estimated Percent of Type of Building Damage	Level of Agreement
Hardee	School	Hardee High School	MECBL	133	Minor	60% - minor	Agreement at Low End
Hardee	School	Wauchula Elementary	SECBL	133	Minor	60% - minor	Agreement at Low End
Osceola	School	Poinciana High School	MLR1	107	Moderate	55% - moderate	Agreement at Low End
Osceola	School	Thacker Elementary	MECBL	104	Minor	19% - minor	Underestimates
Polk	Fire Station	Haines City Fire Dept.	MECBL	107	Minor	20% - minor	Underestimates

Table 11b. Hurricane Ivan Damage - Comparison of Observed Site Specific Critical Facility Damage and HAZUS-MH Wind Damage Curve

County	Type of Facility	Facility Name	HAZUS-MH Wind Class	Peak Gust	Observed Wind Damage	HAZUS-MH Wind Damage Curve Estimated Percent of Type of Building Damage	Level of Agreement
Escambia	Hospital	Baptist Hospital	MECBM	109	Minor	50% - minor	Agreement at Low End
Escambia	Hospital	Naval Hospital Pensacola	CECBM	96	Minor	20% - minor	Underestimates
Escambia	Hospital	Sacred Heart Health System	SECBM	106	Minor	40% - minor	Underestimates
Escambia	Hospital	West Florida Hospital	SECBH	106	Severe	0% - severe	Underestimates
Escambia	School	Bellview Elementary School	MECBL	109	Minor	25% - minor	Underestimates
Escambia	School	Longleaf Elementary	CECBL	108	Severe	0% - severe	Underestimates
Escambia	School	Pine Forest High School	CECBL	113	Moderate	12% - moderate	Underestimates
Escambia	School	West FL High School/Beggs Educational Center	CECBL	113	Moderate	12% - moderate	Underestimates

Figures 15 and **16** illustrate the geographic trend of the comparison of the modeled and observed results for the Hurricane Charley and Hurricane Ivan study regions, respectively. The maps show the percent chance of the HAZUS-MH damage curve predicting the type of observed damage for each of the site specific critical facilities.

Figure 15. Hurricane Charley Damage - Comparison of Observed Site Specific Critical Facility Damage and HAZUS-MH Wind Damage Curve

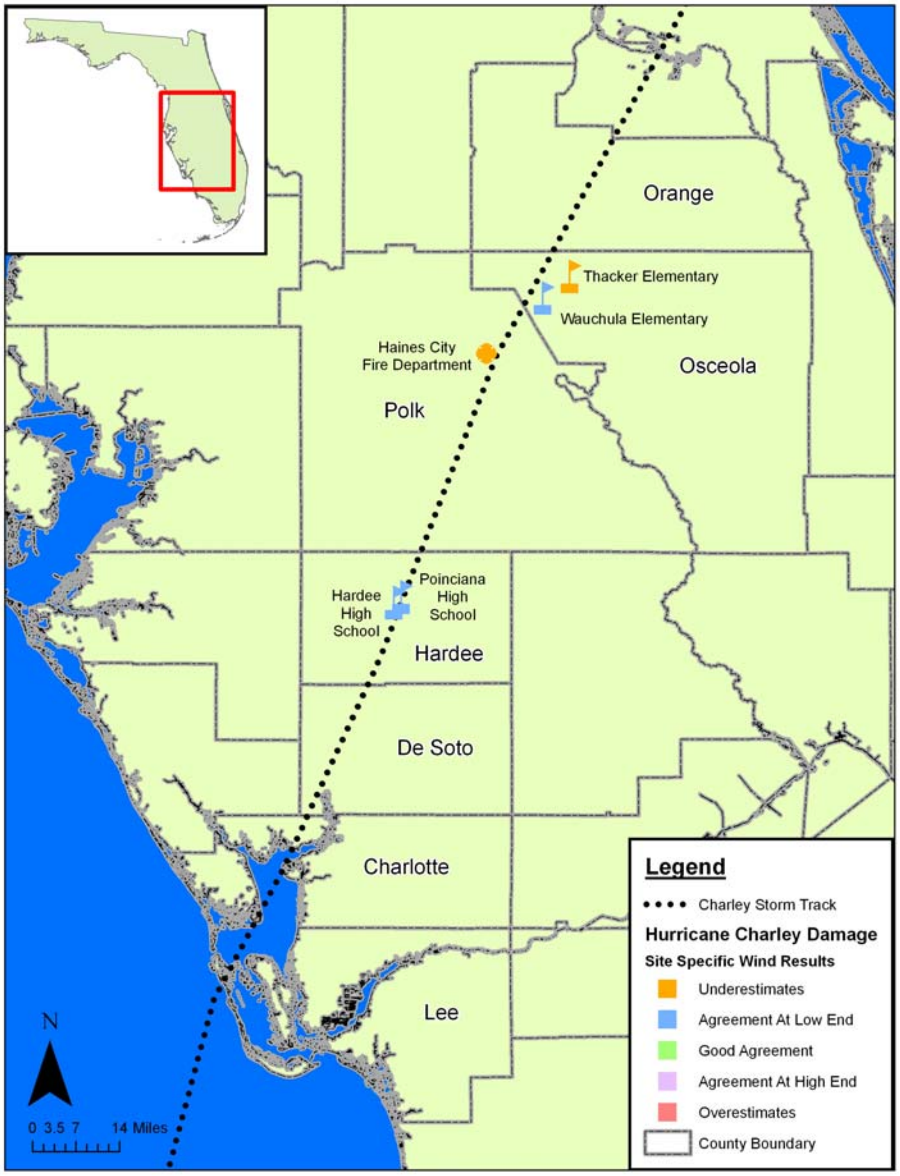
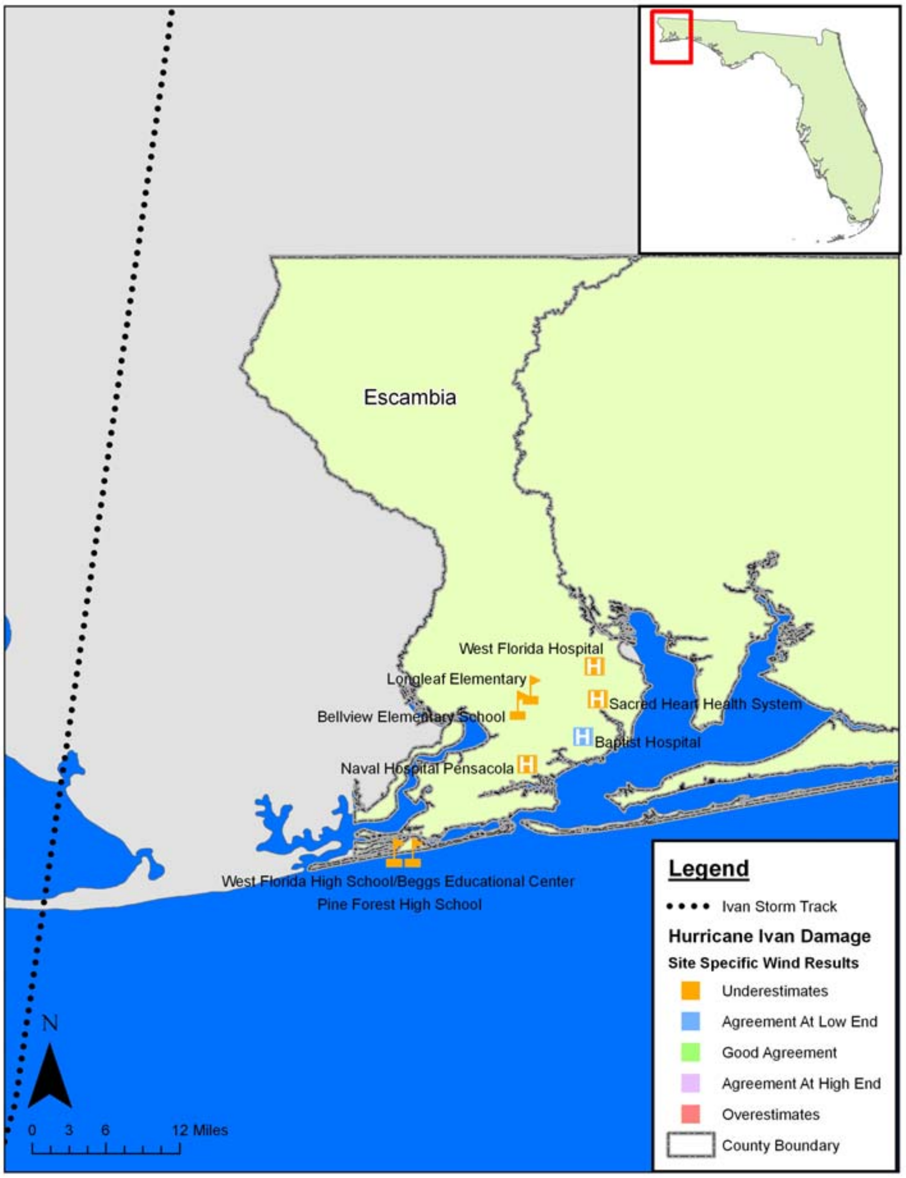


Figure 16. Hurricane Ivan Damage - Comparison of Observed Site Specific Critical Facility Damage and HAZUS-MH Wind Damage Curve



Observations:

- The HAZUS-MH wind damage curve more accurately predicted the type of damage, the closer the facility was located to the hurricane track in nearly all cases for Hurricane Charley. However, this was not the case for Hurricane Ivan. In Escambia County, the critical facilities were located 30 to 50 miles east of the hurricane track. There did not appear to be a correlation between accuracy of damage type estimates for facilities located closer to the path of hurricane. Critical facility damage that was farther away from the path was predicted with less accuracy than damage to facilities that were closer to the track. It is recommended that this be studied for future analysis, collecting more data for damage to critical facilities throughout the county.

- HAZUS-MH wind damage curve estimates were in good agreement at the low end for 60 percent of the sites for Hurricane Charley, but underestimated 88 percent of the sites for Hurricane Ivan.

Wind Loss Curve Comparison for Site Specific Critical Facilities

The economic loss and economic loss ratios provided by the Escambia County School Board were also compared with the HAZUS-MH wind loss curve. The wind loss curve shows the percentage of economic loss associated with a particular wind speed for each modeled building type, expressed as a percentage. The economic loss ratio percentages generated by HAZUS-MH were multiplied by the replacement costs (provided by the School Board) to calculate the economic loss values. **Table 12** shows the observed economic loss and loss ratios compared with HAZUS-MH estimates.

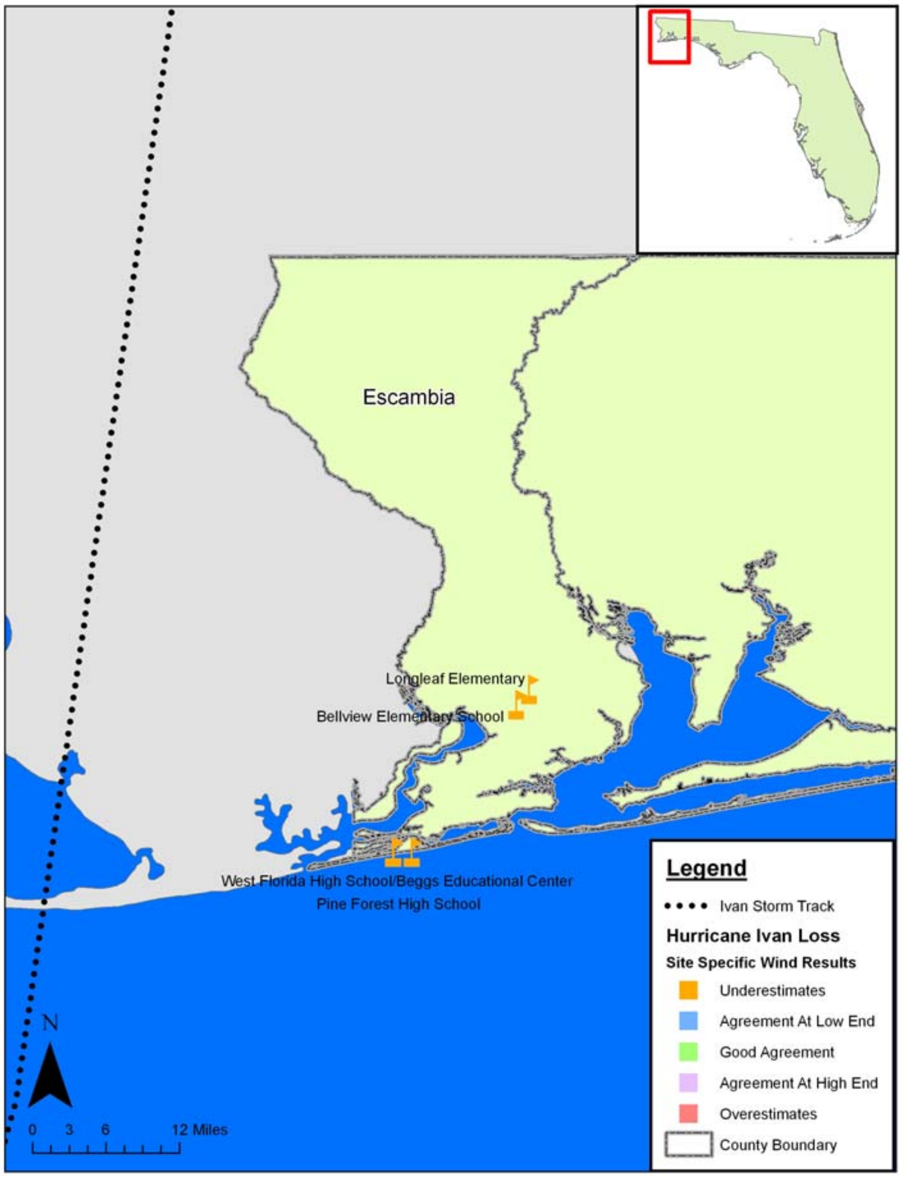
Table 12. Hurricane Ivan Economic Loss - Comparison of Observed Site Specific Critical Facility Economic Loss and Loss Ratios and HAZUS-MH Wind Loss Curve

						Observed Economic Loss Reported by School Board ($)		HAZUS-MH Wind Loss Curve	
County	Type of Facility	Facility Name	HAZUS-MH Wind Class	Peak Gust	Total Building Value (Structure and Contents) ($)	Loss ($)	Loss Ratio	Estimated Building Economic Loss ($)	Estimated Building Economic Loss Ratio
Escambia	School	Bellview Elementary School	MECBL	109	4,700,096	500,000	0.1064	58,751	0.0125
Escambia	School	Longleaf Elementary	CECBL	108	15,454,013	10,000,000	0.6471	6,439	0.0004
Escambia	School	Pine Forest High School	CECBL	113	18,755,925	1,000,000	0.0533	15,630	0.0008
Escambia	School	West FL High School/Beggs Educational Center	CECBL	113	34,710,840	6,000,000	0.1729	28,926	0.0008

Observations:

- HAZUS-MH wind loss curve estimates underestimated for all sites for Hurricane Ivan.

Figure 17. Hurricane Ivan Economic Loss - Comparison of Observed Site Specific Critical Facility Loss and HAZUS-MH Wind Loss Curve



Vulnerability Reduction Measures for Mitigation Options

Of the 13 site-specific critical facilities for which data were collected, two of them reportedly had shutters, and two had hurricane strapping. These were the only two vulnerability reduction measures that were provided in the available data. These facilities are commercial facilities. HAZUS-MH currently allows users to select two mitigation options for commercial facilities which include shutters, and the use of superior metal deck attachment for roofs.

3.3 HAZUS-MH Loss of Functionality for Hospitals

HAZUS-MH was run to obtain hurricane wind induced loss of functionality estimates for hospitals for Hurricane Charley in Charlotte, DeSoto, Hardee, and Orange Counties and for Hurricane Ivan in Escambia County. An attempt was made to compare HAZUS-MH estimates with FHA data. The FHA provided loss of functionality by county, not by individual hospital. These are not direct comparisons since the observed data were aggregated by county and HAZUS-MH estimates were provided by hospital (e.g., FL000091). Comparisons are provided for Charlotte, DeSoto, Hardee, and Orange Counties in **Table 13a** and for Escambia County in **Table 13b**.

Table 13a. Hurricane Charley Hospital Loss of Functionality - HAZUS-MH Site Specific Hurricane Wind Results

County	HAZUS Estimated Days Closed			FHA - Days Closed	HAZUS-MH Validation				
	Lower-End	Optimum HAZUS Estimate	Upper-End						
Charlotte				10*					x
FL000091	161	71	257						
FL000195	96	31	175						
FL000196	96	31	175						
DeSoto				2*					x
FL000104	43	118	200						
FL000108	52	138	223						
Hardee	0	0	0	0			x		
Orange				0					x
FL000071	1	5	20						
FL000072	1	5	15						
FL000074	1	7	27						
FL000131	1	5	19						
FL000138	1	2	7						
FL000219	0	0	0						
FL000229	0	0	0						

* One hospital closed for each period of time.

Table 13b. Hurricane Ivan Hospital Loss of Functionality - HAZUS-MH Site Specific Hurricane Wind Results

County	HAZUS Estimated Days Closed			FHA - Days Closed	HAZUS-MH Validation				
	Lower-End	Optimum HAZUS Estimate	Upper-End						
Escambia				0					x
FL000082	2	8	24						
FL000183	1	5	13						
FL000184	1	7	20						

Observations:

- Even at the aggregate level, HAZUS-MH appears to have overestimated the loss of functionality for hospitals.

- Although there were several hospitals that did close, overall the hospitals remained functional. This is due in part to good building performance, operational capability from auxiliary power, and site design of a hospital to protect key "functional" areas from wind damage.

- HAZUS-MH estimates loss of functionality based on building damage, such as damage to the roof and building openings. This is not a clear indication of complete loss of function, as part of the building could be damaged and the hospital could still be operational. The FHA reported that there was $46.3 million in economic loss to hospitals in the Hurricane Charley study region and Escambia County. Despite the significant economic losses that occurred, only two hospitals closed for brief periods of time. One hospital in Charlotte County closed for 10 days and one hospital in DeSoto County closed for two days.

4.0 CONCLUSION AND RECOMMENDATIONS

The conclusions and recommendations are based on the evaluation of how the HAZUS-MH default building inventory was used to provide results and the observations about the comparison of HAZUS-MH estimates with observed historical data from past hurricane events. This section presents general and detailed conclusions and recommendations for post-disaster data collection, model improvements, and software functionality enhancements. To provide potential future HAZUS-MH improvements, the recommendations are relatively ranked and listed in order of importance under the data collection, modeling, and software functionality headers below.

4.1 Conclusions

To achieve better agreement, the HAZUS-MH default inventory can be improved with more current and accurate data, especially for public and critical facilities, such as schools and government facilities. Also, the some of the observed data received for this study did not allow for direct comparisons with HAZUS-MH results, as data that were collected for past disasters did not differentiate between wind versus flood damage, or the data attributes needed for comparison with HAZUS-MH results were not always presented in a manner for direct comparisons. For example, ARC PDA data included damage from both wind and flood for Hurricane Ivan, and commercial qualitative damage data did not appear to have been collected. HAZUS-MH does not generate results that can be compared with the attributes of some of the damage and loss data that it is currently collected. For example, the damaged building count by qualitative damage states are not generated for all critical facilities, only those which are represented in the general occupancy class such as educational facilities (EDU).

The observed data for the Hurricane Charley study region compared well with HAZUS-MH (1) residential qualitative damage; (2) residential, commercial, and industrial economic loss; and (3) short-term shelter demand estimates. There was better agreement at the regional level, as seen in the Hurricane Charley study region versus the results for one county, Escambia County, in the Hurricane Ivan study region. This appears to be due to several factors. It appears that the HAZUS-MH results consistently underestimated for Escambia County since Hurricane Ivan caused both flood and wind damage and loss. Another possible explanation, could be that the there is better default inventory data for the southwest Florida region versus the northwest Florida region.

HAZUS-MH public and critical facilities qualitative damage (i.e., for schools) and economic loss estimates did not compare well with observed data. HAZUS-MH consistently and fairly significantly underestimated economic loss for public and critical facilities. This appears to be due to several factors. The HAZUS-MH underestimates may be attributed to the age and source of the critical facilities default inventory in HAZUS-MH, which is not as current as the general building stock, specifically the residential building stock. The residential building stock valuations are current as of 2005. However, the critical facilities data are current as of 2001. The critical facilities default data were collected from national and state data providers and likely does not reflect more accurate observed data that is available from local governments. Also, the HAZUS-MH general national building stock inventory is not current or accurate for those specific occupancy classes that were used for the critical facility comparisons (i.e., EDU for schools, GOV for public facilities, and COM6 for hospitals). Observed data such as FEMA PA data can include costs to repair the structure beyond its pre-disaster condition. For example, additional funding can be provided to upgrade public facilities using 406 hazard mitigation, or upgrade to current building codes and design standards. Therefore, the public assistance economic losses will be greater than the HAZUS-MH estimates.

The level of agreement between HAZUS-MH and observed data for site specific critical facilities varied. HAZUS-MH site specific qualitative damage estimates were in good agreement for 80 percent of the sites for Hurricane Charley and 50 percent of the sites for Hurricane Ivan. Considering that HAZUS-MH was designed to be used at a larger scale (i.e., region, county), it appears that the analysis showed that HAZUS-MH estimates compared reasonably well with the observed damage at the site specific level. However, site specific economic loss estimates were underestimated by HAZUS-MH. HAZUS-MH wind damage curve estimates were in good agreement at the low end for 60 percent of the sites for Hurricane Charley, but underestimated 88 percent of the sites for Hurricane Ivan. HAZUS-MH wind loss curve estimates underestimated for all sites for Hurricane Ivan.

HAZUS-MH hospital loss of functionality estimates did not compare well with the observed data. The model significantly overestimated the loss of functionality (i.e., number of days).

4.2 Post-disaster Data Collection Recommendations

Below are the challenges, recommendations, and benefits for future validation studies.

The specific data collection challenges included:

- Modeled estimates for a variety of categories such as: displaced households; debris; damage and loss at the jurisdictional level; damage to site specific facilities; and vulnerability reduction measures through mitigation options were not compared with observed data because the observed data was incomplete, unavailable, or incomparable.
- Data for comparison with HAZUS-MH estimates are not always separated by hazard; and damage data are not collected for commercial, industrial, public, and critical facilities.
- Vulnerability reduction measures were reviewed and data were insufficient to explore further vulnerability measures for the mitigation options in HAZUS-MH. Further research could be conducted to determine what measures are being used to reduce vulnerability. For example, post-disaster damage assessment could be conducted for structures that have been mitigation through the Hazard Mitigation Grant Program.
- Currently there is no coordination with counties prior to hurricane season to determine what data are already being collected that are useful for future HAZUS-MH validation studies and to determine which additional data are required for the local level. There is limited staff available to collect detailed HAZUS-MH data after an event.
- After a disaster event, limited staff is available to collect detailed HAZUS-MH data, because of numerous response and recovery activities. As such, it was a strain on LTRO staff resources to compile the data needed for this validation study. If a county is severely impacted, it is suggested to send support staff to assist with data collection

efforts, as several of the counties contacted during this study had a limited number of staff that was very involved with response and recovery activities.

Specific data collection and analysis recommendations include:

- It is recommended that FEMA convene a focus group to determine the appropriate data to collect to enhance the default inventory and to document observed disaster impacts. The focus group should develop a pre-disaster local data gap analysis and data gathering coordination groups for enhanced planning and mitigation efforts.
- It is recommended that FEMA encourage state and local jurisdictions to use the data collection template (refer to Appendix A) developed for this project to help consistently collect data. This data collection template should be examined by the focus group to ensure that all necessary data are being requested.
- The value and usefulness of these validation studies requires more than readily data and could be focused for further study. Many data sets were incomplete, not available or too specific to be used to compare with an aggregate model. It is recommended that future validation studies should be conducted at a regional level, for counties that only experienced wind damage, and should include data for only wind impacts.
- It is recommended that FEMA prepare prewritten rapid response HMTAP task orders for the types of HAZUS-MH data needed to be collected so deployment to collect the data is executed shortly after the event.
- The benefit for future studies is that better data collection enhances the value and usefulness of HAZUS-MH to support all areas of disaster operations.

4.3 Model Improvement Recommendations

The following were the model challenges for this validation:

- When the study regions were exported, all of the results were not automatically exported with the study region. As such, sharing the results between HAZUS-MH users involved exporting individual results tables.
- The damaged building count is generated from the general building stock for general occupancy classes, but not specific occupancy classes. Damage counts are not provided for critical facilities in HAZUS-MH.
- The default general building stock for the grade school occupancy class (i.e., EDU1) does not include all of the schools that are in the critical facilities default inventory.
- For the site-specific critical facilities analysis, all three hazard scenarios produced the same level of damage for all sites. It appears that varying the wind speed did not have an effect on the damage states at the site-level, as it did at the aggregate level. As such, further analysis should be conducted to determine whether HAZUS-MH is valid for site-specific analysis.

Below are the recommendations for model improvements for future validation studies:

- Develop the capability to retain the results that have been run in HAZUS-MH when it is exported.
- Develop the capability to provide damage counts for critical facilities, and economic loss for critical facilities at the site specific level.
- Develop a process to permit local governments to submit updated building stock inventory for use with HAZUS-MH.
- When possible, develop the functionality in HAZUS-MH models to display and export results the same way for all models.

4.4 Software Functionality Enhancement Recommendations

The following were the software challenges for this validation:

- Damage and loss estimates are not provided at the zip code, jurisdictional, or site specific levels by HAZUS-MH; this would improve the usefulness of the model for comparative analysis.
- HAZUS-MH analysis parameters revert to the default parameters after an analysis is run. Therefore, it can not determine which parameters were selected for analysis after the analysis has been run. Also, when all parameters are not selected for analysis, HAZUS-MH does not always generate all the results specified.
- Damaged building counts are not provided for specific occupancy classes or critical facilities.

Below are the recommendations for future validation studies:

- Develop the capability in HAZUS-MH to produce results at the zip code, jurisdictional, and site specific levels. Develop capability to select zip code or jurisdiction level data attributes from the map view. This functionality will allow for more detailed comparisons and validations of results.
- Develop the capability in HAZUS-MH to identify which analysis parameters have been run, instead of the analysis screen reverting back to default analysis parameter settings. Also, develop the capability within HAZUS-MH to run individual analysis parameters. Although it appears that this can be done, sometimes the results are not provided consistently.
- Develop the functionality to provide the damaged building count for specific occupancy classes and critical facilities in the wind model. This functionality will allow for more detailed comparisons and validations of results.
- Develop the capability to increase or decrease wind speeds by a percentage, instead of having to enter this data manually, and have the option to modify the maximum radius winds and central pressure that corresponds with the wind speed modification. Automate this process instead of having to enter this data by census block or tract or through sequel server.

- In the wind speed map legend that is generated by HAZUS-MH, develop breaks in the range that do not overlap. For example, instead of having the range of wind speeds overlap (<50, 50 – 65, 65 – 80, etc.), do not have them overlap (<50, 51 – 65, 66 – 80, etc.). Currently when the wind speed maps are created with the wind speed labels listed over the census tracts on the map, there are cases where different colored tracts show up with the same wind speed label.
- Allow more standard ArcGIS features in HAZUS-MH such as ability to sum columns in attribute tables, without first having to export as a data layer.

5.0 SOURCES

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APPENDIX A

Templates for Collecting Damaged Data

Appendix A provides data templates that were used to collect data. Data were collected for damages and losses to residential, commercial, and industrial structures and critical facilities.

A-1. County-Level Data Collection Form

Data were requested from Escambia and Santa Rosa Counties for Hurricanes Dennis and Ivan; and Charlotte, Hardee, DeSoto, and Orange for Hurricanes Charley, Frances, and Jeanne, using the following data collection form:

Local Government Damage Survey Data Collection

__________ County
Hurricane ___________: Flood

An analysis is being conducted to compare HAZUS-MH estimates with known damages and losses caused during the 2004 and 2005 hurricane seasons. Results will be used to improve the model's accuracy.

Please provide as much data that is available in the tables below, or in your spreadsheet format (if already available). Please list separately by residential, commercial, and industrial, as data are available.

Also, please send Residential Substantial Damage Estimates and local National Flood Insurance Claims Payments data for flood damages for county and municipal damages.

Please contact <insert staff> at <insert phone number & e-mail> for more information.

Thank you.

General Occupancy Damage and Loss

The following clarifications pertain to residential, commercial, and industrial tables:

(1) "Total Replacement Value" is the assessed value of structures in the county.

(2) "Minor" includes minor damage to roofs, siding, decking, few broken windows, etc.

(3) "Major" requires substantial repairs to house before it is safe for use. Repairs will take a few weeks.

(4) "Destroyed" means total loss/must be demolished.

(5) "Business interruption loss" refers to disaster impacts such as revenue loss.

1.0 RESIDENTIAL STRUCTURES

Counties Affected	Total # of Residential Structures	Total Replacement Value of Residential Structures (1)	Total # Residential Structures Damaged	Total # Residential Structures with Minor Damage (2)	Total # Residential Structures with Major Damage (3)	Total # Residential Structures Destroyed (4)	Economic Loss to Residential Buildings (repair cost)
Unincorporated							
Add Cities, Towns							
Countywide Total							

2.0 COMMERCIAL STRUCTURES

Counties Affected	Total # of Commercial Structures	Total Replacement Value (1)	Total # Commercial Structures Damaged	Total # Commercial Structures with Minor Damage	Total # Commercial Structures with Major Damage	Total # Commercial Structures Destroyed (4)	Economic Loss to Commercial Buildings	
							Building & Content Damage	Business Interruption Loss (5)
Unincorporated								
Add Cities, Towns								
Countywide Total								

3.0 INDUSTRIAL

Counties Affected	Total # of Industrial Structures	Total Replacement Value (1)	Total # Industrial Structures Damaged	Total # Industrial Structures with Minor Damage	Total # Industrial Structures with Major Damage	Total # Industrial Structures Destroyed (4)	Economic Loss to Industrial Buildings	
							Building & Content Damage	Business Interruption Loss (5)
Unincorporated								
Add Cities, Towns								
Countywide Total								

4.0 INJURIES AND DEATHS

Counties Affected	Injuries				Deaths			
	Residential	Commercial	Industrial	Total	Residential	Commercial	Industrial	Total
Unincorporated								
Add Cities, Towns								
Countywide Total								

5.0 ALL OCCUPANCIES (COMBINED)

ONLY fill this out if data are not available by occupancy classes in the previous tables.

Counties Affected	Total # of Structures	Total Replacement Value (1)	Total # Residential Structures Damaged	Total # Residential Structures with Minor Damage	Total # Residential Structures with Major Damage	Total # Residential Structures Destroyed (4)	Economic Loss to Residential Buildings (estimated or actual repair cost)
Unincorporated							
Add Cities, Towns							
Countywide Total							

Critical Facilities Damage and Loss

The following clarifications pertain to critical facilities tables:

(1) Total Replacement Value = Assessed value of structures in the county.
(2) Minor – repairs can be made in 1-2 week(s); school back in use within 3-4 weeks.
(3) Major – repairs take 90 days or more.
(4) Destroyed – needs to be rebuilt.
(5) Estimated Cost of Repairs – include repair or replacement costs, as applicable.

6.0 CRITICAL FACILITIES – SCHOOLS

Counties Affected	Total # of Public Schools	Total Replacement Value of Schools (1)		Total # Schools Damaged	Total # Schools with Minor Damage (2)	Total # Schools with Major Damage (3)	Total # Schools Destroyed (4)	Economic Loss: Estimated Cost of Repairs (5)	
		Building	Content					Building	Content
Unincorporated									
Add Cities, Towns									
Countywide Total									

7.0 CRITICAL FACILITIES – MEDICAL CARE FACILITIES (hospitals and nursing homes, etc.)

Counties Affected	Total # of Hospitals	Total Replacement Cost of Hospitals (1)		Total # Hospitals Damaged	Total # Hospitals with Minor Damage (2)	Total # Hospitals with Major Damage (3)	Total # Hospitals Destroyed (4)	Economic Loss: Estimated Cost of Repairs (5)	
		Building	Content					Building	Content
Unincorporated									
Add Cities, Towns									
Countywide Total									

8.0 CRITICAL FACILITIES – FIRE STATIONS (FS)

Counties Affected	Total # of FS	Total Replacement Cost of FS (1)		Total # FS Damaged	Total # FS with Minor Damage (2)	Total # FS with Major Damage (3)	Total # FS Destroyed (4)	Economic Loss: Estimated Cost of Repairs (5)	
		Building	Content					Building	Content
Unincorporated									
Add Cities, Towns									
Countywide Total									

9.0 CRITICAL FACILITIES – POLICE STATIONS (PS)

Counties Affected	Total # of PS	Total Replacement Cost of PS (1)		Total # PS Damaged from Wind	Total # PS with Minor Damage (2)	Total # PS with Major Damage (3)	Total # PS Destroyed (4)	Economic Loss: Estimated Cost of Repairs (5)	
		Building	Content					Building	Content
Unincorporated									
Add Cities, Towns									
Countywide Total									

10.0 CRITICAL FACILITIES – SHELTERS (primarily schools, churches, civic centers, senior centers, etc.)

Counties Affected	Total # of Shelters	Total Replacement Cost of Shelter (1)		Total # Shelters Damaged from Wind	Total # Shelters with Minor Damage (2)	Total # Shelters with Major Damage (3)	Total # Shelters Destroyed (4)	Economic Loss: Estimated Cost of Repairs (5)	
		Building	Content					Building	Content
Unincorporated									
Add Cities, Towns									
Countywide Total									

11.0 DEBRIS ESTIMATES

Please provide estimates or known quantities (volume – cubic yard, weight – tons) for occupancy-class generated debris and or total debris (whichever is available):

Counties Affected	Debris Generated							
	Residential		Commercial		Industrial		Total	
	Vegetative	C&D	Vegetative	C&D	Vegetative	C&D	Vegetative	C&D
Unincorporated								
Add Cities, Towns								
Countywide Total								

APPENDIX B

Detailed Raw Data Obtained for Observed Damage

The data included in Appendix B was collected from local, state, and federal government agencies and national programs and organizations. Data were provided for damage and economic loss for Hurricanes Ivan and Dennis in Escambia and Santa Rosa Counties; Hurricane Charley in Charlotte, DeSoto, Hardee, Lee, Polk, Orange, and Osceola Counties; Hurricane Frances in Brevard, Indian River, Martin, Okeechobee, Palm Beach, and St. Lucie Counties; and Hurricane Jeanne in Martin and St. Lucie Counties.

B-1. Qualitative Damage Estimates

B-1.1 Residential Damage

Residential damage data were requested from the American Red Cross (ARC), the Florida Department of Insurance Regulation (FLDOIR), and from the counties that are being assessed for this study.

Data: PDA
Source: ARC
Usefulness: Provided qualitative damage estimates of minor and major damage and destruction to residential buildings (e.g., single-family dwelling, apartment/multi-family unit, and manufactured homes).
Limitations: These data were collected through windshield survey, not a physical inspection of the damaged structures. Qualitative damage types are not the same as HAZUS damage types; however, an analysis can be performed of the damage descriptions to match the ARC's damage types with HAZUS damage types. Damages are not separated for wind versus flood damage.
Hurricanes/County(ies): Hurricanes Ivan in Escambia and Santa Rosa Counties; Hurricane Charley in Charlotte, DeSoto, Hardee, Lee, Polk, Orange, and Osceola Counties; and Hurricane Frances in Brevard, Indian River, Martin, Okeechobee, and Palm Beach Counties.

Note: PDA data were not received for Dennis or Jeanne.

Whenever damage states are "0", it is assumed that this data were not available.

Table 1. Preliminary Damage Estimates - Hurricane Charley – Charlotte County

Dwelling Type	Destroyed	Major	Minor	Affected	Inaccessible	Total
Single Family Dwelling	5,013	12,006	12,457	8,373	200	38,049
Apartment/Multi-Family Unit	0	0	0	0	0	0
Mobile Home	0	0	0	0	0	0
Unknown Dwelling Type	0	0	0	0	0	0
Sub-Total	5,013	12,006	12,457	8,373	200	38,049

Table 2. Preliminary Damage Estimates - Hurricane Charley – DeSoto County

Dwelling Type	Destroyed	Major	Minor	Affected	Inaccessible	Total
Single Family Dwelling	149	968	981	0	0	2,098
Apartment/Multi-Family Unit	21	96	70	0	0	187
Mobile Home	3,474	1,607	969	0	0	6,050
Unknown Dwelling Type	0	0	0	0	0	0
Sub-Total	3,644	2,671	2,020	0	0	8,335

Table 3. Preliminary Damage Estimates - Hurricane Charley – Hardee County

Dwelling Type	Destroyed	Major	Minor	Affected	Inaccessible	Total
Single Family Dwelling	122	775	1,791	1,054	153	3,895
Apartment/Multi-Family Unit	0	0	84	0	0	84
Mobile Home	245	277	613	524	308	1,967
Unknown Dwelling Type	0	0	0	0	0	0
Sub-Total	367	1,052	2,488	1,578	461	5,946

Table 4. Preliminary Damage Estimates - Hurricane Charley – Lee County

Dwelling Type	Destroyed	Major	Minor	Affected	Inaccessible	Total
Single Family Dwelling	326	630	6,321	8,665	0	15,942
Apartment/Multi-Family Unit	0	3	158	780	0	941
Mobile Home	5	21	338	203	0	567
Unknown Dwelling Type	0	0	0	0	0	0
Sub-Total	331	654	6,817	9,648	0	17,450

Table 5. Preliminary Damage Estimates - Hurricane Charley – Orange County

Dwelling Type	Destroyed	Major	Minor	Affected	Inaccessible	Total
Single Family Dwelling	2	177	2,036	0	0	2,215
Apartment/Multi-Family Unit	0	0	0	0	0	0
Mobile Home	0	0	0	0	0	0
Unknown Dwelling Type	0	0	0	0	0	0
Sub-Total	2	177	2,036	0	0	2,215

Table 6. Preliminary Damage Estimates - Hurricane Charley – Osceola County

Dwelling Type	Destroyed	Major	Minor	Affected	Inaccessible	Total
Single Family Dwelling	137	487	149	0	5,000	5,773
Apartment/Multi-Family Unit	0	0	0	0	0	0
Mobile Home	0	0	0	0	0	0
Unknown Dwelling Type	0	0	0	0	0	0
Sub-Total	137	487	149	0	5,000	5,773

Table 7. Preliminary Damage Estimates - Hurricane Charley – Polk County

Dwelling Type	Destroyed	Major	Minor	Affected	Inaccessible	Total
Single Family Dwelling	2,012	1,782	1,700	0	0	5,494
Apartment/Multi-Family Unit	0	0	0	0	0	0
Mobile Home	0	0	0	0	0	0
Unknown Dwelling Type	0	0	0	0	0	0
Sub-Total	2,012	1,782	1,700	0	0	5,494

Table 8. Preliminary Damage Estimates - Hurricane Ivan – Escambia County

Dwelling Type	Destroyed	Major	Minor	Affected	Inaccessible	Total
Single Family Dwelling	2,699	6,084	17,280	23,973	684	50,720
Apartment/Multi-Family Unit	2,217	2,373	3,212	3,259	0	11,061
Mobile Home	308	928	2,434	2,666	0	6,336
Unknown Dwelling Type	0	0	0	0	0	0
Sub-Total	5,224	9,385	22,926	29,898	684	68,117

Table 9. Preliminary Damage Estimates - Hurricane Ivan – Santa Rosa County

Dwelling Type	Destroyed	Major	Minor	Affected	Inaccessible	Total
Single Family Dwelling	796	2,469	5,641	10,054	245	19,205
Apartment/Multi-Family Unit	33	261	414	445	0	1,153
Mobile Home	109	296	959	1,106	44	2,514
Unknown Dwelling Type	0	0	0	0	0	0
Sub-Total	938	3,026	7,014	11,605	289	22,872

Table 10. Preliminary Damage Estimates - Hurricane Jeanne – Martin County

Dwelling Type	Destroyed	Major	Minor	Affected	Inaccessible	Total
Single Family Dwelling	32	762	1,639	1,662	38	4,133
Apartment/Multi-Family Unit	8	192	531	130	1	862
Mobile Home	141	389	540	462	3	1,535
Unknown Dwelling Type	0	0	0	0	0	0
Sub-Total	181	1,343	2,710	2,254	42	6,530

Table 11. Preliminary Damage Estimates - Hurricane Jeanne – St. Lucie County

Dwelling Type	Destroyed	Major	Minor	Affected	Inaccessible	Total
Single Family Dwelling	263	781	2,019	12,031	0	15,094
Apartment/Multi-Family Unit	37	56	0	0	0	93
Mobile Home	428	1,031	1,206	631	0	3,296
Unknown Dwelling Type	0	0	0	0	0	0
Sub-Total	728	1,868	3,225	12,662	0	18,483

Background information regarding PDA qualitative damage states versus HAZUS damage states:

Table 12. PDA Damage State Definitions

Destroyed – Structure is a total loss or damaged to such an extent that repairs are not economically feasible. Any one of the following may constitute a status of destroyed:

- Repair of structure is not economically feasible.
- Structure is permanently uninhabitable.
- There is a complete failure of major structural components (collapse of walls or roof).
- Unaffected structure will be required to be removed or demolished due to ordinance (e.g., beachfront homes removed due to severe beach erosion).

Major – Structure has sustained structural or significant damage, is uninhabitable, and requires extensive repairs. Any of the following may constitute major damage:

- Substantial failures to structural elements of the residence (e.g., walls, floors, foundations).
- Damage to the structure exceeds the Disaster Housing Program, Home Repair Grant maximum ($10,000).
- General exterior property damage exceeds the Disaster Housing Program Home Repair Grant maximum (e.g., roads and bridges, wells, earth movement) and has more than 50 percent damage to the structure.
- Damage will take more than 30 days to repair.

Minor – Structure is damaged and uninhabitable, but may be made habitable in a short period of time with home repairs. Any of the following may constitute minor damage:

- Structure can be repaired within 30 days.
- Structure has more than $100 of eligible habitability items through the Disaster Housing Program, Home Repair Grant; or has less than $10,000 of eligible habitability items through the Disaster Repair Program, Home Repair Grant.
- Damage repair costs are less than 50 percent of total value of house.

Affected – Sustained some damage to structure and contents, but is habitable without repairs, and damage to habitability items is less than Disaster Housing Program, Home Repair Grant minimum.

The PDA definitions are very comparable to the ones in HAZUS. For reporting purposes, the following alignment provides the appropriate mapping between the two:

Human Services PDA		**HAZUS-MH Damage States**
Affected	=	Minor Damage
Minor Damage	=	Moderate Damage
Major	=	Severe
Destroyed	=	Destruction

Data: Damaged Residential Structures
Source: DeSoto County
Usefulness: Provided qualitative damage estimates of minor and major damage and destruction to residential buildings.
Limitations: These data were indicative of what has been reported as of January 2006. DeSoto County provided qualitative damage estimates for residential structures that were slightly lower than the PDA data.
Hurricanes/County(ies): Hurricane Charley in DeSoto County.

Table 13. Residential Damage - Hurricane Charley – DeSoto County

County	Total # of Buildings	Total # Damaged Buildings	Minor Damage	Major Damage	Destroyed
DeSoto	10,700	9,672	*3,587	2,589	3,496

* Minor 2,095 plus affected 1,492

Data: Wind Loss Insurance Claims Data
Source: FLDOIR
Usefulness: Provided insurance data for total claims and total losses (i.e., destroyed) for residential properties.
Limitations: These data only reflect insured property losses, but includes damage to appurtenant structures and automobiles, which are not modeled in HAZUS-MH.
Hurricanes/County(ies): All hurricanes and all counties involved in this study.

Table 14. Residential Damage - Hurricane Charley, Charlotte County and Hurricane Ivan, Escambia County (FLDOIR)

County	Disaster	# of Claims Reported	# of Claims Total Loss
Escambia	Ivan	101,715	3,859
Santa Rosa	Ivan	43,785	2,025
Escambia	Dennis	14,330	57,416,279
Santa Rosa	Dennis	21,648	127,077,866
Charlotte	Charley	83,085	8,601
DeSoto	Charley	13,209	1,714
Hardee	Charley	8,101	638
Lee	Charley	78,317	1,945
Orange	Charley	99,164	1,017
Osceola	Charley	42,204	843
Polk	Charley	49,595	1,857
Brevard	Frances	61,321	2,838
Indian River	Frances	31,627	1,730
Martin	Frances	24,064	1,288
Okeechobee	Frances	6,783	587
Palm Beach	Frances	107,926	2,534
St. Lucie	Frances	56,722	4,053
Martin	Jeanne	20,966	626
St. Lucie	Jeanne	31,866	960

* Claims payments for Dennis only reflect those made as of 10/7/2005.

Modeling Usefulness: PDA data for qualitative residential damage estimates (e.g., number of structures with minor or major damage, or destroyed) were compared with the damage estimates generated by the HAZUS-MH Hurricane Wind Model. Although it is widely known that PDA data are based on windshield survey and estimates can be somewhat subjective, this appears to be the best available data set for comparison purposes for this validation study. Insurance claims were much higher than the HAZUS-MH estimates for total damage and the PDA estimates, as the FDOIR data included claims paid for items not modeled in HAZUS-MH such as boats and cars. Therefore the number of claims is not suitable for comparison with HAZUS-MH estimates.

General Limitations: Residential damage data likely contains damage caused by both flood and wind, which are not able to be separated. This does not appear to be a concern for counties that were impacted by Hurricane Charley, as this was predominantly a wind event. However, this is a concern for counties that were impacted by Frances, Ivan, Jeanne, and Dennis. In addition, it will be difficult to determine which damages occurred from Ivan versus Dennis or Jeanne versus Frances, since these storms hit the same areas. As such, all prior damages had not yet been repaired from the first hurricane when the second hurricane caused damage.

B-1.2 Commercial and Industrial Damage

Commercial and industrial damage data were requested from the ARC, the Insurance Services Office, Inc. (ISO), and from the counties that are being assessed for this study. No data were received. ISO data were received for residential, commercial, and industrial damage. These data are not reproduced per licensing agreement requirement.

B-1.3 Critical Facilities Damage

Aggregate Critical Facilities Damage

Critical facilities damage data were requested for medical care facilities, schools, fire stations, police stations, and shelters. Data were requested from the Florida Hospital Association and from the counties that are being assessed for this study.

Data: Damaged Critical Facilities
Sources: Escambia County School Board Risk Manager, Escambia County, and DeSoto County.
Usefulness: Provided qualitative damage estimates of minor, moderate, and major damage to critical facilities from wind.
Limitations: Qualitative damage types are not the same as HAZUS damage types; however, an analysis can be performed of the detailed damage descriptions to match the county’s damage types with HAZUS damage types. The shelter data are not a comprehensive list of all shelter damage as it only includes schools that served as shelters.
Hurricanes/County(ies): Qualitative damage were provided for Escambia County schools, fire stations, and shelters for Hurricane Ivan, and for DeSoto County fire stations and shelters for Hurricane Charley.

Table 15. Critical Facilities Damage – Hurricanes Ivan and Charley

County	Disaster	Critical Facility Type	Total # of Facilities	Total # of Facilities Damaged	Minor	Moderate	Major	Destroyed
Escambia	Ivan	Schools	n/a	n/a	25	17	30	
Escambia	Ivan	Fire Stations	23	23	21	0	2	
Escambia	Ivan	Police Stations	n/a	n/a	n/a	n/a	n/a	
Escambia	Ivan	Shelters	10	n/a	0	3	2	
DeSoto	Charley	Fire Stations	2	2	2	0	0	
DeSoto Cities Total	Charley	Fire Stations	2	2	1		1	
DeSoto	Charley	Shelters		1				1

n/a = not available

Schools Damage

Table 16. Detailed Qualitative Damage Estimates – Hurricane Ivan – Escambia County Schools

School Name	Major	Moderate	Minor
Jim Allen		Portables-Major damage; Minor roof leaks over kitchen.	
Bellview Elementary	Roof missing; major water damage; siding & facial; portables-minor damage.		
Beulah	Damaged bus canopy; roof damage; major water damage.		
Bibbs, Spencer			Siding 100-200 rooms; front entrance awnings; awnings.
Blue Angels, (Shelter)		Major damage east side structural; minor damage throughout; portables damaged.	
Bratt	Roof blown off; major water damage; siding/awnings; bldg. 3-severe water damage.		
Brentwood Elementary	Roof missing main hallways; extensive water damage all spaces.		
Byrneville			Portables - tree damage
Hellen Caro		Roof leaks-major in some areas; broken windows 615; portables A & D-windows.	
Century/Carver			2 trees on new building; 1 tree on #2 portable.

School Name	Major	Moderate	Minor
Cook, N. B.	Main hall skylight gone; major water damage; roof damage; second floor-extensive damage; trap door (over stage) open; kitchen exhaust could fall.		
Cordova Park			Main bldg.-ceiling; A/C damaged by walkway; rms. 111,114-water damage.
Edgewater		Major roof damage - bldg. #2; windows; rms. 138,135,130 extensive.	
Ensley			Roof is good; awnings; trees; *power line
Ferry Pass Elementary		No assessment	
Hallmark			Minor leaks; many trees down.
Holm			Minor roof damage; kitchen, rm. 325; awnings.
Lincoln Park			Roof leaks throughout; awnings; walkways.
Lipscomb (Shelter)		Lift station over flowing; classroom roof leaks all wings; windows & siding on portables.	
Longleaf	Major roof damage; water damage all spaces except new wing.		
McArthur			Roof damage-819; siding-743; bldg. 99; roof leaks-various minor; awnings.
Molino Park (Shelter)		Awnings; roof leaks; major water damage (admin. spaces).	
Montclair			Trees; portables; roof vents.
Myrtle Grove		Extensive roof damage; shingles; leaks in most spaces; trees on portables.	
Navy Point	Major walls rms. 30-33; cafeteria-pine tree; walkways; 2nd floor Windows in 2 Classrooms.		
Oakcrest	Roof damage all spaces; awnings; portables-major damage.		
Pine Meadow		Major trees down; roof damage minor-104, 101, 204, 105, 642, 256; water damage; office-major damage.	
Pleasant Grove		Building 3-roof damage; portables electrical lines.	

School Name	Major	Moderate	Minor
Scenic Heights			300 bldg.-tree on roof; awnings; vent fan off.
Semmes		Siding-portable; bldg 1 & bldg. 9-awning, siding; media center-major damage; backflow preventer box-structural damage.	
Sherwood	Bldg. 3-major roof damage; bldg. 9-no roof; major water damage.		
Suter, A.K.	Roof-118, 112, 119, 100D, 111, 108, 124, 100F, 107, 107C, 205, 203, 125A, 125B; media addition; #99 portable-roof sagging; 8 trees down.		
Warrington Elementary	Roof gone; ceilings; floors; trees; awnings; covered walks.		
Weis, C. A.	Extensive water damage all spaces; awnings; roof damage all spaces.		
West Pensacola		Extensive debris clean-up.	
Yniestra, Allie			Gutters; portables settled.
Molino (Vacant)			Walkways bldgs. 2 & 3
Bailey (Shelter)	Roof system severe; windows out; portable damage.		
Bellview Middle		Cafeteria/kitchen damage; portable damage; water damage; ceiling tiles & water all over; ese/admin. windows, flooding.	
Brentwood Middle		Siding; roof peeling on trailers; minor water damage.	
Brown Barge	Roof damaged over mechanical room; major roof damage-108,109,106,104, 063,cafeteria 208, library, 314,317; awnings, portables.		
Brownsville			Gas leak-secure 14:30; minor water damage; portables-siding & windows; large tree on main building.
Ferry Pass Middle		Main building-shingles; skylights; awnings; siding; office flooded; major water damage-618, 619, 500, 501, 516, kitchen, cafeteria, 201, 202, bookkeepers' office.	

School Name	Major	Moderate	Minor
Ransom			Portables siding damaged-all; windows portables-all; roof-admin.; library-roof, windows; trees total school; water main
Ernest Ward			Minor roof damage; walkways & awnings.
Warrington Middle	Major roof damage bldgs. 1,2,4,5; windows on portables; extensive water damage.		
Wedgewood		Major flooding; library; major roofing damage.	
Workman	Main building-roof; library-water damage; all awnings; girls' p.e.-water damage; cafeteria-water damage; cafeteria-windows; 200 wing-roof.		
Escambia	Gym major roof damage; major leaks; awnings; broken windows.		
Northview		Roof leaks all spaces; minor water damage.	
Pensacola High	Bleachers destroyed; gym destroyed; awnings/ramps; water damage; surveillance cameras stolen.		
Pine Forest	Roof damage; cooling tower destroyed.		
Tate	Lift station down; major water damage-main bldg.; windows-main bldg.; all walkways; cafeteria, gym.		
Washington		Music/choral/band roof damage and water damage; minor roof damage over atrium; water damage-north classrooms.	
Woodham	Cafeteria; media center destroyed; major roof damage; water damage.		
West Florida (Shelter)	Major debris clean-up; major roof damage; bldg. 7-lost roof; awnings/gutters.		
Hall Center			
McDaniel Administration		2nd floor windows w/ extensive water damage; supt. office-water damage.	
Data Center			Perimeter offices water damage; computer room dry.
End User Support	Roof gone; major water damage.		

School Name	Major	Moderate	Minor
Walnut Hill Bus Garage			Shingles; tree damage.
Transportation Main Garage	Major roof damage; 2 roll up doors; water leaks all over wash rack and electronic equipment.		
Andrews, Judy			Broken windows; no roof or water damage.
Dixon			3 broken windows.
Clubbs, A. V.	3 trees w/ roof penetration; major roof leaks; water damage all spaces.		
Escambia Westgate	Roof missing - 505, 506; hallway leaks @ new bldg. seam; cafeteria-broken windows, water damage.		
ESEAL			Quansit huts gone; tool shed gone.
Sid Nelson	Roof damage all buildings, cafeteria kitchen-300, 500, 400, 200; all awnings.		
McMillan/Title I			Portables - heavy damage; minor leaks
Petree Pre-K			Wiring down; shingles blew off roof; tree on covered walkway; tree on fence.
Pickens			Windows-board covers missing.
Environmental Center	Many Trees on Roof.		
Warehouse			Freezer up; 1 unit down; roof over 70 degree room.
George Stone SEE WFHSAT	Awnings/gutters; bldg. 3-flooded; paint booth destroyed; portable 99-destroyed; portable 17-blown off foundation; administration wing-roof destroyed.		
Gibson	No assessment		
Old Carver	No assessment		
Totals	30	17	25

Shelter Damage

Table 17. Shelter Detailed Qualitative Damage Estimates – Hurricane Ivan – Escambia County

School Name	Major	Moderate	Minor
Blue Angels (Shelter)		Major damage east side structural; minor damage throughout; portables damaged.	
Lipscomb (Shelter)		Lift station over flowing; classroom roof leaks all wings; windows & siding on portables.	
Molino Park (Shelter)		Awnings; roof leaks; major water damage (admin. spaces).	
Bailey (Shelter)	Roof system severe; windows out; portable damage.		
West Florida (Shelter)	Major debris clean-up; major roof damage; bldg. 7-lost roof; awnings/gutters.		
Totals	2	3	0

Site Specific Critical Facilities Damage

Critical facility qualitative damage data were provided from prior HAZUS-MH validation studies conducted in 2004 for Hurricanes Charley , Ivan, and Dennis.

Data: Damaged Critical Facilities
Sources: Hurricanes Charley (TO – 332), Ivan (TO – 348), and Dennis (TO – 406).
Usefulness: Provided qualitative damage estimates of minor, moderate, and major damage to critical facilities.
Limitations: Observed damage states collected in the field can be subjective.
Hurricanes/County(ies): Qualitative damage were provided for Osceola and Hardee schools, and a Polk County fire station; and for Escambia County schools, fire stations, and shelters for Hurricane Ivan.

Table 18. Prior HAZUS Validation – Hurricane Charley

County	Type of Facility	Facility Name	Latitude	Longitude	HAZUS Wind Class	Observed Damage
Osceola	EDU1	Poinciana High School	28.239121	-81.486760	SECBL	Moderate
Hardee	EDU1	Wauchula Elementary	27.542352	-81.817834	MLR1	Minor
Hardee	EDU1	Hardee High School	27.529024	-81.834071	MECBL	Minor
Osceola	EDU1	Thacker Elementary	28.289289	-81.424193	MECBL	Minor
Polk	Fire Station	Haines City Fire Dept.	28.108560	-81.622275	MECBL	Minor

Table 19. Prior HAZUS Validation – Hurricane Ivan

County	Type of Facility	Facility Name	Latitude	Longitude	HAZUS Wind Class	Observed Wind Damage	Observed Flood Damage
Escambia	EDU1	Longleaf Elementary	30.486689	-87.291219	CECBL	Severe	None
Escambia	EDU1	Pine Forest High School	30.293898	-87.452102	CECBL	Moderate	None
Escambia	EDU1	West FL High School/Beggs Educational Center	30.293879	-87.451672	CECBL	Moderate	None
Santa Rosa	Fire Station	Navarre Beach VFD #18	30.379285	-86.879664	SECBL	Minor	Minor
Santa Rosa	EDU1	Gulf Breeze Middle School	30.370639	-87.176129	MECBL	Minor	None
Santa Rosa	Hospital	The Friary of Baptist Health Care Center	30.3976	-87.03941	WMUH1	Minor	None
Santa Rosa	Hospital	Gulf Breeze Hospital	30.36104	-87.15677	MECBL	Moderate	None
Escambia	Hospital	Sacred Heart Health System	30.4753	-87.21374	SECBM	Minor	None
Escambia	Hospital	Baptist Hospital	30.43083	-87.23097	MECBM	Minor	None
Escambia	Hospital	West Florida Hospital	30.51439	-87.21784	SECBH	Major	None

Table 20. Prior HAZUS Validation – Hurricane Dennis

County	Type of Facility	Facility Name	Longitude	Latitude	HAZUS Wind Class	Observed Wind Damage	Observed Flood Damage
Escambia	Fire Station	Pensacola Beach FD	30.33813	87.11544	CECBL	Moderate	Moderate
Santa Rosa	EDU2	Pensacola Jr College - Milton Campus	30.60474	-87.07495	MECBM	very minor	none
Santa Rosa	EDU1	Hobbs Middle School	30.62813	-87.06482	MECBL	moderate	none
Santa Rosa	COM6	Santa Rosa Medical Center	30.63452	-87.06714	MECBM	very minor	none
Santa Rosa	EDU1	Pearidge Elementary School	30.60832	-87.11166	MECBL	moderate	none
Santa Rosa	Fire Station	Holley-Navarre Vol. Fire Dept.	30.43208	86.87494	S5	None	none
Santa Rosa	EDU1	West Navarre Elem School	30.40642	86.93256	MLR1	Very Minor	none
Santa Rosa	EDU1	T.R. Jackson Pre-K	30.61542	87.04339	MLR1	None	none
Santa Rosa	COM1	School of Readiness	30.62382	87.0368	MECBL	None	none
Santa Rosa	Fire Station	Fire Station 18	30.37941	86.87975	MECBL	Severe	Moderate
Santa Rosa	COM6	Gulf Breeze Hospital	30.47532	87.21374	SECBM	Minor	Minor

B-1.4 County Structures Damage

Data: Damaged County Structures

Source: Escambia County
Usefulness: Provided number of county structures damaged.
Limitations: Data are not separated by occupancy class, or by hazard (e.g., wind versus flood).
Hurricane/County: Hurricane Ivan for Escambia County

Modeling Usefulness: There was not enough information known about which building occupancy classes were included in the observed data. These data were not suitable for comparison with damage estimates generated by the HAZUS-MH Hurricane Wind Model.

Table 21. County Structure Damage – Hurricane Ivan – Escambia County

Community	Total # of Buildings (county structures)	Total # of Buildings Damaged in Hurricane Ivan	Total # of Buildings Sampled in Survey	Total # of Buildings Surveyed that Sustained at Least Minor Damage	Total # of Buildings Surveyed that Sustained at Least Moderate Damage
Escambia County	240	192*	n/a	n/a	n/a

n/a = not available
County structures damaged (this does not include parks and recreation)

Data: Damaged Structures (countywide)
Source: Santa Rosa County Property Appraiser
Usefulness: Providec qualitative damage estimates of minor and major damage for all buildings (occupancies).
Limitations: County data were not useable as they were not separated by occupancy class, or by hazard (i.e., wind versus flood). As such, ARC PDA data were used for analysis purposes, so that all qualitative damage estimates for residential units will come from one source to be consistent.
Hurricanes/County(ies): Hurricane Dennis in Santa Rosa County

Table 22. Countywide Damaged Structures - Hurricane Dennis – Santa Rosa County

Community	Total # of Buildings (all occupancies)	Total # of Buildings Damaged in Hurricane Dennis	Total # of Buildings Sampled in Survey	Total # of Buildings Surveyed that Sustained at Least Minor Damage	Total # of Buildings Surveyed that Sustained at Least Moderate Damage
Navarre	11,024	200	41	10	2
Bagdad	2,400	29	9	9	7
Milton	3,246	28	164	69	27
Navarre Beach	1,729	0	156	126	36
Pensacola Beach	0	0	5	0	0
Gulf Breeze	2,850	0	12	0	0
Totals	21,249	257	387	214	72

Loss of Function

B-2.1 Critical Facilities

2.3.1.6 Critical Facilities Loss of Function

Critical facilities loss of function data (e.g., loss of use in days) was requested from the FHA and the counties included in this study.

Data: Hospital closures
Source: Florida Hospital Association
Usefulness: Providec economic loss estimates by county.
Limitations: Does not indicate whether closures were due to physical damage or loss of power/water. Does not list damage for each hospital, only by county.
Hurricanes/County(ies): Hurricane Ivan for Escambia County, and for Charlotte, Hardee, DeSoto, and Orange Counties for Hurricane Charley.

Modeling Usefulness: All relevant available data for loss of functionality for critical facilities (e.g., loss of use in days) were compared with the loss of functionality estimates generated by the HAZUS-MH Hurricane Wind Model.

B-2.1.1 Medical Care Facilities

Table 23. Hospital Loss of Function – Hurricane Ivan and Charley

County	Disaster	Number of Hospitals in County (Acute/Other)	Number Responding to FHA survey	Closures	Days Closed
Escambia	Ivan	3/3	2	0	0
Santa Rosa	Ivan	3/1	DNR	DNR	DNR
Charlotte	Charley	3	2	1	10
DeSoto	Charley	1	1	1	2
Hardee	Charley	1	1	0	0
Orange	Charley	10/3	6	0	0

DNR = Did not report

B-2. Shelter Demand

B-3.1 Shelter Population

Pre- and post-disaster shelter population data were requested from the ARC.

Data: Pre- and post-disaster shelter counts – Hurricanes Ivan and Dennis
Source: Ivan: ARC; Dennis: FL Division of Emergency Management (FDEM)
Usefulness: Provided shelter population, from which to derive the number of displaced households by county.

Limitations: Does not include population that evacuated outside the county. This data might include population that were displaced from their homes short-term due to electric and water/sewage damage, not structural damage. Data does not indicate which populations sought shelter to avoid coastal flooding versus wind impacts.
Hurricanes/County(ies): All hurricanes and all counties involved in this study.

Modeling Usefulness: Post-disaster shelter population counts were compared with the shelter population estimates generated by the HAZUS-MH Hurricane Wind Model.

Table 24. Shelter Populations - Hurricanes Charley, Dennis, Frances, Ivan, and Jeanne – All Counties

County	Disaster	Pre-Landfall Shelter Population	Post-Landfall Shelter Population*
Escambia**	Ivan	7,692	978
Santa Rosa**	Ivan	636	349
Escambia***	Dennis	2,472	100
Santa Rosa***	Dennis	878	35
Charlotte	Charley	425	425
DeSoto	Charley	1,374	1,400
Hardee	Charley	537	537
Lee	Charley	8,129	1,191
Orange	Charley	727	70
Osceola	Charley	1,714	102
Polk	Charley	3,390	14
Brevard	Frances	9,701	10,654
Indian River	Frances	4,055	1,205
Martin	Frances	5,558	275
Okeechobee	Frances	1,595	250
Palm Beach	Frances	4,348	17,585
St. Lucie	Frances	4,896	2,745
Martin	Jeanne	1,873	118
St. Lucie	Jeanne	2,118	536

* Data includes post-land fall shelter population the night after the hurricane made landfall.
** Total provided by FDEM.
*** Total provided by the ARC, estimated on post-landfall population.

B-4 Economic Loss

B-4.1 Residential Economic Loss

Residential economic loss data were requested from the FLDOIR, FEMA's Individual Assistance (IA) Program, ISO, and the counties included in this study.

FDOIR and ISO data were received for residential damage. This data are not reproduced per licensing agreement requirement.

Data: Wind Loss Insurance Claims Data; value of repair or replacement cost
Source: FLDOIR

Usefulness: Provided insurance claims for residential properties.
Limitations: These data only reflect insured property losses.
Hurricanes/County(ies): All hurricanes and all counties involved in this study.

Modeling Usefulness: Insurance losses were compared with loss estimates generated by the HAZUS-MH Hurricane Wind Model. It did not appear that IA data were be useful for this validation study, as the program provides loans to homeowners for $5,200 for property loss, which typically represents only a portion of the loss.

Table 25. Department of Insurance Regulation Wind Loss Claims Payments – Hurricanes Charley, Dennis, Frances, Ivan, and Jeanne – All Counties

County	Disaster	Claims Payments*
Escambia	Ivan	1,698,123,360
Santa Rosa	Ivan	668,074,159
Escambia	Dennis	38,336,681
Santa Rosa	Dennis	56,755,861
Charlotte	Charley	2,561,459,188
DeSoto	Charley	283,494,623
Hardee	Charley	138,479,116
Lee	Charley	1,014,468,730
Orange	Charley	990,660,827
Osceola	Charley	560,179,016
Polk	Charley	554,140,262
Brevard	Frances	988,571,302
Indian River	Frances	766,420,342
Martin	Frances	423,664,555
Okeechobee	Frances	94,125,899
Palm Beach	Frances	1,165,038,320
St. Lucie	Frances	1,127,106,791
Martin	Jeanne	201,448,046
St. Lucie	Jeanne	246,490,019

* Claims payments for Dennis only reflect those made as of 10/7/2005.

B-4.2 Commercial and Industrial Economic Loss

No observed data were used for this study

Commercial economic loss data were requested from the Small Business Administration (SBA), ISO, and the counties included in this study. It was decided that SBA data would not reflect accurate economic loss, as SBA provides business loans to those who apply.

Commercial and industrial damage data were requested from the ARC, the Insurance Services Office, Inc. (ISO), and from the counties that are being assessed for this study. No data were received. ISO data were received for residential, commercial, and industrial damage. This data are not reproduced per licensing agreement requirement.

B-4.3 Critical Facilities Economic Loss

B-4.3.1 Medical Care Facilities

Critical facilities economic loss data requested from the FHA and the counties included in this study.

Data: Hospital Economic Loss
Source: Florida Hospital Association
Usefulness: Provided economic loss estimates for hospitals by county.
Limitations: The data does not list economic loss for each hospital; only by county.
Hurricanes/County(ies): Economic loss data were provided for Hurricane Ivan for Escambia County, and for Charlotte, Hardee, DeSoto, and Orange Counties, for Hurricane Charley.

Table 26. Hospital Economic Loss - Hurricanes Ivan and Charley

County	Hurricane	Actual Number of Hospitals in County (Acute/Other)	Number Responding to FHA survey	Total Cost for Repairs	Cost Estimates Related to Patient Care	Staffing Costs
Escambia	Ivan	3/3	2	$20,335,000	$4,600,000	$1,040,800
Santa Rosa	Ivan	3/1	DNR	DNR	DNR	DNR
Charlotte	Charley	3	2	$23,000,000	DNR	DNR
DeSoto	Charley	1	1	$2,501,000	DNR	DNR
Hardee	Charley	1	1	DNR	DNR	DNR
Orange	Charley	10/3	6	$284,978	$571,500	$874,666

DNR = Did not report

B-4.3.2 Schools

Data: School Economic Loss
Source: Escambia County School Board Risk Manager
Usefulness: Provided economic losses to school buildings and educational facilities.
Limitations: Economic losses are not separated by building and contents.
Hurricane/County: Economic loss data were provided for Hurricane Ivan for Escambia County.

Table 27. School Economic Loss – Hurricane Ivan – Escambia County

Location Name	Building Value	Contents Value	Est. Damages
Jim Allen Elementary	4,841,890	718,190	250,000
Judy Andrews Pre-K	995,805	149,371	20,000
Bailey Middle	12,818,250	1,922,738	6,000,000
Bellview Elementary	4,087,040	613,056	500,000
Bellview Middle	8,999,640	1,349,946	450,000
Beulah Elementary	5,042,480	756,372	750,000
Spencer Bibbs Elementary	3,848,720	577,308	150,000
Blue Angels Elementary	8,858,407	1,763,000	400,000

Location Name	Building Value	Contents Value	Est. Damages
Brentwood Elementary	3,756,400	563,460	700,000
Brentwood Middle	6,766,740	1,015,011	250,000
Brown Barge Middle	4,067,990	610,199	1,000,000
Brownsville Middle	8,117,820	1,217,673	150,000
Byrneville Elementary	673,840	101,076	75,000
Hellen Caro Elementary w Cafeteria Expansion	6,491,506	966,580	400,000
Carver Century K-8	5,253,120	911,482	100,000
Carver (Middle Old)	6,109,809	916,471	no data
Cook Elementary - AV Clubbs Ctr.	2,149,440	322,416	300,000
N.B. Cook Elementary	11,000,000	1,650,000	1,000,000
Cordova Park Elementary	3,800,400	570,060	100,000
Dixon Elementary	3,093,680	464,052	50,000
Edgewater Elementary	3,513,120	526,968	200,000
Ensley Elementary	3,945,286	636,560	200,000
Escambia High w Elevator	19,025,048	2,825,690	1,000,000
Escambia Westgate Center & Snoezelen Bldg.	6,101,580	1,093,965	1,500,000
Ferry Pass Elementary	4,012,400	601,860	200,000
Ferry Pass Middle	7,110,540	1,066,581	400,000
McMillan Learning Ctr. Goulding (Pre-K)	2,256,072	338,411	100,000
Hallmark Elementary	2,517,200	377,580	75,000
Holm Elementary	10,447,800	2,134,818	150,000
Lincoln Park Elementary	3,503,600	525,540	150,000
RC Lipscomb Elementary	6,726,320	1,008,948	150,000
Lakeview Center	no data	no data	no data
Longleaf Elementary	14,587,950	866,063	10,000,000
McArthur Elementary	4,305,760	645,864	150,000
Molino Elementary	1,758,080	263,712	50,000
Molino Park Elementary	10,861,556	1,200,000	200,000
Montclair Elementary	3,445,840	516,876	75,000
Myrtle Grove Elementary	3,869,760	580,464	300,000
Navy Point Elementary	4,287,440	643,116	500,000
Northview High	11,017,400	1,652,610	450,000
Oakcrest Elementary & Media Center	4,420,534	695,348	500,000
Pensacola High School	21,210,800	3,181,620	1,500,000
Petree Pre-K	940,969	141,145	75,000
Pine Forest High	16,309,500	2,446,425	1,000,000
Pine Meadow Elementary	4,731,280	709,692	250,000
Pleasant Grove Elementary	3,420,640	513,096	150,000
Ransom Middle	11,023,200	1,653,480	50,000
Scenic Heights Elementary	4,902,720	735,408	100,000
Semmes Elementary & Media Center	4,065,964	665,762	350,000
Sherwood Elementary	4,671,517	701,606	1,500,000
Sidney W. Nelson Pre-K	3,658,052	548,708	300,000
George Stone Vocational (AKA) West FL High/Beggs Educational Center	29,918,122	4,792,718	6,000,000
Suter Elementary	2,800,320	405,019	400,000
Tate High	25,367,100	3,805,065	8,000,000

Location Name	Building Value	Contents Value	Est. Damages
Ernest Ward Middle & Pump House	6,337,530	950,630	100,000
Ernest Ward Bus Facility	no data	no data	no data
Warrington Elementary	3,821,680	573,252	5,000,000
Warrington Middle	7,102,620	1,065,393	1,000,000
Washington High	19,319,100	2,897,865	450,000
Wedgewood Middle	6,552,270	982,841	4,000,000
Weis Elementary	6,325,760	948,864	2,000,000
West Pensacola Elementary	4,524,400	678,660	350,000
Woodham High School	17,401,200	2,610,180	4,000,000
Workman Middle & ESE Suite	9,146,601	1,363,132	4,000,000
Yniestra Elementary	2,692,800	403,920	100,000
Administrative Office	2,359,474	353,921	150,000
Gibson School Federal Project	470,015	70,502	no data
Maintenance and Transportation	1,727,933	259,190	no data
Kirskey Warehouse	344,677	51,702	n/a
Administrative Bldg. (End-User)	208,440	31,266	400,000
Data Center	1,252,493	187,874	100,000
Central Warehouse	3,408,912	511,337	75,000
Transportation Facility	2,626,683	394,002	550,000
Roy L. Hyatt Environmental Studios	175,805	26,371	200,000
J.E. Hall Center-Support Svc. Facilities Planning	9,131,215	1,369,682	500,000
Storage - Pickens Book Dept.	1,645,050	246,758	50,000
ESEAL	1,263,731	189,560	100,000
Bratt Elementary	3,162,640	474,396	800,000
Occupied by Plumbers & Pipefitters	137,000	no data	no data
Occupied by USO	1,800,000	no data	200,000
Occupied by Property Appraiser	372,000	no data	no data
Same as above Building 2	135,000	no data	no data
Data Center-EDP Only	no data	no data	no data
Portables to be added effective 7/1/04	no data	no data	no data
Freezer Food-All Schools	no data	no data	1,500,000
Vehicles-Various:	no data	no data	no data
Trucks	no data	no data	100,000
Cars	no data	no data	no data
Buses	no data	no data	250,000
Total	$484,951,476	$72,300,474	$74,645,000

B-4.3.3 Fire Stations

Data: Fire Station Replacement Cost
Source: Escambia County
Usefulness: Provided replacement cost of fire stations, but does not break the replacement costs down by fire station, which would have been useful to update the HAZUS default inventory. So, this data are not useful by itself.
Limitations: Economic loss was not provided, which is necessary to determine the loss ratio.

Hurricane/County: Replacement cost data were provided for Hurricane Ivan for Escambia County.

Table 28. Fire Station Replacement Cost – Hurricane Ivan – Escambia County

Disaster	County	Total Replacement Cost of Fire Stations
Ivan	Escambia	$10,414,593

B-4.3.4 Police Stations

No observed data were received.

B-4.3.5 Shelters

Data: Shelter (schools) economic loss
Source: Escambia County School Board Risk Manager
Usefulness: Provided economic loss to shelter buildings.
Limitations: This was not a comprehensive list of all shelter damage as it only included schools that served as shelters.
Hurricane/County: Shelter economic loss was provided for Hurricane Ivan for Escambia County.

Table 29. Shelter Economic Loss – Hurricane Ivan – Escambia County

School Name	Cost of Reconstruction or Remediation
Blue Angels, (Shelter)	$400,000
Lipscomb (Shelter)	$150,000
Molino Park (Shelter)	$200,000
Bailey (Shelter)	$6,000,000
West Florida (Shelter)	$6,000,000
Totals	$12,750,000

B-4.3.6 County Structures

Data: County structures total replacement value
Source: Escambia County
Usefulness: Provides replacement cost of all county structures (except for parks and recreation), but does not break the replacement costs down by structure, which would have been useful to update the HAZUS default inventory. So, this data are not useful by itself.
Limitations: Economic loss was not provided, which is necessary to determine the loss ratio.
Hurricane/County: Replacement cost data were provided for Hurricane Ivan for Escambia County.

Table 30. County Structures Replacement Cost – Hurricane Ivan – Escambia County

Disaster	County	Total Replacement Cost of County Structures*
Ivan	Escambia	$175,648,373

* This does not include Parks and Recreation.

Data: Public Assistance Category E (Buildings) Summary Data
Source: FEMA Public Assistance Program
Usefulness: This data provided the total PA costs for buildings, prepared as Category E project worksheets (PWs).

Costs Covered By PA: Category E PWs cover losses not covered by insurance for the repair or restoration or publicly owned and maintained structures, equipment (e.g., electrical, mechanical, telecommunications), and contents (e.g., furniture, books, computers). Sometimes vegetative or construction and demolition (C&D) debris removal costs, or mold remediation costs are included in Category E PWs, and sometimes these costs are covered under Categories A or B PWs. As such, it is indiscernible as to whether the PA summary data includes these costs and to what degree (e.g., none, some, or all). This information could be identified by perusing each Category E PW, which is a very time consuming process.

As stated on FEMA.gov, FEMA may pay for upgrades that are required by certain codes and standards, such as roof bracing installed following a hurricane, and upgrades to meet standards regarding use by the disabled. For repairs, upgrades are limited to damaged elements only. If a structure must be replaced, the new facility must comply with all applicable codes and standards regardless of the level of FEMA funding. If a damaged building must be replaced, FEMA has the authority to pay for a building with the same capacity as the original structure. However, if the standard for space per occupant has changed since the original structure was built, FEMA may pay for an increase in size to comply with that standard while maintaining the same occupant capacity. A federal or state agency or statute must mandate the increase in space; it cannot be based only on design practices for an industry or profession.

Limitations: This data does not reflect costs that were covered by insurance or insurance deductibles, which can grossly underestimate building repair/replacement costs. This data does reflect economic loss to critical facilities, but includes costs for most public buildings. Sometimes building economic loss can be covered under other PA categories. For example temporary repairs/mold remediation could be covered under Category B – Emergency Protective Measures, or repairs could be covered under Category G, Parks, Recreation, and Other. This data includes both wind and flood loss, which does not allow for direct comparison, but is a useful benchmark.
Hurricanes/County(ies): All hurricanes and all counties involved in this study.

Table 31. Public Buildings Economic Loss – FEMA Public Assistance

County	Hurricane	Total Obligated
Charlotte	Charley	$25,156,724
DeSoto	Charley	$3,557,181
Hardee	Charley	$1,989,438
Lee	Charley	$4,546,783
Orange	Charley	$10,398,422
Osceola	Charley	$4,931,922
Polk	Charley	$2,946,422
Brevard	Frances	$5,324,603
Indian River	Frances	$3,192,071
Martin	Frances	$10,889,585
Okeechobee	Frances	$1,044,711
Palm Beach	Frances	$12,765,742
St. Lucie	Frances	$20,342,900
Escambia	Ivan	$38,761,211
Santa Rosa	Ivan	$4,797,993
Martin	Jeanne	$4,182,316
St. Lucie	Jeanne	$5,523,031
Escambia	Dennis	$2,741,666
Santa Rosa	Dennis	$2,181,305

Modeling Usefulness: FHA, Escambia County schools, and PA economic loss data could not be directly compared with the loss estimates for critical facilities, generated by the HAZUS-MH. Hurricane Wind Model. Shelter loss cannot be compared with HAZUS-MH estimates because there are no building characteristic data (e.g., building type) to run a user defined scenario.

B-4 Debris Generated

Debris quantities for both vegetative and construction and demolition debris types were requested from the FEMA Public Assistance Program and the counties included in this study. Some data were received from the jurisdictions.

Data: Debris quantities data for Santa Rosa County for Hurricane Dennis; and DeSoto and Hardee Counties, and Hardee cities for Hurricane Charley.
Source(s): Santa Rosa, DeSoto, and Hardee Counties
Usefulness: Provides vegetative debris estimates as of January 2006. This is an incremental quantification of debris, and this quantity will very likely increase in the future. This data set does not appear to be accurate for comparison with HAZUS-MH debris quantity estimates.
Limitations: Debris quantities are not separated by wind versus flood hazard. Does not include concrete and demolition debris estimates. Debris operations are still underway in some of these

counties; therefore, these estimates will not reflect the total quantity once all debris has been removed from eligible areas. It was difficult to determine the amount of debris generated for Orange County, as not all of the debris had been collected for Hurricane Charley when Hurricane Frances made landfall.
Hurricane(s)/County(ies): Debris quantity estimates were provided by Santa Rosa County for Hurricane Dennis, and DeSoto and Hardee Counties for Hurricane Charley.

Modeling Usefulness: Debris quantities provided by these counties were not compared with the debris quantity estimates generated by the HAZUS-MH Hurricane Wind Model, as the observed quantities appear to be incremental. Comparing this observed data with HAZUS-MH would not result in a fair comparison.

Table 32. Debris Estimates – Hurricanes Ivan, Dennis and Charley – Escambia, Santa Rosa, DeSoto, and Hardee Counties

County	Disaster	Total	C&D	Veg
Escambia	Ivan	NDR	NDR	NDR
Santa Rosa	Ivan	NDR	NDR	NDR
Escambia	Dennis	NDR	NDR	NDR
Santa Rosa	Dennis	17M TN	NDR	NDR
DeSoto	Charley	95K CY	NDR	95K CY
Hardee	Charley	11K CY	NDR	11K CY
Hardee Cities	Charley	165K CY	NDR	165K CY

NDR = No data received.

Note: It was difficult to determine the amount of debris generated for Orange County, as not all of the debris had been collected for Charley when Frances made landfall.

B-5 Injuries and Deaths

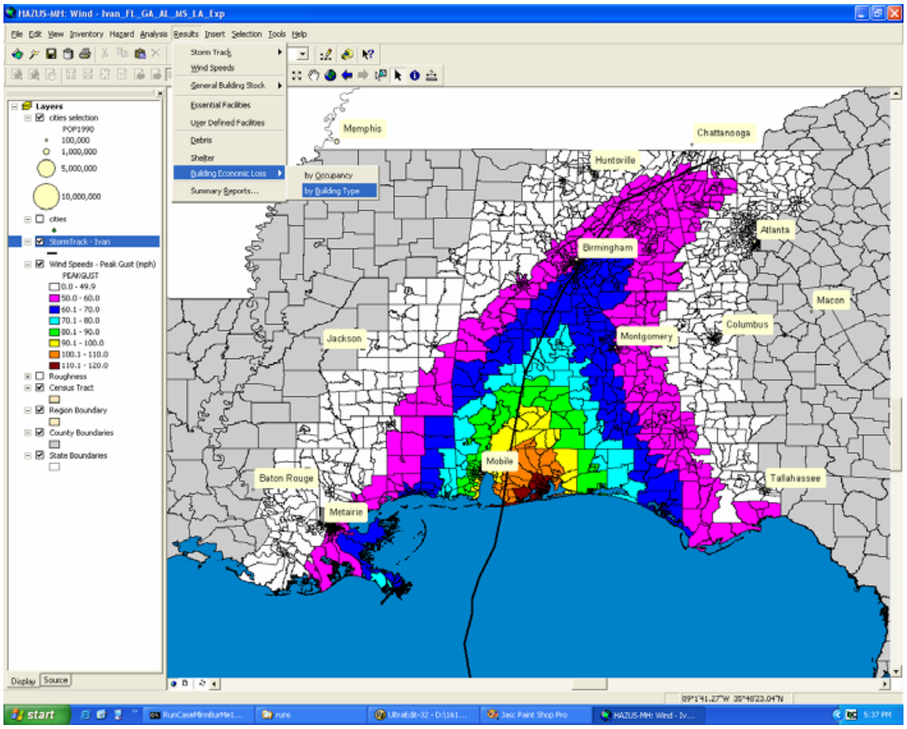
Table 33. County Structures Replacement Cost – Hurricane Charley – DeSoto County

Disaster	County	Injuries (Residential)	Deaths (Residential)
Charley	DeSoto	12	1

APPENDIX C
ARA Prior HAZUS Validation Report

DRAFT Final Report – November 22, 2004

HAZUS-MH Support for Hurricanes Charley, Frances, Ivan and Jeanne



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November 2004

ARA 16567

1. Introduction

In August and September of 2004, four hurricanes made landfall in Florida and Alabama (see Table 1). In response to a request for support from the Federal Emergency Management Agency (FEMA) Response Division, FEMA's Mitigation Division contracted with Applied Research Associates, Inc. (ARA) to provide near real-time loss estimation support using HAZUS-MH. ARA performed hurricane wind field modeling and hurricane wind loss estimates before, during, and after each of the four hurricanes. In addition, ABS Consulting performed coastal and inland flooding loss estimates for the first three hurricanes under a subcontract to ARA.

Table 1. Summary of 2004 Hurricanes Assessed Using HAZUS-MH

	Landfall Conditions			
Hurricane	Location	Date	NHC Saffir-Simpson Category	NHC 1-minute Sustained Wind Speed (mph)
Charley	Charlotte County, FL	8/13/04	4	145
Frances	Martin County, FL	9/5/04	2	105
Ivan	Baldwin County, AL	9/16/04	3	130
Jeanne	Martin County, FL	9/26/04	3	115

This report summarizes the analyses performed by ARA and ABS and lessons learned. The hurricane wind loss estimates performed by ARA are discussed in Section 2. The coastal and inland flooding loss estimates performed by ABS Consulting are discussed in Section 3.

2. HAZUS-MH Hurricane Wind Loss Estimates

This section summarizes the approach and lessons learned by ARA in developing hurricane storm tracks, wind fields, and wind loss estimates for Hurricanes Charley, Frances, Ivan, and Jeanne.

At the time of the analyses, two versions of the HAZUS-MH hurricane model were available:

1. HAZUS-MH version 1.0 (Build 31) – the first and only official FEMA release of HAZUS-MH to date.
2. HAZUS-MH Build 36A – a developmental version of HAZUS-MH Maintenance Release 1 (MR1). The completed version of HAZUS-MH MR1 is expected to be delivered to FEMA in December 2004.

With respect to near real-time estimates of hurricane wind losses, there are three key differences between Build 31 and Build 36A:

1. Build 36A includes an updated database of general building stock valuations. The baseline building valuations in the southeastern United States are approximately 18% lower than the valuations given in Build 31.[1] In this report, the baseline building valuation data in Builds 31 and 36A are referred to as the "old" and "new" valuations, respectively.
2. Build 36A includes a new capability to automatically download and import National Hurricane Center (NHC) Forecast/Advisories (F/A) from the HurrEvac ftp site. In Build 31 this information had to be manually input into the HAZUS hurricane scenario wizard.
3. Build 36A includes a new capability to accept radii to 50 knot or 34 knot winds at points on the storm track where the maximum wind speeds (either observed or forecast) are less than hurricane force (i.e., the radius to 64 knot winds is undefined). This improvement allows better modeling of damage and loss as the system intensifies from a tropical storm to a hurricane and as it weakens again after landfall.

Initially during Hurricane Charley, loss estimates were computed using both Build 31 and Build 36A and using both the old and the new building valuation data. Since Builds 31 and 36A produced essentially the same loss estimates given the same hurricane scenario definition and the same building inventory data, we decided to stop using Build 31 after Forecast/Advisory 17 (FA17) on August 13, 2004.[2] Furthermore, because the "new" valuation data provide a better represent the true replacement value of the building stock in Florida and its neighboring states, we also decided to stop using the old valuation data after FA19 on August 13, 2004.
In general, three categories of hurricane track models were evaluated for each storm:

1. **FA.** The Forecast/Advisory tracks directly model the information provided in the NHC Forecast/Advisory. These tracks were generated by mapping the FA parameters (i.e., central pressure, maximum sustained wind speed, and maximum radius to 64, 50, or 34 knot winds) to the fundamental HAZUS hurricane storm track parameters (i.e., central

[1] The changes in general building stock valuation between Build 31 and Build36A are the result of a more refined implementation of the RSMeans regional cost multipliers.

[2] See, for example, Hurricane Charley runs 3 and 5 in Table 3.

pressure, Holland profile parameter (B), and radius to maximum winds). This mapping was accomplished either by: (a) directly using the HurrEvac download and validation option in Build 36A, or (b) running the mapping algorithms off-line and manually inputting the resulting parameters into the HAZUS hurricane scenario wizard.

2. **ARA.** The ARA tracks use the NHC FA represent our best estimate of the hurricane intensity parameters based on data from the following sources: (1) NHC Forecast/Advisories, (2) H*Wind surface wind analysis output provided by Hurricane Research Division (HRD), and (3) surface level wind and pressure observations to determine the values of the profile parameter and radius to maximum winds.
3. **Hwind.** H*Wind tracks (actually peak 3-second wind gust estimates by census tract centroid) were provided to ARA as research products by the HRD. Two swaths were made available for each of the four storms: an initial estimate made near the time of landfall and a final estimate generally made within 2-4 days after landfall.

Each of the three track models used the actual or forecast position and time information from the latest official NHC Forecast/Advisory. In a few cases, minor adjustments to the overland track positions were made in the ARA tracks to provide a smoother track because the storm coordinates in the Forecast/Advisories are rounded to tenths of degrees.

The evolutions of HAZUS wind loss estimates for Hurricanes Charley, Frances, Ivan, and Jeanne are summarized in Tables 3-6.[3]

The following paragraphs highlight several observations and recommendations resulting from our analysis:

Loss Estimates Based on NHC Tracks

As with Hurricane Isabel in 2003, the general trend seen in Tables 3-6 is that the tracks based directly on NHC Forecast/Advisories tend to produce wind speeds and loss estimates that are significantly higher than the ARA or H*Wind tracks.

Recommendation: Although the Forecast/Advisory import capability provides a simple and efficient method for estimating losses for an approaching hurricane, emergency managers should not rely solely on the direct use of NHC Forecast/Advisories for response planning and mobilization decisions.

Loss Estimates Based on H*Wind Swaths

With the exception of Hurricane Charley, the final loss estimates based on H*Wind swaths provided by HRD are very comparable to the loss estimates from the ARA tracks. To a large degree, this is to be expected because the ARA tracks rely heavily on the same off-shore and coastal observations used by H*Wind. However, the models do tend to diverge inland from the coast, primarily because of differences in the two filling models. This difference was most pronounced in Hurricane Charley.

*Recommendation: FEMA should continue to encourage the NHC to operationalize the H*Wind surface wind analysis capability as a needed decision support tool for response planning.*

[3] Complete sets of summary reports (quick, global, economic, shelter, and debris) and peak gust wind swath maps have been archived for each run and can be furnished to FEMA in electronic format upon request.

Loss Estimates Based on ARA Tracks

Over the course of the four hurricanes, ARA developed a repeatable process for extracting the storm track information from multiple sources, mapping this information into the format required by the HAZUS hurricane model, generating peak gust estimates, and iterating once or twice, if necessary. This process was generally carried out during the first 30 minutes or so following the release of each Forecast/Advisory and the results were immediately transmitted to FEMA via e-mail or ftp. Once the track was finalized and sent to FEMA, loss calculations were performed by ARA using the HAZUS-MH tool. In general, copies of five summary reports (quick, global, economic, shelter, and debris) and a map of the peak gust wind swath were archived for each run. The remaining time between advisories was used to perform comparisons of modeled wind speed traces, wind direction traces, and atmospheric pressure traces to observations at as many locations a possible. This process was repeated through landfall. A final “best estimate” ARA track was generally available within 2-3 days of landfall.

Recommendation: The process for estimating the track parameters should be automated as much as practical in order to ensure timely, accurate, and cost-effective loss estimates for future hurricanes. However, we should not attempt to fully automate this process. Expert knowledge and judgment will always be necessary to identify and address errant observational data and other unusual situations.

Storm Track Time Step

Hurricane Charley was an intense, small, and fast-moving storm. The current time interval used in HAZUS-MH for evaluating peak gust wind speeds is once every 15 minutes. This time step was too large for Hurricane Charley and resulted in an underestimate of peak gust wind speeds in some census tracts. This was confirmed in Run #31, which was a re-analysis of Run #29 using a 3-minute time step instead of a 15-minute time step. The loss estimate for Run #31 increased by over 75%.

Recommendation: An algorithm should be developed and implemented in HAZUS-MH to allow a variable time step based on the forward translation speed, size, and intensity of the storm.

Set-up, Analysis, and Post-Processing Times

The time required to create the run the analysis and process the results after the release of a new Forecast/Advisory and the development of the new storm track parameters was generally on the order of 20-40 minutes (depending on the size of the study region) on a 3 GHz Pentium 4 with 1 GB of RAM. When the forecast track shifted outside the bounds of the previous study region, an additional time of 10-20 minutes was usually required to generate a new study region. Although these times were generally viewed to be acceptable, the following opportunities for reducing the turnaround time have been identified.

Recommendation: A tool should be added to the hurricane model to automatically generate a pre-selected set of reports and maps at the end of a scenario analysis. This task has been funded under the current HAZUS contract and will be implemented in MR2.
Recommendation: A tool should be added to the hurricane model to automatically generate the list of counties needed to encompasses a user-specified storm track. There should be an option to review this information and pass it directly to the HAZUS shell to create a new study region.

Loss Estimates

Initial estimates of industry-wide insured losses have been released by ISO for each of the four hurricanes. The ISO estimates cannot be directly compared to the estimates produced by HAZUS-MH because the ISO estimates include losses for automobiles and boats, appurtenant structure losses, and additional living expenses, yet do not include deductibles or uninsured properties. In spite of these differences, insured loss estimates do provide a useful benchmark for the HAZUS-MH wind loss estimates.

Table 2. Summary of Initial ISO Insured Loss Estimates

Hurricane	Landfall Date	ISO Press Release Date	Initial ISO Insured Loss Estimate ($B)	HAZUS-MH Estimate Based on Final ARA Tracks from Tables 3-6 ($B)	States Included
Charley	8/13/04	8/25/04	6.7	7.1	FL
Frances	9/5/04	9/23/04	4.1	1.8	FL
Ivan	9/16/04	10/14/04	5.3	1.6	FL, AL, GA
Jeanne	9/26/04	10/26/04	2.8	2.8	FL
2004 Total	--	--	18.9	13.3	--

Also shown in Table 2 are the HAZUS-MH loss estimates based on the final ARA storm tracks. It can be seen that the ISO and HAZUS-MH estimates for Hurricanes Charley and Jeanne are very similar, but there are significant differences in the estimates for Hurricanes Frances and Ivan. Further investigation is required to better understand these differences.[4]

Recommendation: A follow-on task should be planned to perform a more detailed analysis of the HAZUS-MH loss estimates relative to the final ISO loss estimates for all four hurricanes.

[4] Upon further review of the Hurricane Frances results, it now appears that the final ARA track model developed for Run #31 may have given too much weight to the surface level wind speeds measured at the Florida Coastal Monitoring Program towers. Therefore, the previous ARA best track estimate developed for Run #29 may be a better representation of the actual storm track than the track that was subsequently developed for Run #31. The resulting loss estimate from Run #29 was $3.2B. More recent runs for Hurricane Frances have produced results between $3.0B and $5.8B, through updates in wind model parameters brought about through correction of the FCMP tower wind speeds for terrain effects. Major updates to the Ivan estimates due to hurricane modeling issues are not expected

Table 3. Wind Loss Estimates for Hurricane Charley

Run	Date	Build	Valuation	Study Region	Scenario	Advisory	Track	Peak Gust (mph)	Loss ($B)	Displaced Households (1,000's)
1	13-Aug	31	Old	Charley_FL31Cnty_B31_OldVal	Charley_B31_16_90pct_PJV	16	ARA	119	5.0	9.9
2	13-Aug	36A	New	Charley_FL31Cnty_B36A_NewVal	Charley_2004_160	16	FA	126	12.0	33.8
3	13-Aug	31	Old	Charley_FL31Cnty_B31_OldVal	Charley_FLCnty31_B31_OldVal_CliffFA16	16	FA	122	11.4	25.5
4	13-Aug	36A	Old	Florida26	Charley_Cliff_FA16_Try2	16	FA	122	11.3	26.6
5	13-Aug	36A	Old	Florida31	Charley_Cliff_FA16_Try2	16	FA	122	11.4	26.6
6	14-Aug	31	Old	Charley_16	Charley_16	16	ARA100	127	13.9	33.3
7	13-Aug	36A	Old	Florida26	Charley_2004_160	16	FA	126	15.7	37.4
8	13-Aug	36A	Old	Florida31	Charley_2004_160	16	FA	126	15.7	37.4
9	13-Aug	36A	New	Charley_FL31Cnty_B36A_NewVal	C_FL31Cnty_B36A_New_AF17_90_PJV	17	ARA	118	4.3	8.5
10	13-Aug	36A	Old	Florida31	Charley_2004_170	17	FA	134	32.1	89.4
11	13-Aug	36A	New	Charley_FL31Cnty_B36A_NewVal	C_PJV_Adv17	17	ARA	131	24.6	73.5
12	13-Aug	31	Old	Charley_FL31Cnty_B31_OldVal	C_FL31Cnty_B31_old_AF17Cliff	17	FA	125	27.5	64.4
13	13-Aug	36A	New	Charley_FL28Cnty_B36A_NewVal	Charley_2004_180	18	FA	160	17.1	68.1
14	13-Aug	36A	New	Charley_FL28Cnty_B36A_NewVal	Adv18_Reduced_B	18	ARA	142	9.7	28.6
15	13-Aug	36A	New	Charley_FL28Cnty_B36A_NewVal	Charley_2004_190	19	FA	163	10.9	44.1
16	13-Aug	36A	New	Charley_FL28Cnty_B36A_NewVal	Charley_AF19_Reduced_Rmax	19	ARA	147	7.9	24.9
17	13-Aug	36A	New	Charley_FL31Cnty_B31_NewVal	Charley_2004_180	18?	FA	134	24.4	79.2
18	13-Aug	36A	Old	Florida31	Charley_FA17_Cliff	17	FA	125	27.5	66.2
19	13-Aug	36A	Old	Florida28	Charley_2004_180	18	FA	160	21.1	72.0
20	13-Aug	36A	New	Charley_FL26Cnty	Charley_2004_160	16	FA	126	12.0	33.8
21	13-Aug	36A	Old	Florida26	Charley_2004_160	16	FA	126	15.7	37.4
22	13-Aug	36A	Old	Florida26	HWIND_FA17	17	Hwind	136	8.4	21.2
26	13-Aug	36A	Old	Florida28	Charley FA19 Cliff	19	FA	167	16.6	58.5
27	14-Aug	36A	New	Charley_FL28_B36A_NewVal	Charley_2004_211	21	FA	161	5.2	20.0
28	14-Aug	36A	New	Charley_FL28_B36A_NewVal	Charley_2004_211Corrected	21	FA	161	5.2	20.0
29	14-Aug	36A	New	Charley_FL28_B36A_NewVal	FA22_ARA4	22	ARA	146	6.4	18.0
30	14-Aug	36A	New	Charley_FL28_B36A_NewVal	hwind_5pmSat_charley	22	Hwind	159	3.2	12.3
31	23-Aug	36A	New	Charley_FL28_B36A_NewVal	FA22_ARA4	22	ARA	146	11.4	34.6
32	27-Aug	36A	New	Charley_FL28_B36A_NewVal	hwind_charley_27aug04	22	Hwind	147	2.7	7.7
33	30-Aug	36A	New	Charley_B36A_NewVal_FL28Cnty	Charley_ARA_30Aug2004	22	ARA	150	7.1	22.3

Landfall at ~5pm EDT (2100Z) on 8/13 (same time as FA19)

Advisory	FA	ARA	Hwind
FA18	17.1	9.7	
FA19	10.9	7.9	
FA21	5.2		
FA22		6.4	3.2
FA22-3min		11.4	
Final		7.1	2.7

Hurricane Charley Loss Estimates

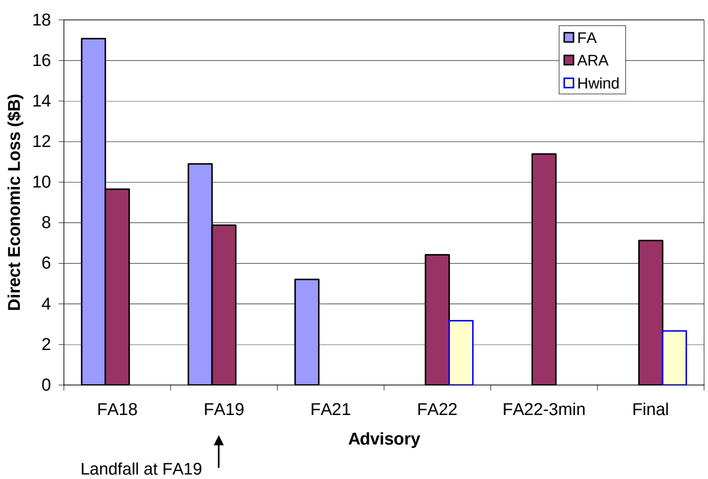
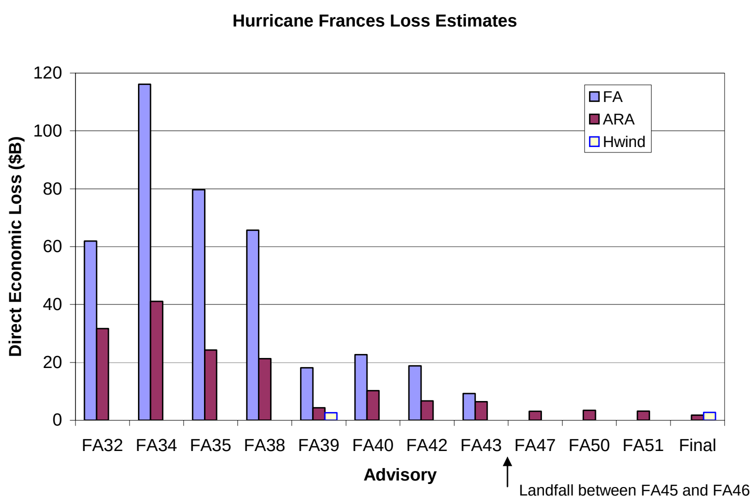


Table 4. Wind Loss Estimates for Hurricane Frances

Run	Date	Build	Valuation	Study Region	Scenario	Advisory	Track	Peak Gust (mph)	Loss ($B)	Displaced Households (1,000's)
1	1-Sep	36A	New	Frances_B36A_NewData_15WF_FL	Frances_PJV_20040901_1718_32_Alt	32	ARA	147	31.7	114.9
2	1-Sep	36A	New	Frances_B36A_NewData_15WF_FL	Frances_PJV_20040901_1718_32_FA	32	FA	164	61.9	273.1
3	2-Sep	36A	New	Frances_B36A_NewData_15WF_FL	Frances_PJV_2004_340	34	FA	169	116.1	501.0
4	2-Sep	36A	New	Frances_B36A_NewData_15WF_FL	Frances_PJV_34_Alt	34	ARA	151	41.1	160.6
5	2-Sep	36A	New	Frances_B36A_NewVal_20040902_1004_49Cn	Frances_PJV_Adv35Alt	35	ARA	148	24.3	89.4
6	2-Sep	36A	New	Frances_B36A_NewVal_20040902_1004_49Cn	Frances_PJV_Adv35	35	FA	167	78.1	340.7
7	2-Sep	36A	New	Frances_B36A_NewVal_20040902_1004_49Cn	Frances_2004_350	35	FA	170	79.7	339.9
8	3-Sep	36A	New	Frances_B36A_NewVal_20040902_1004_49Cn	Frances_2004_380	38	FA	159	65.7	251.7
9	3-Sep	36A	New	Frances_B36A_NewVal_20040902_1004_49Cn	Frances_PJV_38	38	FA	162	69.7	287.4
10	3-Sep	36A	New	Frances_B36A_NewVal_20040902_1004_49Cn	Frances_PJV_38_ALT	38	ARA	148	21.3	79.4
11	3-Sep	36A	New	Frances_B36A_NewVal_20040902_1004_49Cn	Frances_PJV_39_ALT	39	ARA	120	4.3	8.6
12	3-Sep	36A	New	Frances_B36A_NewVal_20040902_1004_49Cn	Frances_Hurrevac_39	39	FA	136	18.1	52.2
13	3-Sep	36A	New	Frances_B36A_NewVal_20040902_1004_49Cn	Frances_PJV_39	39	FA	137	16.8	49.8
14	3-Sep	36A	New	Frances_B36A_NewVal_20040902_1004_49Cn	FrancesHwind39	39	Hwind	114	2.6	4.4
15	3-Sep	36A	New	Frances_B36A_NewVal_20040902_1004_49Cn	Frances_2004_400	40	FA	142	22.7	80.7
16	3-Sep	36A	New	Frances_B36A_NewVal_20040902_1004_49Cn	Frances_PJV_40	40	FA	145	29.5	102.9
17	3-Sep	36A	New	Frances_B36A_NewVal_20040902_1004_49Cn	Frances_PJV_40_ALT	40	ARA	129	10.2	25.0
18	4-Sep	36A	New	Frances_B36A_NewVal_20040902_1004_49Cn	Frances_PJV_42_ALT	42	ARA	118	6.7	13.2
19	4-Sep	36A	New	Frances_B36A_NewVal_20040902_1004_49Cn	Frances_PJV_42	42	FA	131	17.2	45.7
20	4-Sep	36A	New	Frances_B36A_NewVal_20040902_1004_49Cn	Frances_2004_421	42	FA	125	18.8	46.0
21	4-Sep	36A	New	Frances_B36A_NewVal_20040904_57Cnty	Frances_PJV_43_Alt	43	ARA	117	6.4	12.3
22	4-Sep	36A	New	Frances_B36A_NewVal_20040904_57Cnty	Frances_2004_430	43	FA	125	9.2	21.4
26	4-Sep	36A	New	Frances_B36A_NewVal_20040904_57Cnty	Frances_PJV_43	43	FA	131	17.8	48.7
27	5-Sep	36A	New	Frances_B36A_NewVal_20040904_57Cnty	Frances_PJV_47_Alt	47	ARA	115	3.1	5.9
28	6-Sep	36A	New	Frances_B36A_NewVal_20040902_1004_49Cn	Frances_PJV_50_Alt2	50	ARA	115	3.4	6.1
29	6-Sep	36A	New	Frances_B36A_NewVal_FL_Final	Frances_PJV_51_Alt	51	ARA	115	3.2	6.0
30	10-Sep	36A	New	Frances_B36A_NewVal_FL_Final	Frances_HWIND_091004	Final	Hwind	111	2.7	5.6
31	28-Sep	36A	New	Frances_B36A_NewVal_20040904_57Cnty	Frances_28Sep04_ARA	Final	ARA	106	1.8	2.3

Landfall at ~1am EDT (0500Z) on 9/5 (between FA45 at 0300Z and FA46 at 0900Z)

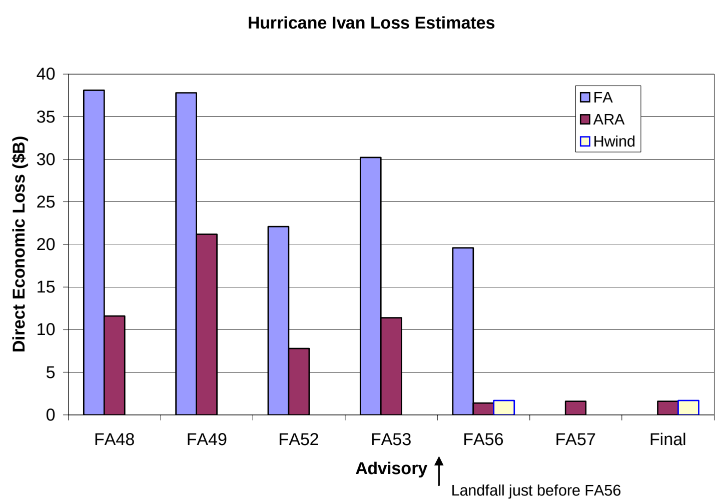


Advisory	FA	ARA	Hwind
FA32	61.9	31.7	
FA34	116.1	41.1	
FA35	79.7	24.3	
FA38	65.7	21.3	
FA39	18.1	4.3	2.6
FA40	22.7	10.2	
FA42	18.8	6.7	
FA43	9.2	6.4	
FA47		3.1	
FA50		3.4	
FA51		3.2	
Final		1.8	2.7

Table 5. Wind Loss Estimates for Hurricane Ivan

Run	Date	Build	Valuation	Study Region	Scenario	Advisory	Track	Peak Gust (mph)	Loss ($B)	Displaced Households (1,000's)
1	14-Sep	36A	New	Ivan_FL_GA_AL_MS_LA_Expanded	Ivan_2004_480	48	FA	165	48.6	227.8
2	14-Sep	36A	New	Ivan_FL_GA_AL_MS_LA_Expanded	Ivan_PJV_Adv48	48	FA	164	38.1	174.6
3	14-Sep	36A	New	Ivan_FL_GA_AL_MS_LA	Ivan_PJV_Adv48_Alt	48	ARA	146	11.6	40.2
4	14-Sep	36A	New	Ivan_FL_GA_AL_MS_LA_Expanded	Ivan_PJV_Adv49	49	FA	159	37.8	184.3
5	14-Sep	36A	New	Ivan_FL_GA_AL_MS_LA	Ivan_PJV_Adv49_Alt	49	ARA	149	21.2	97.8
6	15-Sep	36A	New	Ivan_FL_GA_AL_MS_LA_Expanded	Ivan_2004_520	52	FA	147	13.6	52.6
7	15-Sep	36A	New	Ivan_FL_GA_AL_MS_LA_Expanded	Ivan_PJV_Adv52	52	FA	156	22.1	98.3
8	15-Sep	36A	New	Ivan_FL_GA_AL_MS_LA	Ivan_PJV_Adv52_Adj	52	ARA	137	7.8	25.1
9	15-Sep	36A	New	Ivan_FL_GA_AL_MS_LA_Expanded	Ivan_PJV_Adv53	53	FA	152	30.2	131.7
10	15-Sep	36A	New	Ivan_FL_GA_AL_MS_LA	Ivan_PJV_Adv53_Alt	53	ARA	142	11.4	42.9
11	16-Sep	36A	New	Ivan_FL_GA_AL_MS_LA_Expanded	Ivan_2004_560	56	FA	149	19.6	72.5
12	16-Sep	36A	New	Ivan_FL_GA_AL_MS_LA	Ivan_PJV_Adv56_Adj	56	ARA	118	1.4	2.0
13	16-Sep	36A	New	Ivan_FL_GA_AL_MS_LA_Expanded	Ivan_HWND_091604_1107am	56	Hwind	121	1.7	2.9
14	16-Sep	36A	New	Ivan_FL_GA_AL_MS_LA	Ivan_PJV_Adv57_Adj	57	ARA	118	1.6	2.6
15	17-Sep	36A	New	Ivan_FL_GA_AL_MS_LA	Ivan_PJV_Adv60_Adj	59	ARA	118	1.6	2.6
16	17-Sep	36A	New	Ivan_FL_GA_AL_MS_LA_Expanded	Ivan_HWND_091704_1352	59	Hwind	121	1.7	2.9

Landfall at ~2am CDT (0700Z) on 9/16 (between FA55 at 0300Z and FA56 at 0900Z)

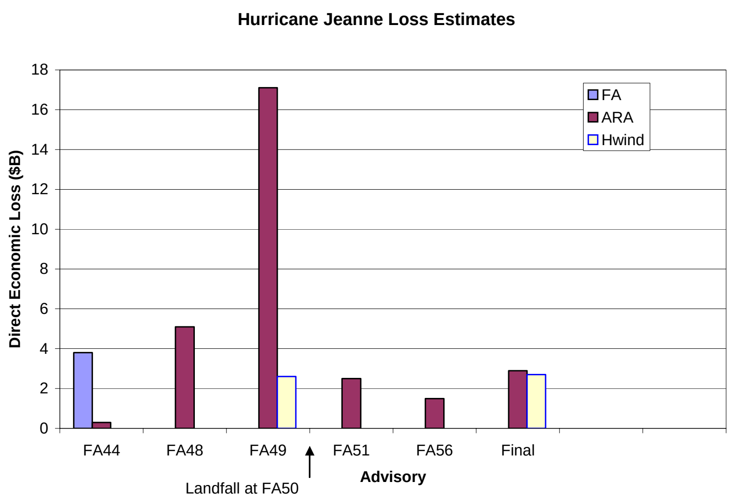


Advisory	FA	ARA	Hwind
FA48	38.1	11.6	
FA49	37.8	21.2	
FA52	22.1	7.8	
FA53	30.2	11.4	
FA56	19.6	1.4	1.7
FA57		1.6	
Final		1.6	1.7

Table 6. Wind Loss Estimates for Hurricane Jeanne

Run	Date	Build	Valuation	Study Region	Scenario	Advisory	Track	Peak Gust (mph)	Loss ($B)	Displaced Households (1,000's)
1	24-Sep	36A	New	Jeanne_FL_NoPanhandle	Jeanne_PJV_adv44_Adj	44	ARA	85	0.3	0.1
2	24-Sep	36A	New	Jeanne_FL_NoPanhandle	Jeanne_PJV_adv48	44	ARA	115	3.8	7.0
3	25-Sep	36A	New	Jeanne48	Jeanne_48_ARA	48	ARA*	130	12.6	33.5
4	25-Sep	36A	New	Jeanne48	Jeanne_48_ARA_NoIntensification	48	ARA	117	5.1	9.6
5	25-Sep	36A	New	Jeanne48	Jeanne_49_HRD_Based	49	ARA*	140	25.1	77.7
6	25-Sep	36A	New	Jeanne48	Jeanne_49_ARA	49	ARA	134	17.1	46.3
7	25-Sep	36A	New	Jeanne48	Jeanne_49_Hwind	49	Hwind	123	2.6	5.1
8	26-Sep	36A	New	Jeanne_51	Jeanne_51_ARA2	51	ARA	110	2.5	4.1
9	27-Sep	36A	New	Jeanne_51	Jeanne_52_Hwind	52	Hwind	105	0.8	0.9
10	27-Sep	36A	New	Jeanne_51	Jeanne_56a_ARA	56	ARA	105	1.5	1.9
11	28-Sep	36A	New	Jeanne_51	Jeanne_56a_ARA2	56	ARA	113	2.9	5.1
12	28-Sep	36A	New	Jeanne_51	Jeanne_28Sep04_Hwind	56	Hwind	114	2.7	4.2

Landfall just after 11pm EDT on 9/25 (i.e., just after FA50 at 0300Z on 9/26)



Advisory	FA	ARA	Hwind
FA44	3.8	0.3	
FA48		5.1	
FA49		17.1	2.6
FA51		2.5	
FA56		1.5	
Final		2.9	2.7

3. HAZUS-MH Flood Loss Estimates

3.1 Hurricane Charley

This section documents the work performed by ABS Consulting using the HAZUS-MH floodmodel for Hurricane Charley. The work began on August 13, the day Charley made landfall on the western side of Florida. HAZUS flood model study regions were constructed for the coastal counties predicted to be in Charley's path.

Inputs

Using the results of SLOSH runs posted on the National Hurricane Center (NHC) website, the coastal flood hazard was computed based on the SLOSH storm surge elevations. By the time the hurricane made landfall, the actual storm track was south of the predicted track. As such, additional flood model study regions were built, and the coastal hazard was recomputed based on the most recent SLOSH results. The DEM for each county was downloaded from the National Elevation Dataset (NED) on the USGS website. Following are pertinent details regarding the flood model runs:

Charley hurricane advisory	18
HAZUS build number	31
HAZUS DVD data version	Build 36
Counties analyzed	Florida: Charlotte, Collier, Lee, Monroe, Sarasota

Approach/Methodology

We ran each county with the storm surge elevation that we received from the NHC. The projected surge elevations showed little variation across each county, so a uniform surge elevation was applied to each county. In HAZUS, only General Building Stock (Damage and Loss) and Essential Facilities analyses were run in the interest of time.

Results

The projected surge elevations and flood discharges for each county is shown in the table below. The resulting loss estimates are also shown below.

County	Surge Elevation (ft)	Building Loss ($)	Processing Time	
			Hazard	Analysis
Charlotte	4.5	471,520	3 min	9 hours
Collier	8	6,318,000	3 min	12 hours
Lee	13.5	48,472,000	6 min	18 hours
Monroe	5.5	2,537,000	2 hr 10 min	9 hours
Sarasota	3	704,000	10 min	3 hours

Lessons Learned

The exercise of applying the HAZUS flood model for coastal flooding has brought forth some lessons that can be applied to future hurricanes:

- **Study Region Size –** *The number of census blocks impacted over a county due to a large coastal flood can be quite high. As such, it's recommended to build single county study regions for coastal analysis.*
- **Storm Track –** *In the final hurricane advisories prior to landfall, the storm track changed rather significantly. Due to this, the affected counties and associated storm*

surges can also change in a short period of time. Hence, it is recommended to delay running of the coastal model until the true storm track is known.

- **Validation –** *For future hurricanes, it would be useful to acquire measured storm surge elevations and apply them to the coastal model, in order to help validate the accuracy of the model results. At this time it is not clear if the surge elevations computed in the final SLOSH runs mimicked actual surge elevations.*
- **Computer Requirements –** *At this time, coastal analysis in the HAZUS flood model is much more computer-intensive than riverine analysis. It is important to use the most powerful machine available in terms of processor speed and RAM.*
- **Relative Impact –** *For Hurricanes Charley, Frances, and Ivan, hurricane winds and riverine flooding had a greater impact on damage than coastal storm surge.*

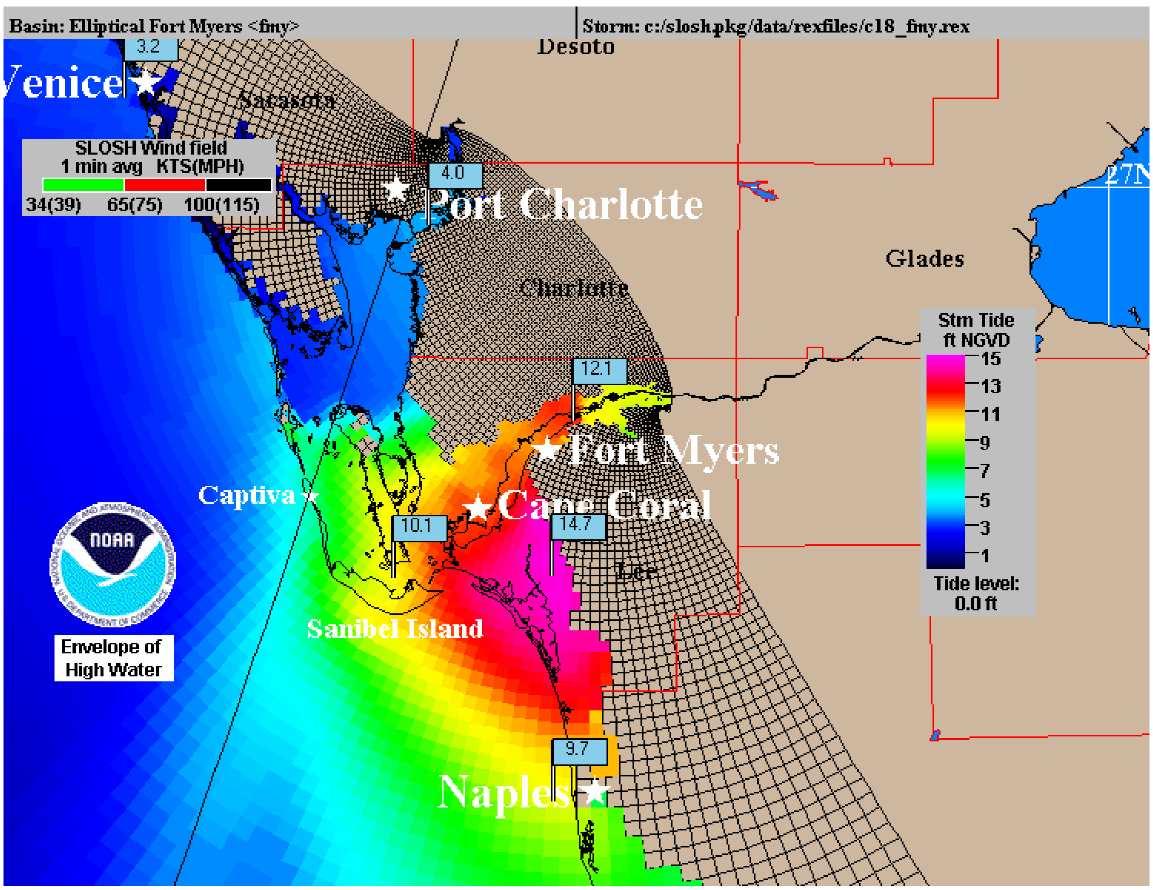


Figure 1. NHC Storm Surge Map

3.2 Hurricane Frances

This section documents the work performed by ABS Consulting using the HAZUS-MH flood model for Hurricane Frances. The work began with a flood analysis of a swath of counties in Central Florida. As the storm moved west, another group of counties in and around the Florida panhandle were run through the flood model. Later the storm moved north and stalled in the region along the North Carolina – Tennessee border. A third group of counties were run for this area. This was the first effort to use the HAZUS Flood Model over a large area in a real-time

setting. In an effort to reduce processing times, these first three groups of study regions were analyzed for dollar exposure, not for damage and loss.
Later in the process, discharge values for selected streams were obtained by FEMA for two counties in central Florida, and a few areas in western North Carolina. Study regions for these areas were also constructed. For these study regions, dollar losses were computed.

Inputs
A map of the area to be analyzed was posted on the National Hurricane Center (NHC) website and is attached at the end of this report. John Ingargiola, of the Department of Homeland Security, provided a document with the peak discharges from gages of the affected area. The DEM for each county was downloaded from the National Elevation Dataset (NED) on the USGS website. Following are pertinent details regarding the flood model runs:

Frances hurricane advisory	50
HAZUS build number	37+ (Build 37 with updated flood software)
HAZUS DVD data version	Build 36
Counties analyzed	Florida: Hillsborough, Pasco SR1-Brevard, Indian River, St. Lucie (all in FL) SR2-Seminole, Orange, Osceola, Okeechobee (all in FL) SR3-Polk, Hardee, DeSoto, Highlands (all in FL) SR4-Pinellas, Hillsborough, Manatee, Sarasota (all in FL) SR5-Hernando, Pasco, Sumter, Lake (all in FL) SR6-Calhoun, Gulf, Liberty, Franklin (all in FL) SR7-Gadsen, Leon, Wakulla (all in FL) SR8-Walton, Holmes, Washington, Bay (all in FL) SR9-Geneva, AL, Houston, AL, Jackson, FL SR10-Early, Miller, Seminole, Decatur (all in GA) SR11-Graham, Swain, Jackson, Haywood (all in NC) SR12-Blount, Sevier, Jefferson, Cocke (all in TN) SR13-Hambler, Greene, Washington, Unicoi (all in TN) SR14-Madison, Buncombe, Yancey, McDowell (all in NC) SR15-Mitchell, Avery, Burke, Caldwell (all in NC) Florida: Manatee, Pasco, Hillsborough North Carolina: Buncombe, Madison, Transylvania, Gaston, Stanly

Approach/Methodology
Given the relatively low storm surges predicted for Hurricane Frances, the focus was on riverine flooding. The 15 study regions in Florida were analyzed for dollar exposure, not for damage and loss. The selection of specific counties to be analyzed was based on the flood outlook from NOAA's Southeast River Forecast Center, obtained through a link on the FEMA website. Areas identified on the map as "Significant River Flooding Likely" were included in flood study regions. The maps are shown as Figures 2 and 3.
Due to the large amount of inventory data and cell size of the depth grids, the flood model is ideally run with one county per region. To cut down analysis time, river networks were defined based on a 25-square mile drainage area, resulting in fairly large streams. Peak rainfall estimates were received but those data were difficult to apply to HAZUS because the flood model does not perform rainfall-runoff modeling.
The flood hazard was based on current/peak discharges at gages provided by FEMA. The gages had to be located in each study region, in which the information was provided or was

found on NOAA's website. In HAZUS, the hydrologic analysis was skipped because the discharges were already provided. The discharges were distributed downstream of each respective gage.

For study regions in which damage analyses were performed, the results include the General Building Stock (Damage and Loss) and Essential Facilities. The results also contain exposure estimates for each of the analysis areas, in terms of full replacement costs and depreciated costs for residential and government occupancies, along with population totals. The totals include any census blocks that intersect the floodplain boundary. Losses were only computed for the Florida and North Carolina single county regions.

Results

The projected flood discharges for each county are shown in the following table. The resulting loss estimates are not available due to problems in the analysis portion of the program.

County	Flood Discharge	River Name	Processing Time	
			Hazard	Analysis
SR1	100-yr	Entire SR		NA
SR2	100-yr	Entire SR	9 hrs	NA
SR3	100-yr	Entire SR		NA
SR4	100-yr	Entire SR	6.5 hrs	NA
SR5	100-yr	Entire SR	9 hrs	NA
SR6	100-yr	Entire SR	6.5 hrs	NA
SR7	100-yr	Entire SR	4 hrs	NA
SR8	100-yr	Entire SR		NA
SR9	100-yr	Entire SR		NA
SR10	100-yr	Entire SR	6 hrs	NA
SR11	100-yr	Entire SR	6.5 hrs	NA
SR12	100-yr	Entire SR	10 hrs	NA
SR13	100-yr	Entire SR		NA
SR14	100-yr	Entire SR		NA
SR15	100-yr	Entire SR	7.5 hrs	NA
Hillsborough, FL	5,000, 7,000, 11,500 cfs	Hillsborough, Alafia, & Little Manatee	4 hrs	1.5 hrs
Pasco, FL	3,000 cfs	Anclote	4 hrs	30 min
Buncombe, NC	50,000 cfs	French Broad	1.5 hrs	20min
Madison, NC	43,000 and 64,500 cfs	French Broad	1.5 hrs	20min
Transylvania, NC	22,000 cfs	French Broad	1 hr	25 min
Gaston, NC	10,200 cfs	South Fork Catawba	1 hr	20 min
Stanly, NC	52,500 cfs	Rocky	12 min	20 min

Lessons Learned

Through this analysis, several lessons were learned that can be applied to the use of the HAZUS flood model during future hurricanes:

- **Computers –** *There is a 4-county limit on the size of flood model study regions due to the system limits on the size of study region databases. As such, in order to analyze a large area, it is necessary to build multiple study regions. With time crunches typical with emergency response, one of the most important factors in the analysis for these study regions was the availability of multiple computers, which allowed for simultaneous analysis.*
- **Study Region Creation –** *Based on the river to be analyzed, care should be exercised during study region creation. If a river to be analyzed forms a border between counties, the study region should include the counties on both sides of the river. Otherwise, the synthetic stream network may not be continuous.*
- **Processing Time –** *The computers used for this exercise had 3.2 GHz processors, with 2 GB of RAM, and tens of gigabytes of hard drive space. For HAZUS flood analysis, the processor speed and RAM are very important. The total processing times are listed in the tables above.*

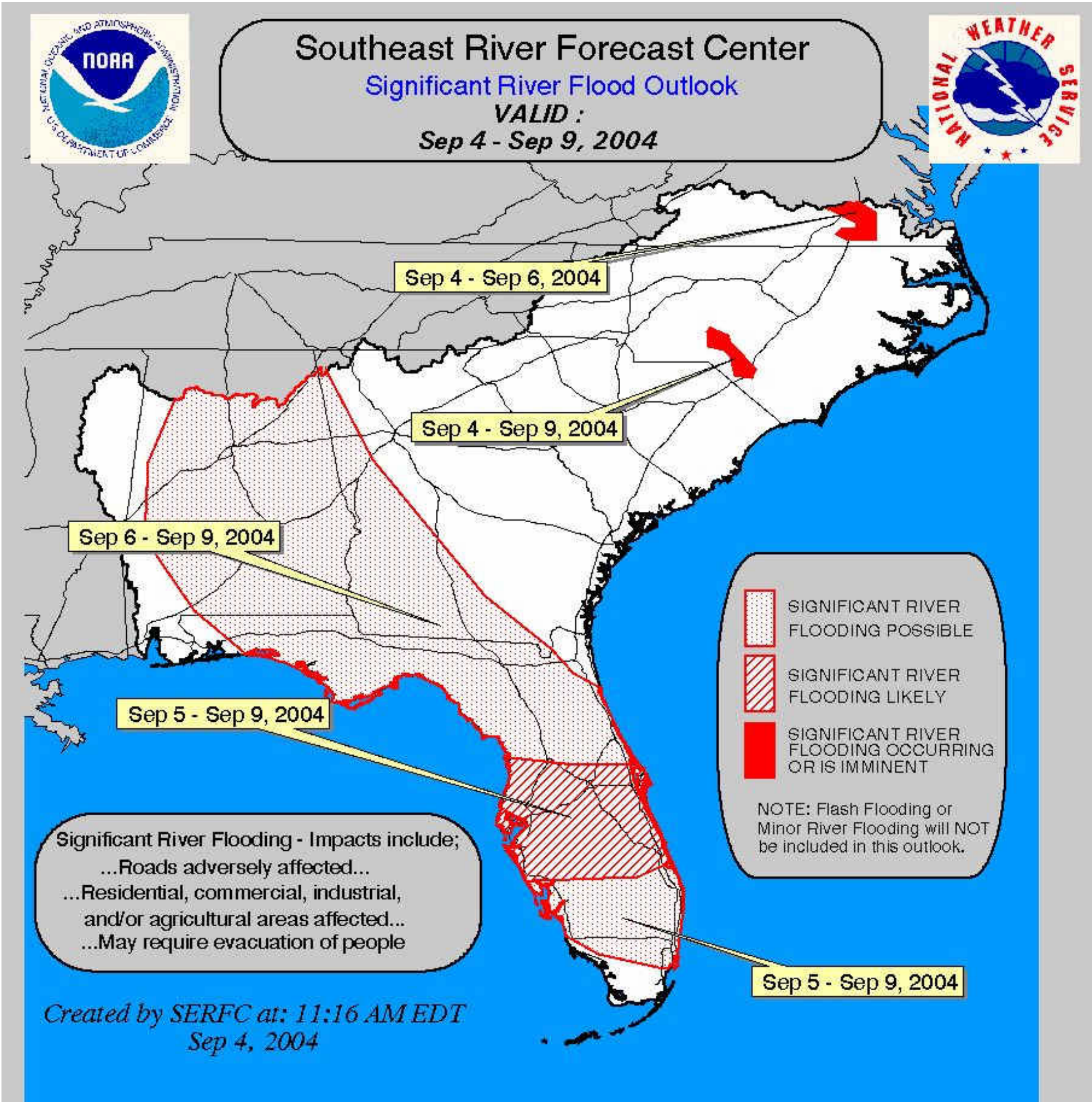


Figure 2. Florida Forecasted Affected Areas

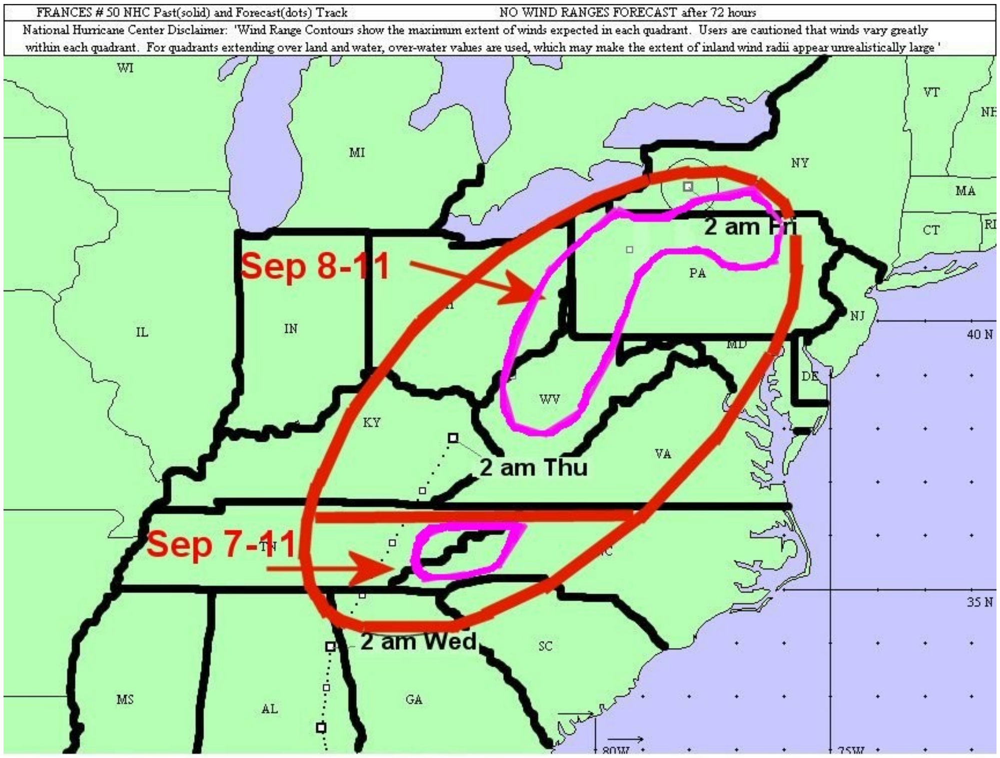


Figure 4. North Carolina Forecasted Affected Areas

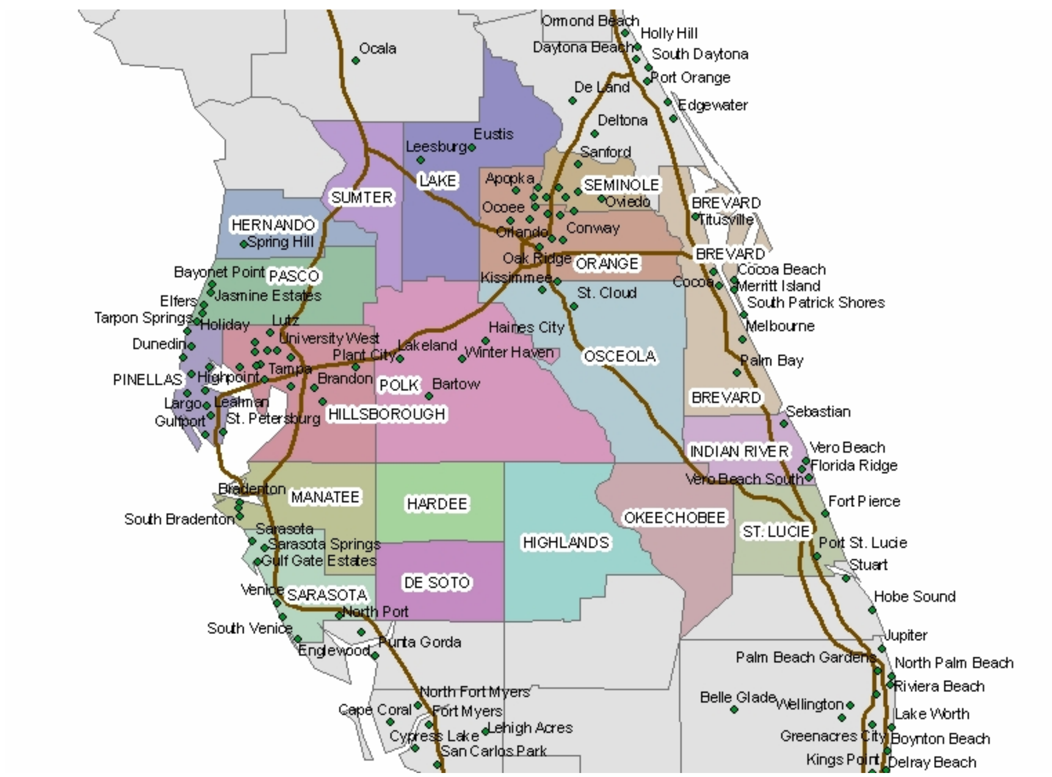


Figure 5. Central Florida Counties Analyzed

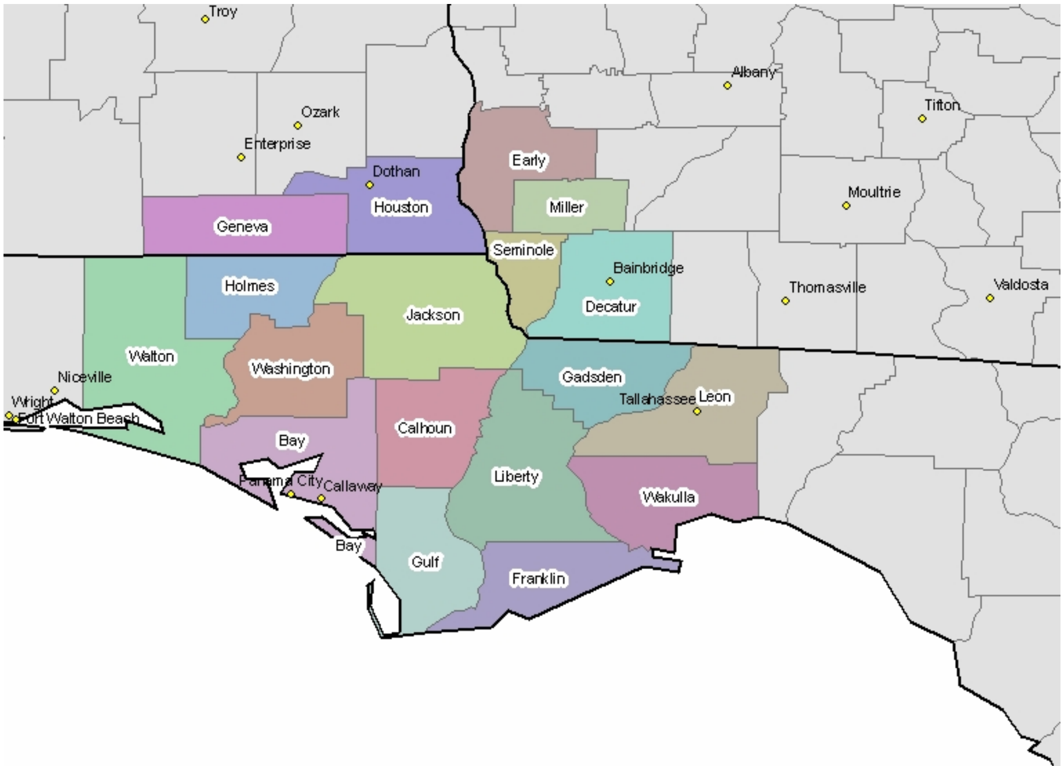


Figure 6. Florida Panhandle Counties Analyzed

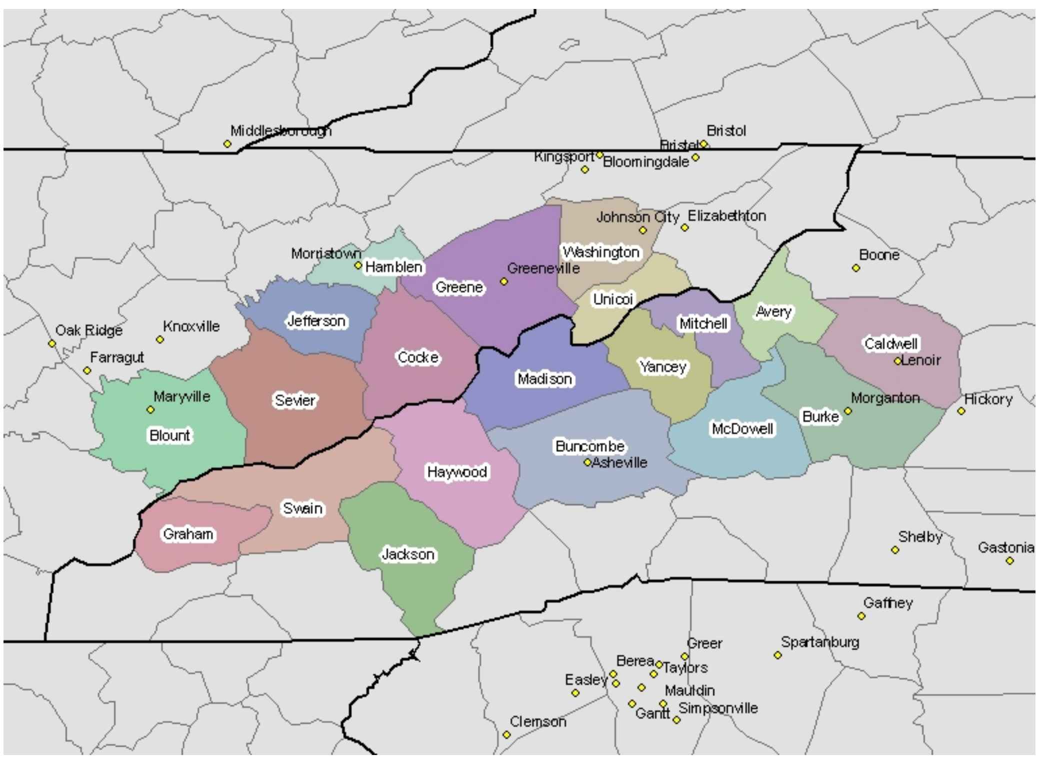


Figure 7. North Carolina – Tennessee Border Counties Analyzed

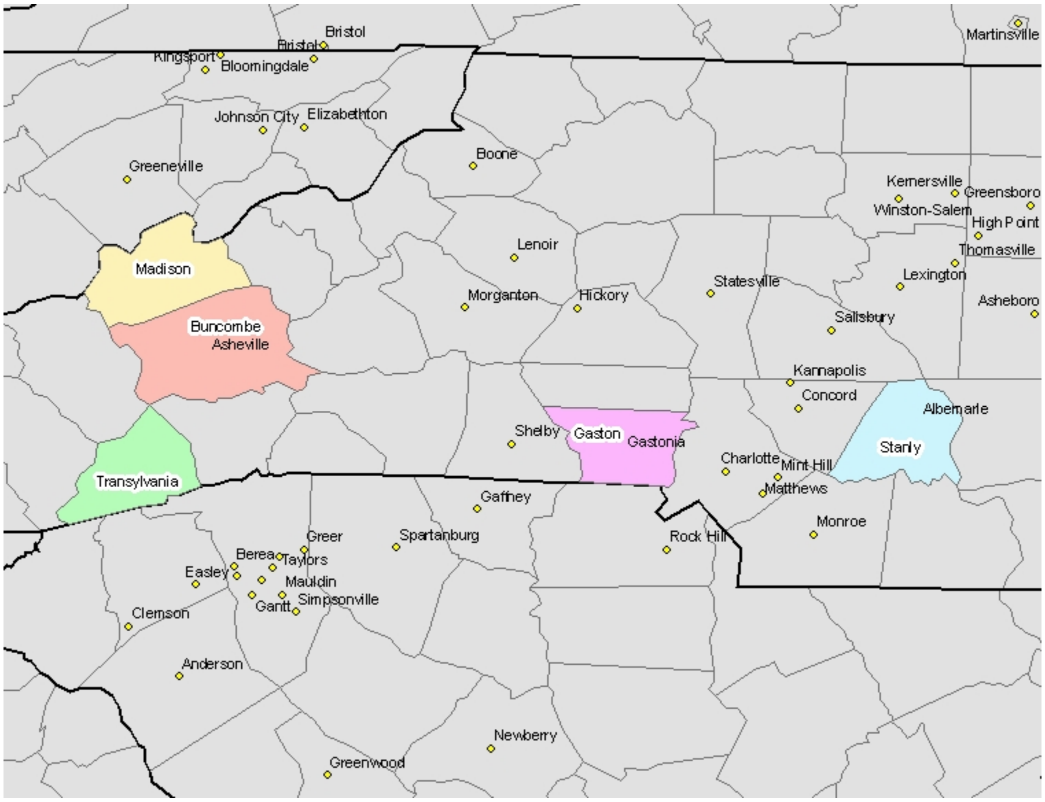


Figure 8. North Carolina Study Regions

3.3 Hurricane Ivan

This section documents the work performed by ABS Consulting using the HAZUS-MH flood model for Hurricane Ivan.

Inputs

Using the results of SLOSH runs posted on the National Hurricane Center (NHC) website, the coastal flood hazard was computed based on the SLOSH storm surge elevations, as seen in Figure 9. For riverine analyses, John Ingargiola, of the Department of Homeland Security, provided documents with the peak discharges from gages of the affected area. The DEM for each county was downloaded from the National Elevation Dataset (NED) on the USGS website.

Following are pertinent details regarding the flood model runs:

Ivan hurricane advisory	56
HAZUS build #	37+ (Build 37 with updated flood software)
HAZUS DVD data version	Build 36
Counties analyzed	Coastal: Baldwin, AL, Escambia, FL, Santa Rosa, FL Riverine: SR1-Buncombe, NC, Madison, NC SR2-Transylvania, NC, Henderson, NC SR3-Graham, NC, Swain, NC SR4-Allegheny, PA, Beaver, PA SR5-Allegheny, PA, Westmoreland, PA, Armstrong, PA SR6-Jefferson, OH, Brooke, WV, Hancock, WV SR7-Ohio, WV, Marshall, WV, Belmont, OH, Monroe, OH

Approach/Methodology

In order to run the coastal analysis, the storm surge elevation for each county's coast was estimated from the SLOSH results. The projected surge elevations showed little variation across each county, so a uniform surge elevation was applied to each county. In HAZUS, the General Building Stock (Damage & Loss) and Essential Facilities analyses were computed. For the riverine analysis, aggregating flood study regions in the flood model only allows for a maximum of 4 counties per region, so five study regions were constructed for the exposure analysis. The riverine analysis consisted of multi-county study regions, seen below in Figures 10 through 12. Specific study region maps are included in the zip file. Due to the large amount of inventory data and cell size of the depth grids, the flood model is ideally run with one county per region. To cut down analysis time, river networks were defined based on a 25-square mile drainage area, resulting in fairly large streams.
River discharges were computed using hydrologic regression analysis. As such, floodplains were determined assuming a 100-year return period flood. The flood hazard was based on current/peak discharges at gages provided by FEMA. The gages had to be located in each study region, in which the information was provided or was found on NOAA's website. In HAZUS, the hydrological analysis was skipped because the discharges were already provided. The discharges were distributed downstream of each respective gage. The analyses ran in HAZUS for each study region includes the General Building Stock (Damage and Loss) and Essential Facilities. Exposure estimates for each of the analysis areas were computed, in terms of full replacement costs and depreciated costs for residential and government occupancies, along with population totals. The totals include any census blocks that intersect the floodplain boundary. The global summary reports were produced for each of the study regions. The exceptions are study regions 6 and 7 along the Ohio River. There were technical difficulties with the flood model that didn't allow for loss computations at the time of this report.

Results

The projected surge elevations and flood discharges for each county is shown in the table below. The resulting loss estimates are not available due to problems in the analysis portion of the program.

Coastal Analysis

County	Surge Elevation (ft)	Coast Name	Processing Time	
			Hazard	Analysis
Baldwin, AL	7	Baldwin	5 min	7 hr 41min
Escambia, FL	7	Escambia	7 min	3 hr 8 min
Santa Rosa, FL	7.5 and 3.6	Santa Rosa	2 min	6 hr 2 min

Riverine Analysis

County	Flood Discharge (cfs)	River Name	Processing Time	
			Hazard	Analysis
Buncombe, NC	30,300	French Broad	1 hr 32 min	16 min
Madison, NC	48,000 and 74,600	French Broad	1 hr 32 min	16 min
Transylvania, NC	19,400	French Broad	45 min	14 min
Graham, NC	30,750	Tuskasegee	58 min	22 min
Swain, NC	30,750	Tuskasegee	58 min	22 min
Henderson, NC	19,400	French Broad	45 min	14 min
Allegheny, PA	197,000 and 193,000 and 178,000 and 325,000	Allegheny, Ohio	1 hr 23 min, 1 hr 25 min	1 hr 31min, 47 hr 46min
Westmoreland, PA	194,000	Allegheny	1 hr 23min	1 hr 31min
Armstrong, PA	174,000	Allegheny	1hr 23min	1 hr 31min
Beaver, PA	361,000	Ohio	1 hr 25min	47 hr 46min
Jefferson, OH	356,000 and 351,000 and 346,000	Ohio	36 min	4 min
Belmont, OH	353,000	Ohio	1 hr 32 min	8 min
Monroe, OH	346,000	Ohio	1 hr 32 min	8 min
Brooke, WV	368,000	Ohio	36 min	4 min
Hancock, WV	368,000	Ohio	36 min	4 min
Ohio, WV	353,000	Ohio	1 hr 32min	8 min
Marshall, WV	357,000	Ohio	1 hr 32min	8 min

Lessons Learned

Through this analysis, several lessons were learned that can be applied to the use of the HAZUS flood model during future hurricanes:

- **Computers –** *There is a 4-county limit on the size of flood model study regions due to the system limits on the size of study region databases. As such, in order to analyze a large area, it is necessary to build multiple study regions. With time crunches typical with emergency response, one of the most important factors in the analysis for these study regions was the availability of multiple computers, which allowed for simultaneous analysis.*
- **Processing Time –** *The computers used for this exercise had 3.2 GHz processors, with 2 GB of RAM, and tens of gigabytes of hard drive space. For HAZUS flood analysis, the processor speed and RAM are very important. The total processing times are listed in the tables above.*

- **Riverine Study Region Creation –** *Based on the river to be analyzed, care should be exercised during study region creation. If a river to be analyzed forms a border between counties, the study region should include the counties on both sides of the river. Otherwise, the synthetic stream network may not be continuous.*
- **Coastal Study Region Creation –** *At this time it is recommended to build a single county study region for coastal analysis. The number of census blocks impacted over a county due to a large coastal flood can be quite high, resulting in long general building stock processing times.*
- **Storm Track –** *In the final hurricane advisories prior to landfall, the storm track changed rather significantly. Due to this, the affected counties and associated storm surges can also change in a short period of time. Hence, it is recommended to delay running of the coastal model until the final storm track is known.*
- **Validation –** *For future hurricanes, it would be useful to acquire measured storm surge elevations and apply them to the coastal model, in order to help validate the accuracy of the model results. At this time it is not clear if the surge elevations computed in the final SLOSH runs mimicked actual surge elevations.*

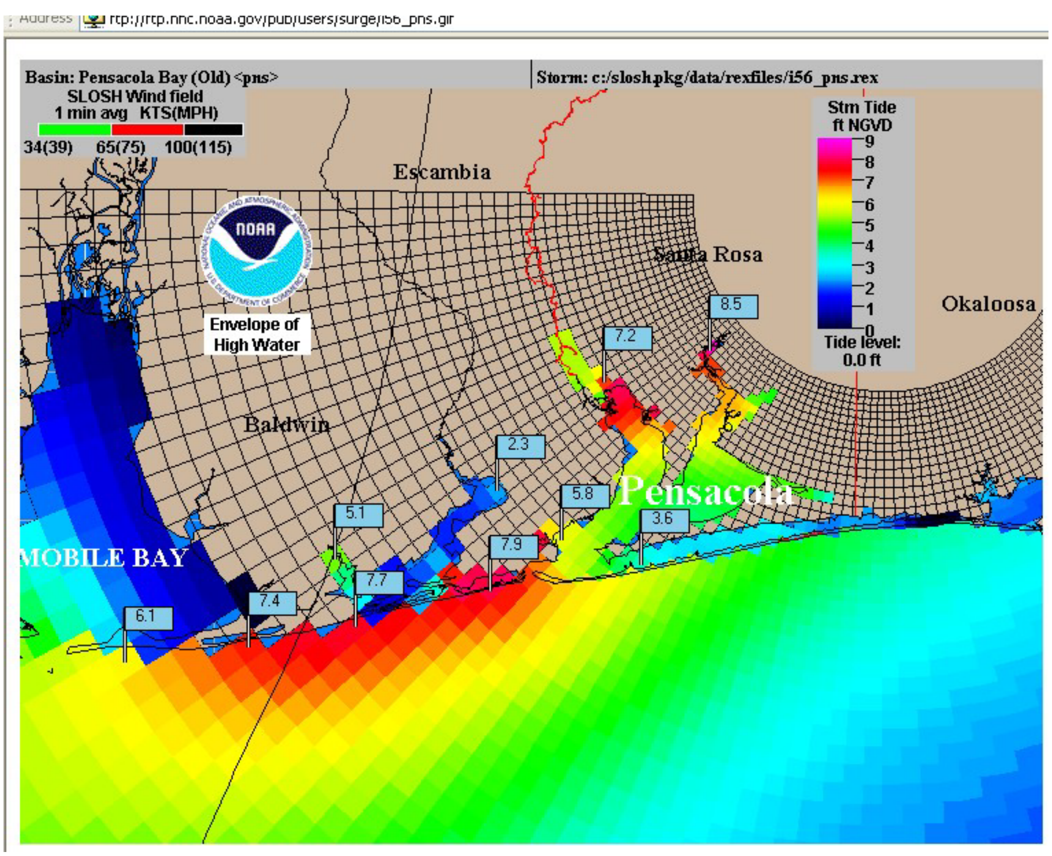


Figure 9. SLOSH Output Map

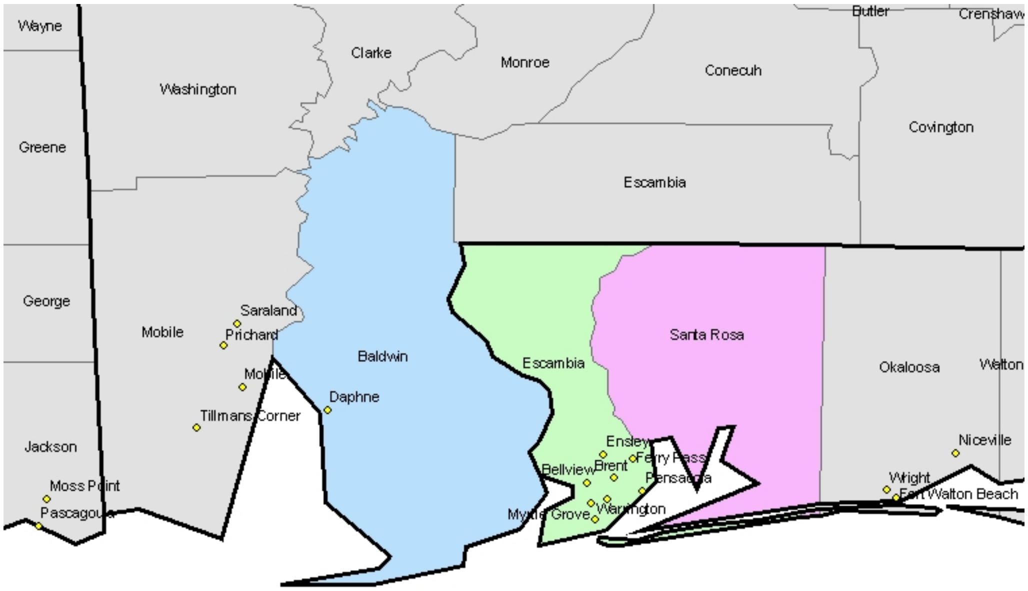


Figure 10. Alabama-Florida Study Regions

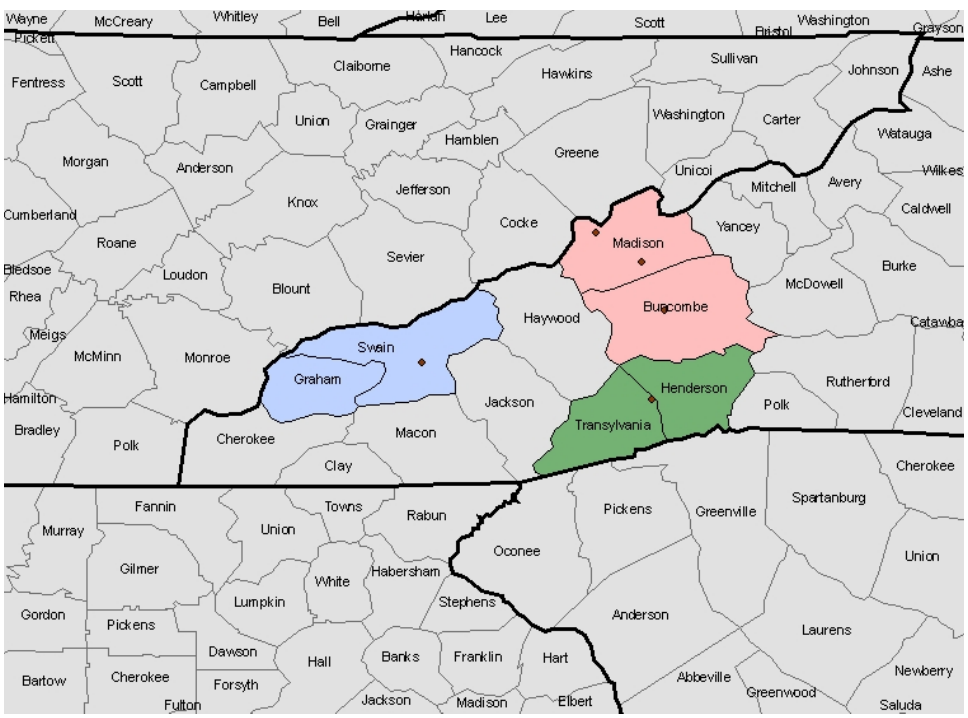


Figure 11. North Carolina Study Regions

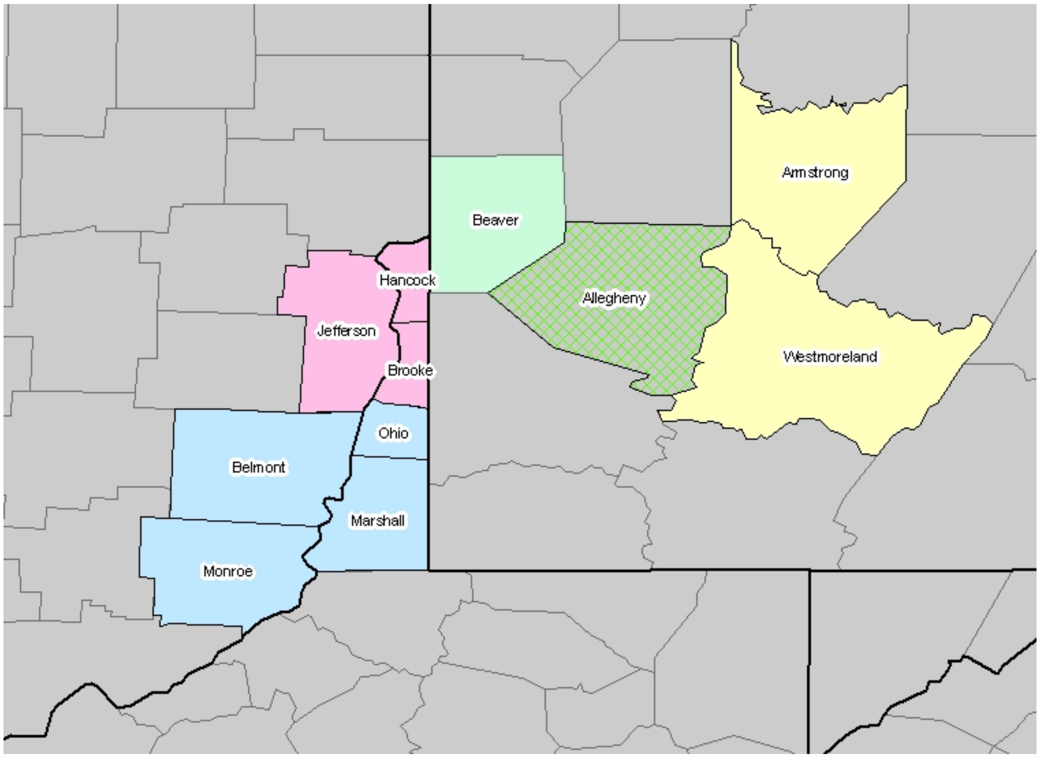


Figure 12. Ohio-Pennsylvania-West Virginia Study Regions

APPENDIX D
ACKNOWLEDGEMENTS: CONTACT LOG

Caller	Contact Name	Agency Or Organization	County Data Requested For	Requested	Date Of Phone Or Email Contact	Date Data Received	Comments
Stacy Robinson	Rick Burgess	Charlotte County GIS	Charlotte	Follow-up on Tom's request for county damage data	12/2/2005; 12/6/05	No response	
Stacy Robinson	Ron Peacock	Charlotte Co Schools	Charlotte	Follow-up on Tom's request for school damage data	12/2/2005	No response	
Stacy Robinson	Danny Killcollins	FDEM	ALL	Statewide shelter info for Charley, Ivan, and Dennis	12/2/2005	Referred to Barbara Bratcher	
Stacy Robinson	Barbara Bratcher	FDEM	ALL	Statewide shelter info for Charley, Ivan, Dennis, Francis, and Jeanne	12/2/2005	Referred to Michael Whitehead	
Stacy Robinson	Michael Whitehead	FLDBPR	ALL	Statewide shelter info for Charley, Ivan, and Dennis	12/5/2005; 1/11/2006	12/5/2005 and ongoing	Rec'd pre- and post-landfall shelter estimates for all counties for Charley, Ivan, Dennis, Jeanne, and Frances.
Stacy Robinson	AC Castello	Florida Hospital Assoc	ALL	Statewide hospital damage info for Charley, Ivan, and Dennis	12/2/2005	Sent a report and was referred to Debbie Hegerty	
Stacy Robinson	Debbie Heggerty	Florida Hospital Assoc	ALL	Statewide hospital damage info for Charley, Ivan, and Dennis	12/2/2005	Rec'd what limited data they had	
Stacy Robinson	Karen Thornhill	Santa Rosa Co	Santa Rosa	Follow-up on Tom's request for county damage data	12/2/2005	Rec'd limited data (apparently what Tom asked for)	

Caller	Contact Name	Agency Or Organization	County Data Requested For	Requested	Date Of Phone Or Email Contact	Date Data Received	Comments
Lisa Flax	Karen Thornhill	Santa Rosa Co	Santa Rosa	Sent e-mail to request data per revised collection forms	1/17/2006		
Lisa Flax	Karen Thornhill	Santa Rosa Co	Santa Rosa		1/18/2006		Left follow-up message
Lisa Flax	Karen Thornhill	Santa Rosa Co	Santa Rosa		1/19/2006		Left follow-up message
Lisa Flax	Gregg Cotton	Santa Rosa Co PW	Santa Rosa	Debris estimate	1/18/06	1/18/06	17.M TN for Dennis
Stacy Robinson	NW FL Red Cross	NW FL Red Cross	Escambia & Santa Rosa	Shelter counts, damaged housing counts and displaced HH	12/2/2005; 1/12/06	No response	Dent follow-up email 1/12
Stacy Robinson	Charlotte Co Red Cross (mike Lee)	Charlotte Co Red Cross	Charlotte	Shelter counts, damaged housing counts, and displaced HH	12/2/2005; 1/12/06	No response	Sent follow-up email 1/12
Stacy Robinson	Becky Sebren	Central FL Red Cross	Orange	Shelter counts, damaged housing counts, and displaced HH	12/2/2005; 1/11/2006	12/5; awaiting another response	Referred to Orange County EM for damaged housing counts
Stacy Robinson	Luke Wood	Manatee Red Cross	Hardee	Shelter counts, damaged housing counts, and displaced HH	12/2/2005; 1/11/2006	12/5/2006	Requested Frances and Jeanne 1/11/2006
Stacy Robinson	SW FL Red Cross	SW FL Red Cross	DeSoto	Shelter counts, damaged housing counts, and displaced HH	12/2/2005	No response	Sent follow-up email 1/12 to Bill Sullivan (see contact below)
Stacy Robinson	Pam Miner	PBS&J Chipley	Help ID FDOT3 contacts		12/1/2005	12/5/2006	
Stacy Robinson	Denny Wood	FDOT3	Escambia & Santa Rosa		12/5/2005	12/5/2006	Referred to Tina Hegan
Stacy Robinson	John Locke	FDOT3	Escambia & Santa Rosa		12/5/2005	12/5/2005	
Stacy Robinson	Tina Hegan	FDOT3	Escambia & Santa Rosa		12/5/2005	12/7/2005	Rec'd spreadsheets of all road repair and DOT debris removal costs

Caller	Contact Name	Agency Or Organization	County Data Requested For	Requested	Date Of Phone Or Email Contact	Date Data Received	Comments
Stacy Robinson	Mike Healy	FDOT3	Orange	Debris estimates	12/5/2005	12/5/2005	
Stacy Robinson	Bill Sullivan	DeSoto County Red Cross	DeSoto	Displaced HH and damaged housing counts	1/12/2006	1/17/2006	
Lisa Flax	Rick Burgess	City of Punta Gorda	Charlotte	County damage and loss data	1/17/2006		Left message about data collection.
Lisa Flax	Rick Burgess	City of Punta Gorda	Charlotte		1/18/2006		Asked about status of data collection; he will check and call tomorrow
Lisa Flax	Angela Whitehead	Charlotte County / Solid Waste	Charlotte	Debris estimates	1/18/2006		She will e-mail available data
Lisa Flax	Greg Colton	Santa Rosa Co / Public Works	Santa Rosa	Debris estimates	1/18/2006		He will e-mail available data
Lisa Flax	Sherry Babcock	Escambia County	Escambia	County damage and loss data	1/17/2006		
Lisa Flax	Sherry Babcock	Escambia County	Escambia		1/18/2006		Left message about data collection
Lisa Flax	Sherry Babcock	Escambia County	Escambia		1/19/2006		Spoke with Sherry and her Director. They are very busy with hurricane recovery effort and it will take a lot of effort and time to provide requested data. Will see if they can work on it.
Lisa Flax	Susan Holt	Escambia County/Solid Waste	Escambia		1/18/2006		Left message about debris data request

Caller	Contact Name	Agency Or Organization	County Data Requested For	Requested	Date Of Phone Or Email Contact	Date Data Received	Comments
Stacy Robinson	Steve Detwiler and John Witcher	Orange County EM and Orange Co. Property Appraiser	Orange	Emailed data survey	1/17/2006		Referred to them by Becky Sebren. Received damage totals by damage state for Charley, Frances, and Jeanne on 1/23. OCEM is working on other info requested.
Stacy Robinson and Nathan Slaughter	Don Daniels	St. Lucie EM	St. Lucie	Stacy emailed data survey, Nathan followed up with phone call	1/19/2006		Spoke to Mr. Daniels - he indicated that he was very busy but would try to make time for this. Did not give an indication of when he would have data ready.
Stacy Robinson	Keith Holman	Martin EM	Martin	Emailed data survey	1/17/2006		1/18-he is gathering the data
Stacy Robinson and Darrin Punchard	Catherine Furr, Dawn Ballard, Larry Hilton, Adrian Cline	DeSoto County--EM, Chamber of Commerce, Bldg&Zoning, School superintendent	DeSoto	Stacy emailed data survey; Darrin followed up with phone calls	1/17/2006	1/24/2006 (schools)	Received schools data from Florence Gobble. Catherine Furr currently collecting other data.
Stacy Robinson and Darrin Punchard	Rich Shepard, Janet Gilliard, Kathy Crawford, Park Winter, Betty Croy, Joann McCray, and County Chamber of Commerce	Hardee County--EM, Community Development, Property Appraiser, Economic Development, School Superintendent's office, and chamber of commerce	Hardee	Stacy emailed data survey; Darrin followed up with phone calls	1/17/2006	1/19/06 (partial)	Received updated critical facility listing from Rich S. Damage survey data are still being gathered by others.

Appendix E
H*Wind Wind Speeds and ARA Modeled Wind Speeds

This appendix shows the variation between the Hwind and ARA-modeled tracks in sustained wind speed prediction at the jurisdiction level for each of the Hurricanes considered in this report.

(1) Hurricane Charley

		Hwind			ARA		
City/Place	**County**	**MIN**	**MAX**	**MEAN**	**MIN**	**MAX**	**MEAN**
Charlotte Harbor	Charlotte	119	126	122	105	108	106
Charlotte Park	Charlotte	93	122	108	104	111	108
Cleveland	Charlotte	85	117	102	65	116	99
Englewood	Charlotte	42	55	47	54	75	65
Grove City	Charlotte	44	44	44	59	106	80
Harbour Heights	Charlotte	105	122	113	108	108	108
Manasota Key	Charlotte	44	56	52	59	59	59
Port Charlotte	Charlotte	94	126	112	87	108	104
Punta Gorda	Charlotte	76	137	112	104	111	108
Rotonda	Charlotte	58	79	67	75	106	91
Solana	Charlotte	117	117	117	104	116	110
Arcadia	Desoto	75	102	85	72	106	97
Southeast Arcadia	Desoto	73	91	80	72	105	94
Bowling Green	Hardee	86	105	96	89	100	95
Wauchula	Hardee	104	113	110	87	105	93
Zolfo Springs	Hardee	103	110	107	87	105	96
Alva	Lee	43	48	45	0	56	22
Bokeelia	Lee	73	137	94	118	118	118
Bonita Springs	Lee	40	63	52	0	56	32
Buckingham	Lee	46	49	48	0	57	33
Burnt Store Marina	Lee	65	89	77	91	108	101
Cape Coral	Lee	48	89	57	69	108	78
Charleston Park	Lee	43	43	43	0	0	0
Cypress Lake	Lee	48	48	48	62	67	65
East Dunbar	Lee	48	48	48	60	62	61
Estero	Lee	43	62	48	0	56	41
Fort Myers	Lee	48	49	48	0	69	59
Fort Myers Shores	Lee	48	49	49	53	56	55
Gateway	Lee	46	48	47	0	51	17
Harlem Heights	Lee	48	48	48	66	66	66
Iona	Lee	48	49	48	65	74	69
Lehigh Acres	Lee	40	49	45	0	54	7
Lochmoor Waterway Estates	Lee	48	48	48	69	73	71

		Hwind			ARA		
City/Place	**County**	**MIN**	**MAX**	**MEAN**	**MIN**	**MAX**	**MEAN**
Matlacha	Lee	65	65	65	118	118	118
McGregor	Lee	48	48	48	64	70	66
North Fort Myers	Lee	48	52	49	53	104	71
Olga	Lee	47	48	48	0	56	22
Page Park	Lee	48	48	48	62	62	62
Palmona Park	Lee	48	48	48	68	72	70
Pine Island Center	Lee	71	101	81	100	118	109
Pine Manor	Lee	48	48	48	62	64	63
Pineland	Lee	92	101	96	118	118	118
San Carlos Park	Lee	46	48	47	54	59	56
Sanibel	Lee	51	99	73	81	109	95
St. James City	Lee	59	97	76	100	118	109
Suncoast Estates	Lee	48	48	48	66	72	68
Three Oaks	Lee	46	47	47	0	56	41
Tice	Lee	48	48	48	59	62	60
Villas	Lee	48	48	48	56	65	61
Whiskey Creek	Lee	48	48	48	62	66	64
Apopka	Orange	26	40	30	0	55	28
Azalea Park	Orange	63	88	77	77	80	79
Bay Hill	Orange	38	50	44	63	73	68
Bay Lake	Orange	33	52	39	62	72	67
Belle Isle	Orange	83	91	87	79	81	80
Bithlo	Orange	37	43	40	59	71	64
Christmas	Orange	33	34	33	59	59	59
Citrus Ridge	Orange	30	35	32	0	72	45
Conway	Orange	82	88	84	79	81	80
Doctor Phillips	Orange	43	50	47	67	73	69
Eatonville	Orange	57	71	64	64	71	68
Edgewood	Orange	72	88	80	79	81	81
Fairview Shores	Orange	57	76	66	64	74	70
Goldenrod	Orange	74	87	80	78	79	79
Gotha	Orange	33	37	35	59	65	62
Holden Heights	Orange	66	88	75	78	81	80
Hunters Creek	Orange	81	93	87	78	84	82
Lake Buena Vista	Orange	38	58	47	62	73	67
Lake Butter	Orange	31	43	35	50	67	61
Lake Hart	Orange	48	50	49	58	73	66
Lockhart	Orange	44	57	51	55	67	62
Maitland	Orange	57	71	65	65	76	71
Meadow Woods	Orange	63	93	81	70	83	78
Oak Ridge	Orange	58	79	69	76	81	78
Oakland	Orange	27	28	28	0	50	17
Ocoee	Orange	29	34	31	0	62	48
Orlando	Orange	37	91	64	58	81	75
Orlovista	Orange	37	52	46	63	68	66
Paradise Heights	Orange	30	30	30	0	51	17

		Hwind			ARA		
City/Place	**County**	**MIN**	**MAX**	**MEAN**	**MIN**	**MAX**	**MEAN**
Pine Castle	Orange	72	91	82	81	82	81
Pine Hills	Orange	32	48	40	59	69	64
Sky Lake	Orange	72	79	75	79	82	81
South Apopka	Orange	30	32	31	0	55	39
Southchase	Orange	88	89	88	78	82	81
Taft	Orange	91	91	91	73	82	79
Tangelo Park	Orange	65	65	65	77	77	77
Tangerine	Orange	24	24	24	0	0	0
Tildenville	Orange	28	31	29	50	50	50
Union Park	Orange	53	68	58	71	78	76
Wedgefield	Orange	34	42	36	59	71	65
Williamsburg	Orange	65	72	68	77	82	79
Windermere	Orange	33	43	37	50	63	57
Winter Garden	Orange	27	33	30	0	55	30
Winter Park	Orange	71	88	80	71	80	76
Zellwood	Orange	24	29	27	0	0	0
Campbell	Osceola	85	95	90	80	84	82
Celebration	Osceola	39	70	53	72	72	72
Citrus Ridge	Osceola	31	55	40	52	74	65
Kissimmee	Osceola	57	95	85	70	84	80
Poinciana	Osceola	50	98	79	72	85	80
St. Cloud	Osceola	44	55	50	62	72	66
Yeehaw Junction	Osceola	63	88	77	70	81	77
Auburndale	Osceola	32	42	36	54	70	63
Babson Park	Osceola	50	59	56	73	84	80
Bartow	Osceola	36	61	47	55	90	73
Citrus Ridge	Osceola	31	41	37	0	74	52
Combee Settlement	Osceola	28	31	29	0	52	10
Crooked Lake Park	Osceola	63	63	63	84	84	84
Crystal Lake	Osceola	28	31	30	0	52	21
Cypress Gardens	Osceola	67	83	75	78	89	83
Davenport	Osceola	59	85	72	74	85	80
Dundee	Osceola	90	100	95	89	91	90
Eagle Lake	Osceola	51	60	55	76	81	79
Fort Meade	Osceola	78	106	90	90	100	94
Frostproof	Osceola	52	54	53	57	73	65
Fussels Corner	Osceola	29	34	32	0	61	46
Gibsonia	Osceola	27	27	27	0	0	0
Haines City	Osceola	54	95	74	67	89	81
Highland City	Osceola	35	35	35	55	59	57
Highland Park	Osceola	59	69	64	82	87	85
Hillcrest Heights	Osceola	57	57	57	73	84	79
Inwood	Osceola	42	51	46	68	75	71
Jan Phyl Village	Osceola	38	51	43	59	76	69
Kathleen	Osceola	26	27	26	0	0	0
Lake Alfred	Osceola	40	58	46	65	78	71

		Hwind			ARA		
City/Place	County	MIN	MAX	MEAN	MIN	MAX	MEAN
Lake Hamilton	Osceola	90	90	90	89	91	90
Lake Wales	Osceola	62	103	89	78	94	87
Lakeland	Osceola	27	32	28	0	55	4
Lakeland Highlands	Osceola	29	32	30	0	58	27
Loughman	Osceola	55	79	69	72	85	79
Medulla	Osceola	28	29	29	0	0	0
Mulberry	Osceola	31	34	33	0	58	38
Polk City	Osceola	28	31	29	0	52	17
Wahneta	Osceola	60	77	68	81	84	83
Waverly	Osceola	83	103	96	87	94	90
Willow Oak	Osceola	28	29	29	0	55	11
Winston	Osceola	27	28	28	0	0	0
Winter Haven	Osceola	40	100	63	65	91	78

(2) Hurricane Ivan

		Hwind			ARA		
City/Place	County	MIN	MAX	MEAN	MIN	MAX	MEAN
Bellview	Escambia	89	91	90	84	87	85
Brent	Escambia	87	90	88	83	85	84
Century	Escambia	89	90	89	73	77	75
Ensley	Escambia	87	91	89	83	84	84
Ferry Pass	Escambia	86	90	88	82	84	83
Gonzalez	Escambia	90	92	91	82	84	83
Goulding	Escambia	86	87	87	84	85	85
Molino	Escambia	92	93	92	80	81	81
Myrtle Grove	Escambia	88	91	89	85	87	86
Pensacola	Escambia	84	103	92	82	87	84
Warrington	Escambia	88	90	89	86	89	87
West Pensacola	Escambia	88	90	89	85	87	86
Bagdad	Santa Rosa	80	83	82	69	78	75
Gulf Breeze	Santa Rosa	83	103	97	79	82	81
Jay	Santa Rosa	85	87	86	77	77	77
Milton	Santa Rosa	82	84	83	69	76	74
Pace	Santa Rosa	85	88	87	78	82	80

APPENDIX F
Glossary

At Risk – Exposure values that include the entire building inventory or population value in a census block or tract that lie within, or bordering the inundation areas or any area potentially exposed to a hazard based on location.

Building – A structure that is walled and roofed, principally above ground and permanently fixed to a site. The term includes a manufactured home on a permanent foundation on which the wheels and axles carry no weight.

Census Block– A subdivision of a census tract (or, prior to 2000, a block numbering area), a block is the smallest geographic unit for which the U.S. Census Bureau tabulates 100-percent data. Many blocks correspond to individual city blocks bounded by streets, but blocks – especially in rural areas – may include many square miles and may have some boundaries that are not streets.

Census Tract – A small, relatively permanent statistical subdivision of a county delineated by a local committee of census data users for the purpose of presenting data. Census tract boundaries normally follow visible features, but may follow governmental unit boundaries and other non-visible features in some instances; they always nest within counties. Designed to be relatively homogeneous units with respect to population characteristics, economic status, and living conditions at the time of establishment, census tracts average about 4,000 inhabitants. They may be split by any sub-county geographic entity.

Critical Facility – Facilities that are critical to the health and welfare of the population and that are especially important following a hazard. Critical facilities include essential facilities, transportation systems, lifeline utility systems, high-potential loss facilities, and hazardous materials sites. As defined for the Portland risk assessment, this category includes: schools, hospitals, fire stations, police stations, and hazardous materials sites.

Content Value – The value of a building's content include all the items in a building, excluding the structure itself. The values are estimated to be 50 percent of the residential structural value and 100 percent of the commercial building replacement value.

Duration – The length of time a hazard occurs.

Erosion – Wearing away of the land surface by detachment and movement of soil and rock fragments, during a flood or storm or over a period of years, through the action of wind, water, or other geologic processes.

Exposure – The number and dollar value of assets that are considered to be at risk during the occurrence of a specific hazard.

Extent – The size of an area affected by a hazard or the occurrence of a hazard.

Federal Emergency Management Agency (FEMA) – Independent agency (now part of the Department of Homeland Security) created in 1978 to provide a single point of accountability for all federal activities related to disaster mitigation and emergency preparedness, response, and recovery.

Geographic Information Systems (GIS) – A computer software application that relates data regarding physical and other features on the earth to a database to be used for mapping and analysis.

Hazard – A source of potential danger or an adverse condition that can cause harm to people or cause property damage. For this risk assessment, priority hazards were identified and selected for the pilot project effort. A natural hazard is a hazard that occurs naturally (such as flood, wind, and earthquake). A man-made hazard is one that is caused by humans (for example, a terrorist act or a hazardous material spill). Hazards are of concern if they have the potential to harm people or property.

Hazard Mitigation – Sustained actions taken to reduce or eliminate the long-term risk and effects that can result from the occurrence of a specific hazard. For example, building a retaining wall can mitigate potential hazards.

HAZUS (Hazards U.S.) – A GIS-based nationally standardized earthquake loss estimation tool developed by FEMA. HAZUS was replaced by HAZUS-MH (see below) in 2003.

HAZUS-MH (Hazards U.S. - Multi-Hazard) – A GIS-based nationally standardized earthquake, flood, and wind loss estimation tool developed by FEMA. The purpose of this pilot project is to demonstrate and implement the use of HAZUS-MH to support risk assessments.

HAZUS-MH Provided Data – The databases included in the HAZUS-MH software that allow users to run a preliminary analysis without collecting or using local data.

HAZUS-MH Risk Assessment Methodology – This analysis uses the HAZUS-MH modules (earthquake, wind [hurricane] and flood) to analyze potential damages and losses. For this pilot project risk assessment the earthquake and flood hazards were evaluated using this methodology.

HAZUS-MH Supported Risk Assessment Methodology – This analysis involves using inventory data in HAZUS-MH combined with knowledge such as (1) information about potentially exposed areas, (2) expected impacts, and (3) data regarding likelihood of occurrence for hazards.

Infrastructure – The public services of a community that have a direct impact on the quality of life. Infrastructure includes communication technology such as phone lines or Internet access, vital services such as public water supplies and sewer treatment facilities, and transportation systems (such as airports, heliports, highways, bridges, tunnels, roadbeds, overpasses, railways, bridges, rail yards, depots; and waterways, canals, locks, seaports, ferries, harbors, dry docks, piers, and regional dams).

Intensity – A measure of the effects of a hazard occurring at a particular place.

Inventory – The assets identified in a study region. The inventory assessment addresses what can be lost when a disaster occurs, that is, what community resources are at risk. Assets include people, buildings, transportation, and other valued community resources.

Lifelines – Critical facilities that include utility systems (potable water, wastewater, oil, natural gas, electric power facilities, and communication systems) and transportation systems (airways, bridges, roads, tunnels, and waterways).

Loss Estimation – The process of assigning hazard-related damage and loss estimates to inventory, infrastructure, lifelines, and population data. HAZUS-MH can estimate the economic and social loss for specific hazard occurrences. Loss estimation is essential to decision making at all levels of government and provides a basis for developing mitigation plans and policies. It also supports planning for emergency preparedness, response, and recovery.

Occupancy Classes – Categories of buildings used by HAZUS-MH (for example, commercial, residential, industrial, government, and “other”).

Replacement Value – The cost of rebuilding or repairing a structure. This cost is usually expressed in terms of cost per square foot and reflects the present-day cost of labor and materials to construct a building of a particular size, type, and quality.

Risk – The estimated impact that a hazard would have on people, services, facilities, and structures in a community; the likelihood of a hazard occurring and resulting in an adverse condition that causes injury or damage. Risk is often expressed in relative terms such as a high, moderate, or low likelihood of sustaining damage above a particular threshold due to occurrence of a specific type of hazard. Risk also can be expressed in terms of potential monetary losses associated with the intensity of the hazard.

Risk Assessment – A methodology used to assess potential exposure and estimated losses associated with priority hazards. The risk assessment process includes four steps: (1) identifying hazards, (2) profiling hazards, (3) conducting an inventory of assets, and (4) estimating losses. This pilot project report documents this process for selected hazards addressed as part of the pilot project.

Scale – A proportion used in determining a dimensional relationship; the ratio of the distance between two points on a map, and the actual distance between the two points on the earth’s surface.

Structure – Something constructed (for example, a residential or commercial building).

Substantial Damage – Damage of any origin sustained by a structure in a SFHA, for which the cost of restoring the structure to its pre-hazard event condition would equal or exceed 50 percent of its pre-hazard event market value.

Vulnerability – Description of how exposed or susceptible an asset is to damage. This term depends on an asset’s construction, contents, and the economic value of its functions. Like indirect damages, the vulnerability of one element of the community is often related to the vulnerability of another. For example, many businesses depend on uninterrupted electrical power. If an electric substation is flooded, it will affect not only the substation itself, but a number of businesses as well. Often, indirect effects can be much more widespread and damaging than direct ones.

Vulnerability Assessment – Evaluation of the extent of injury and damage that may result from a hazard event of a given intensity in a given area. The vulnerability assessment should address impacts of hazard occurrences on the existing and future built environment.