

# Using Hazus for Mitigation Planning

*August 2018*



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This work was conducted as a collaborative effort between the FEMA Emergency Management Agency (FEMA) Natural Hazards Risk Assessment Program, National Mitigation Planning Program, and the Hazus Program.

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**Thank you to all of the FEMA Mitigation Planning Team for all of the input, best practices, and graphics.**



## Document History

<b>Affected Section or Subsection</b>	<b>Date</b>	<b>Description</b>
First Publication	August 2018	Initial version of released guidance. The content was derived from draft document "Using Hazus Results in the Hazard Mitigation Plan, Hazus Job Aid", December 2007

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## ACRONYMS AND ABBREVIATIONS

Acronym	Definition
AAL	Average Annualized Loss
AEBM	Advanced Engineering Building Module
BCA	Benefit-Cost Analysis
CDMS	Comprehensive Data Management System
DFIRM	Digital Flood Insurance Rate Map
DMA	2000 Disaster Mitigation Act of 2000
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
GBS	General Building Stock
GIS	Geographic Information System
HIFLD	Homeland Infrastructure Foundation-Level Data
HPL	High Potential Loss
HSIP	Homeland Security Infrastructure Program
MSDIS	Missouri Spatial Data Information Service
NHRAP	Natural Hazard Risk Assessment Program
SEMA	State Emergency Management Agency
UDF	User-Defined Facility
USGS	United States Geological Survey
VDEM	Virginia Division of Emergency Management

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## 1.0 Introduction

Hazard mitigation is the effort to reduce loss of life and property by lessening the impact of disasters. It is most effective when implemented under a comprehensive, long-term mitigation plan. State, local and tribal governments engage in hazard mitigation planning to identify risks and vulnerabilities associated with natural disasters and develop long-term strategies for protecting people and property from future hazard events. Mitigation plans are key to breaking the cycle of disaster damage, reconstruction, and repeated damage.

To facilitate the support for better mitigation, Congress enacted the Disaster Mitigation Act of 2000 (DMA 2000), which encourages state, local and tribal governments to further encourage mitigation planning. To be eligible for Federal Emergency Management Agency (FEMA) funds, communities must prepare hazard mitigation plans that comply with DMA 2000. The Robert T. Stafford Disaster Relief and Emergency Assistance Act (Stafford Act), as amended by the Disaster Mitigation Act of 2000, provides the legal basis for state, local, and tribal governments to undertake risk-based approaches to reducing natural hazard risks through mitigation planning. Specifically, the Stafford Act requires state, tribal and local governments to develop and adopt FEMA-approved hazard mitigation plans as a condition for receiving certain types of non-emergency disaster assistance.

This job aid demonstrates how Hazus results can be incorporated into hazard mitigation plans and assists with the development of hazard mitigation actions. Other publications, such as Hazus user and technical guidance documents, describe in depth how to use the software or discuss technical approaches for risk analysis. These valuable resources are referenced throughout this guide and can be found using the links at the end of the document.

### 1.1 About This Document

While the purpose of this job aid is to help users identify and understand the types of reports, tables, maps and data produced in Hazus that can be incorporated into a Hazard Mitigation Plan, it can also be used by those who are interested in using the software to support the results of the risk assessment in mitigation plans.

Users of this document can include, but are not limited to:

- Plan authors;
- Mitigation planners;
- State and local in-house geographic information system (GIS) staff;
- Regional planning commissions;
- Universities;
- Planning researchers and students;
- Consultants;
- Plan reviewers; and
- State, tribal and local officials, including contract officers

This job aid assumes users have GIS and Hazus software or can access these resources through their organization, or by hiring a consultant who can run the program.

The job aid is organized in accordance with the steps of the risk assessment process. Each step discusses how the Hazus outputs can be used and incorporated into a risk assessment.

## 1.2 What Is Hazus?

Hazus is a GIS-based software that can be used to estimate potential damage, economic loss, and social impacts from earthquake, flood, tsunami and hurricane wind hazards. The Hazus software includes nationwide general GIS datasets, and a model for the four natural disasters below. The model results can support the risk assessment piece of mitigation planning.

<p><b>Earthquake model</b></p> 	<p>Estimates damages and losses to buildings, essential facilities, transportation, and utility lifelines from a single scenario or probabilistic earthquake analysis. There are also tools that allow the user to integrate earthquake hazard data generated outside of Hazus into the earthquake model. This model estimates debris generation, shelter requirements, casualties, and fire following an earthquake disaster.</p>
<p><b>Flood model</b></p> 	<p>Generates flood hazard data using nationwide hydrological datasets. There are also tools that allow the user to integrate flood hazard data generated outside of Hazus software into the flood model. This model estimates the expected levels of damage to infrastructure and buildings. Debris generation and shelter requirements, as well as agricultural losses, can be calculated with this model.</p>
<p><b>Tsunami model</b></p> 	<p>Can produce analyses that have several pre-tsunami and/or post-tsunami applications. Use of the methodology will generate an estimate of the consequences to a county or region of a "scenario tsunami," i.e., a tsunami with a specified inundation depth, velocity, and location. The resulting "loss estimate" generally will describe the scale and extent of damage and disruption that may result from the scenario tsunami.</p>
<p><b>Hurricane wind model</b></p> 	<p>Can create the wind hazard data from a historical or real-time event, probabilistic event, or from a user-defined scenario. Estimates of potential damage and economic loss to buildings can then be calculated. The storm surge analysis combines the wind and coastal flood model to simulate storm surge for historical, and manual hurricanes. The model combines the wind and flood losses.</p>

Hazus is packaged with datasets that include building inventories and infrastructure for the entire United States. Because Hazus is currently built on GIS technology, the inventory and infrastructure datasets can be mapped and intersected with the hazard information created from the four models. More information on Hazus data inputs can be found in Section 1.4.

Following the intersection, Hazus determines the effects of wind, ground shaking, and water depths on buildings and infrastructure to calculate losses and damages. The outputs and estimates can be used in hazard mitigation planning, emergency response, and planning for recovery and reconstruction.

Losses estimated in Hazus are based on the accuracy of input data. Basic analysis can be developed using the default data and parameter data provided within Hazus. Users can conduct more advanced analysis using more accurate data that is specific to the region, hazard, population, etc. User-supplied data improves the accuracy of inventories and/or parameters.

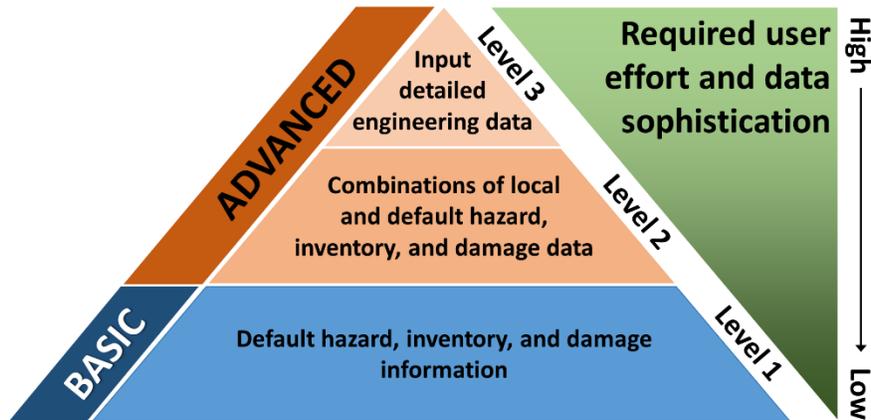
Advanced-level analyses may also incorporate data from third-party studies. The user must determine the appropriate level of analysis to meet the user's needs and resources, as illustrated in Figure 1 and described below. For more information on data inputs, see Section 1.4.

Hazus analysis can be performed at three different levels:

- A Level 1 basic analysis can be performed simply using the default data provided. This level of analysis is very coarse, and because the results will be subject to a much higher level of uncertainty, this should serve primarily as a baseline for further study. The user will still be able to produce basic maps and results. Limited additional data will be required to complete the flood analysis. Site specific input data produces more accuracy in vulnerability identification and loss estimation amounts. If the data is available, it is highly recommended that a user integrate site-specific data to reduce uncertainty associated with the results of default data. Using a user-defined depth grid, in the flood model, against default state data is classified as a level 1 analysis and is the recommendation of Hazus Program.
- A Level 2 advanced analysis increases the accuracy and precision of an analysis by incorporating user-supplied data relevant to a given hazard. While the data included with the Hazus software can be utilized to run a basic level one analysis, level two inputs are supplied by local sources and contain a higher level of detail. This can include datasets that model the hazards in more detail, or datasets that increase the accuracy of the inventory information. Incorporating more detailed data will improve the quality of the results. Level 2 is broadly defined as the incorporation of user-defined hazard and updated GBS or site-specific data.
- A Level 3 advanced analysis achieves the highest degree of precision and involves modifying or substituting the model parameters and/or equations, relevant to a given hazard. Users can modify inputs depending on the time and resources available. Keeping track of the data used is suggested so that any relationships between input and results is documented. It is usually done by advanced users experienced with both the hazard and the Hazus software.

FEMA's Natural Hazard Risk Assessment Program (NHRAP) encourages users to conduct Level 2 or 3 analyses to improve the accuracy of results and recommends the use of user-defined data (e.g., depth grids for all flood analysis) for mitigation planning.

**Figure 1: Hazus Analysis Levels**



Source: FEMA

Hazus creates credible estimates for losses and damages; datasets created on the local level typically provide greater detail than the datasets that are packaged with Hazus (Level 1). Incorporating local datasets into the analysis will improve the results.

### **1.3 Hazus Outputs**

The user plays a major role in selecting the scope and nature of the output of a Hazus analysis. A variety of maps can be generated for visualizing the extent of the losses. Numerical results may be examined at the level of the census block or tract or may be aggregated by county or region.

There are three main categories of Hazus outputs, as shown in Figure 2: direct physical damage, induced damage, and direct losses. Direct physical damage includes general building stock (GBS), essential facilities, high potential loss facilities, transportation systems, utility systems, and user-defined facilities. Induced damage includes building debris, tree debris generation and fire following disaster occurrence. Direct losses include losses for buildings, contents, inventory, income, crop damage, vehicle loss, injuries, casualties, sheltering needs and displaced households.

**Figure 2. Hazus Outputs**

Hazus Capabilities	Earthquake Ground Shaking Ground Failure	Flood Frequency   Depth Riverine   Coastal Surge	Hurricane Wind   Surge	Tsunami Depth   Momentum Flux   Runup   Velocity
<b>Inputs</b>				
Historic	✓		✓	
Deterministic	✓	✓	✓	✓
Probabilistic	✓	✓	✓	
User-supplied	✓	✓	✓	✓
Other supported inputs	Real-time & scenario USGS ShakeMaps	Risk MAP, User-supplied depth grids (ArcGRID, GeoTIFF, IMAGINE), HEC-RAS (.FLT)	Hurrevac, User-supplied wind files (.dat)	NOAA PMEL SIFT, State models
<b>Direct Damage</b>				
General Building Stock	✓	✓	✓	✓
Essential Facilities	✓	✓	✓	
Transportation Systems	✓	✓		
Utility Systems	✓	✓		
User-Defined Facilities	✓	✓	✓	✓
<b>Induced Damage</b>				
Fire Following	✓			
Debris Generation	✓	✓	✓	
<b>Direct Losses</b>				
Cost of Repair	✓	✓	✓	✓
Income Loss	✓	✓	✓	✓
Agricultural		✓		
Casualties	✓			✓
Shelter and/or Evacuation Needs	✓	✓	✓	✓
Average Annualized Loss (AAL)	✓	✓	✓	

Source: FEMA

The earthquake model has the most extensive output options, while the tsunami model has the fewest. While Hazus can model many impacts across the multiple hazards, methodologies are not available for every hazard to have the same outputs. Additionally, not every output or methodology is relevant to every hazard (e.g., crop losses for earthquake hazards).

### 1.4 Hazus Inputs

Three types of input datasets are included in Hazus:

- Default (Aggregated)
- Site Specific
- Hazard Specific

The default data represents a collection of information that is common across all hazard models. There are seven inventory data categories that are included in the Hazus provided inventory dataset: general building stock, essential facilities, high potential loss facilities, hazardous material facilities, transportation systems, and demographics. For more details on these datasets, refer to Section 3.2.

To reduce uncertainty associated with the results of default data, the NHRAP recommends that a user augment or replace the Hazus default information with more refined data. Loss estimation results are highly dependent on the quality and quantity of user input data. Region specific input data can increase the accuracy of vulnerability identification and loss estimation amounts.

Site-specific datasets are comprised of discrete points representing various facilities and systems. Structures may include essential facilities, high potential loss facilities, user-defined facilities, and hazardous material sites. Systems may include transportation systems and utility systems.

In Hazus, the hazard specific data represents the characteristics distinctively defined for each hazard. Each hazard type has a corresponding dataset that is necessary for analysis and informs the loss estimation process. Users can choose to input new data to more accurately depict a specific hazard scenario. It is always recommended that users import hazard data from authoritative sources.

**Table 1. Hazus Inputs**

Model	Input
All	<ul style="list-style-type: none"> <li>• User-Defined Facilities</li> <li>• Model Building Type</li> </ul>
Flood	<ul style="list-style-type: none"> <li>• Depth Grids (arcgrid, fgdb, img)*</li> <li>• DFIRM data</li> <li>• Damage curves</li> <li>• DEM</li> </ul>
Hurricane	<ul style="list-style-type: none"> <li>• Hurrevac import*</li> <li>• .dat census tract data file (ex. H*Wind)*</li> </ul>
Earthquake	<ul style="list-style-type: none"> <li>• ShakeMap*</li> <li>• Deterministic Event</li> <li>• USGS Probabilistic Seismic Hazard Maps</li> <li>• User-Supplied Ground Shaking Maps</li> </ul>
Tsunami	<ul style="list-style-type: none"> <li>• Depth and momentum flux grids*</li> <li>• Limited Risk MAP data available</li> </ul>

Source: FEMA

\*Preferred import hazard data

Once input data has been determined, Hazus offers an assessment of potential damages and losses that may incur for the defined hazard event. More detailed information for minimum inventory for loss estimation methodology can be found in FEMA's Hazus User Manuals for Flood, Hurricane, Tsunami, and Earthquake.

### 1.4.1 Integrating User-Provided Data

Much of the information in the Hazus supplied inventory is used by all the hazards that Hazus supports. This inventory is referred to as common, or shared, inventory and the remainder of the inventory is unique to the different hazards.

Each model includes tools for integrating user-provided hazard data. The earthquake model is enhanced by user-provided hazard maps (soils, elevation, liquefactions), while the hurricane model is enhanced by Hurrevac data.

User-defined facilities (UDF) can be helpful for analyzing individual structures. Without the creation of user-defined damage functions, the only facilities that can be analyzed as user-defined facilities are those that can be characterized as one of the specific occupancy classes used in the General Building Stock. UDFs are comprised of data from online sources such as county assessor databases, raw data supplied from the community or county, or census data. This data is generally more refined as the analysis is now applied to parcel specific data.

FEMA's Comprehensive Data Management System (CDMS) provides Hazus users with the ability to integrate their local data into the analysis process. CDMS enables integration of locally

developed non-hazard data and validates that user data are compliant with Hazus requirements. For more information about CDMS and how it can be used to integrate local data, see the CDMS User Guidance document.

The default UDF table is typically empty, and the user must populate it with data specific to the area that is being analyzed. Users can import UDF data through CDMS by using the UDF fields within the state database, rather than using the UDF import options within the individual study regions. Once imported into CDMS, the data will be aggregated to a study region. If the data includes points and an occupancy class, Hazus will generate a UDF layer based on the default data. If importing UDF data directly to the study region without CDMS, the user must convert the data to a personal geodatabase (the only format the UDF import option supports) and ensure the data have populated the minimum required field. The personal geodatabase (.mdb) file must then be converted to a feature class using ArcCatalog.

Data can also be exported from Hazus for additional geospatial processes and analysis. Once imported into the statewide datasets, CDMS will allow users to query, sort, export, and print information. Hazus data exports may be features only, features and raster, or rasters only. The export may include a metadata xml file, and it can be reprojected after the export. Users can also choose to export tables generated through Hazus into an Excel or Microsoft Access.

The following table estimates the labor hours necessary for creating Hazus data. The numbers listed may vary based on availability of data and experience of the user.

**Table 2. Estimated Labor Hours for Creating Hazus Data**

<b>Task</b>	<b>Estimated Labor Hours</b>
Creating UDF with CDMS (structure-level data with occupancy class only)	8 Hours/1,000 Structures (for additional structures: 200 Structures/Hour)
Full custom UDF with local data**	32 Hours/1,000 Structures (for additional structures: 50 Structures/Hour)
Level 1 hazard analysis with imported user-defined hazard input*	3 Hours/County (could be longer for large counties with high resolution depth grids)
Full level 2 analysis (UDF and user-defined hazard input)***	64 Hours/County and 1,000 Structures (for additional structures: 50 Structures/Hour)
Exporting data using Hazus export tool	30 Minutes/Study Region

Source: FEMA

\*user-defined flood hazard data and default dasymmetric data are not a level 2 analysis

\*\*based on new Hazus Level 2 guidance

\*\*\*development of both UDF and flood hazard data using Hazus Level 2 guidance

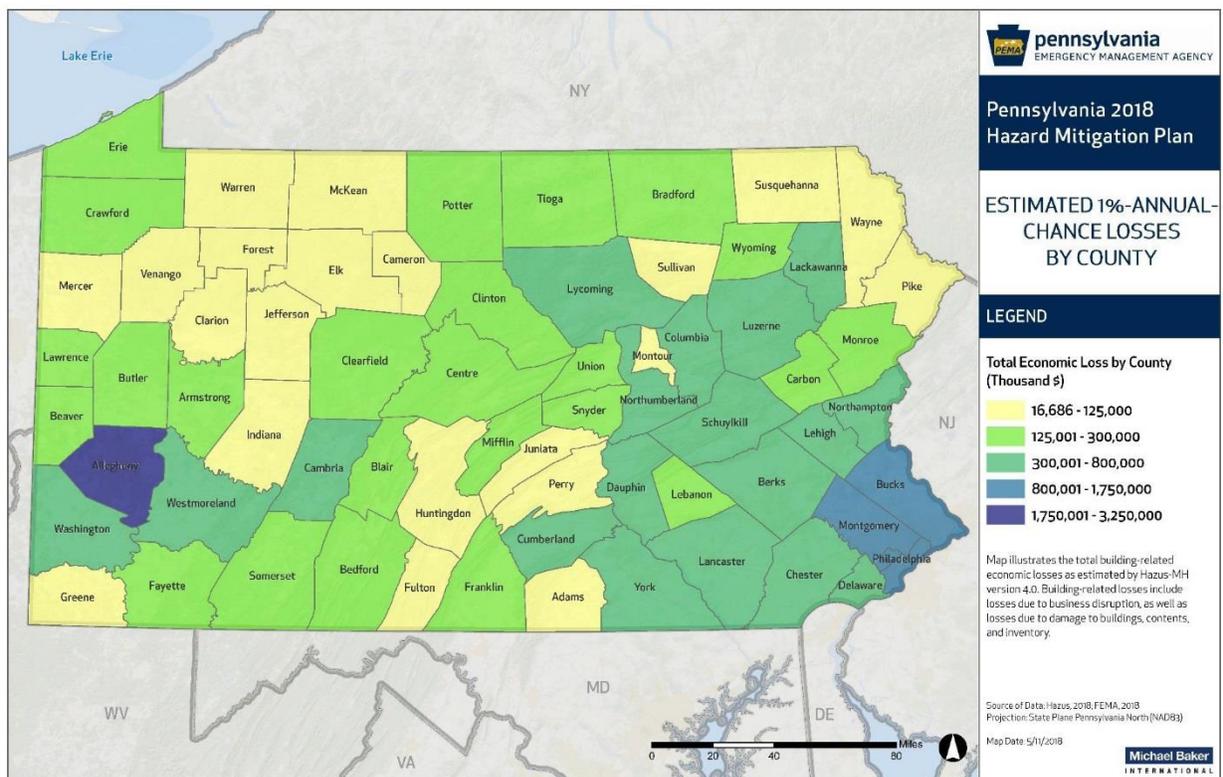
#### 1.4.1.1 User-Provided Data: Flood Example

Hazus can create probabilistic flood hazard data through an internal hydraulic & hydrology (H&H) model. This can provide a very general understanding of flood risk, however, as the Risk MAP program evolved, multi-frequency depth grid data are increasingly available from the

FEMA Maps Service Center or FEMA Regional Office. This data should be used instead of the Hazus H&H methodology when possible.

For example, the 2018 Pennsylvania State Hazard Mitigation Plan incorporates a statewide Level 2 Hazus Flood Study, in which the latest available FEMA flood data and the best available ground elevation data were used to derive local flood depths, as depicted in Figure 3. In addition, the default Hazus inventory of essential facilities was replaced with a more accurate inventory derived from the Department of Homeland Security’s Homeland Infrastructure Foundation-Level Data (HIFLD). This enhanced data was combined with the default Hazus building inventory and default depth-damage curves to estimate direct damages and associated social and economic impacts.

**Figure 3. Example of User-Provided Hazard Import Data in Flood Model**

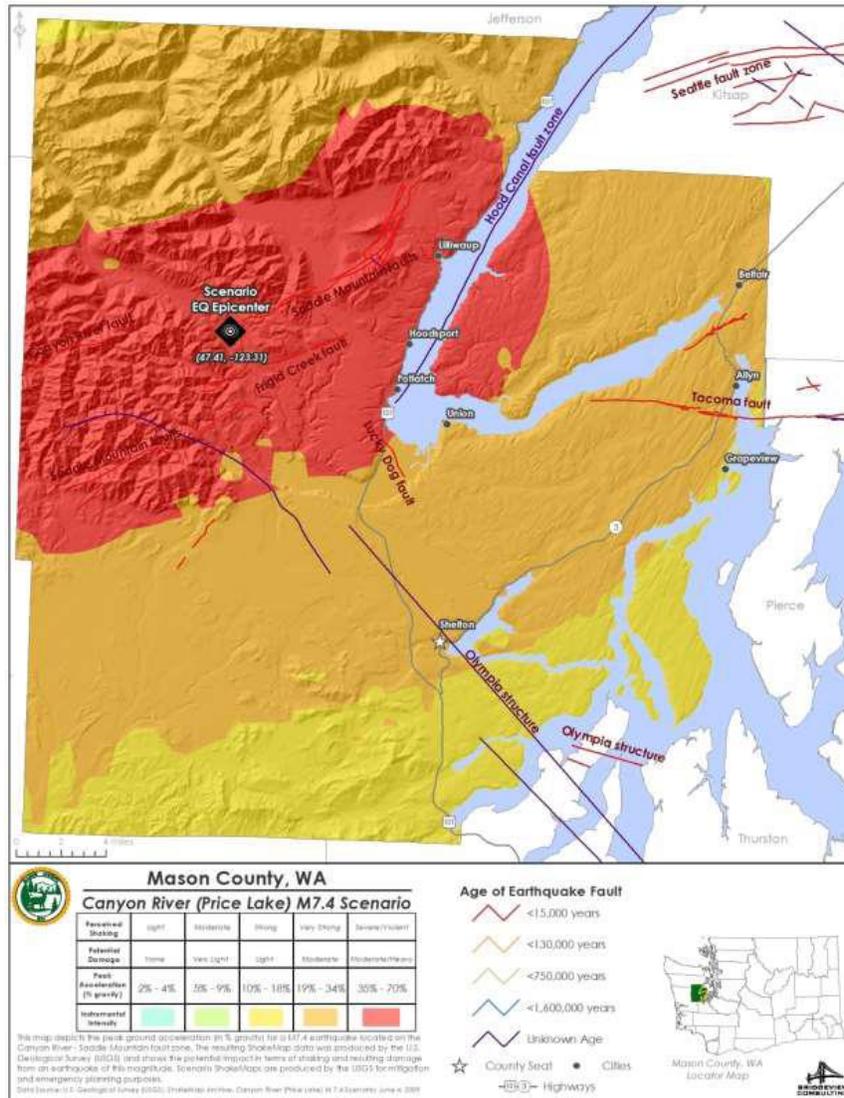


Source: 2018 Draft Pennsylvania State Hazard Mitigation Plan

### 1.4.1.2 User-Provided Data: Earthquake Example

The Mason County, Washington Multi-Jurisdiction Hazard Mitigation Plan update in 2017 used USGS ShakeMap data and Hazus to analyze multiple scenarios. Earthquake scenario maps were created to illustrate the expected ground motions and effects of hypothetical large earthquakes for specified areas. Property losses were then estimated through the Level 2 Hazus analysis for the Cascadia, Canyon River, and Nisqually earthquake scenarios events utilizing the USGS/Washington State Department of Natural Resources scenario catalog data and FEMA GIS datasets.

**Figure 4. Example of User-Defined Hazard Import Data in Earthquake Model**



Source: 2017 Mason County Multi-Jurisdiction Hazard Mitigation Plan

## 2.0 Defining the Study-Region

When writing a mitigation plan, the planning area needs to be clearly defined to help identify which hazards are of more interest and where these hazards are more likely to occur. For a local mitigation plan, the planning area can be a city, a town, entire county, or tribal lands. When more than one local jurisdiction is involved, the plan is referred to as a multi-jurisdictional mitigation plan. The planning area for a state mitigation plan is the entire state. For a tribal or regional plan, the planning area may include multiple areas that may not be contiguous. Hazus allows the user to define the planning area by creating a study region. A study region is the geographic area Hazus will use to conduct the various flood, hurricane, tsunami, and earthquake scenarios, and can be defined at the census block, census tract, county, or state level in the flood and tsunami models. In the earthquake and hurricane models, the study region can be defined at the census tract, county, or state levels. Defining the study region to create a

state mitigation plan or a local mitigation plan for an entire county is straightforward. To define the study region for a sub-county jurisdiction, the Hazus user will need to select the census blocks or tracts within the sub-county jurisdiction.

Once the user identifies the study region, Hazus can be used to create the base map to graphically represent the area. The base map will help planners profile hazards and will be used throughout the entire risk assessment. The base map may include region or state boundaries; geographic references such as roads and bodies of water; and buildings such as schools, police and fire stations, and hospitals. Figure 5 provides a sample base map prepared using Hazus.

**Figure 5. Base Map**



Source: FEMA/Hazus

Data used to create the base map may include default data from Hazus or data provided by different agencies. Data included in the software, such as demographic and economic data, are directly derived from decennial Census Bureau data and are updated after the data is released each decade. Hazus also includes inventory data for schools, police and fire stations, hospitals, and emergency response resources.

Although data included in Hazus is fairly recent, it might not be as detailed as data provided by the user, therefore users should confirm what is included and what data needs to be acquired. Using local data provided by different agencies or downloaded from local websites can improve the results of the risk assessment. The benefit of using local data is that key features of the community can be better represented. With local data, the user can add, delete, or manipulate existing data in Hazus, and therefore get more accurate results.

### 3.0 Using Hazus for Risk Assessment

Risk assessments, conducted for hazard mitigation, estimate the potential economic and social impact that a natural hazard can have on buildings, people, services, and infrastructure. Higher-quality data produces better and more reliable results in the risk assessment. Accurate and reliable risk assessment results help communities develop sound mitigation options to reduce their vulnerabilities. Figure 6 illustrates the concept of risk as the relationship, or overlap, between hazards and community assets. The smaller the overlap, the lower the risk.

**Figure 6. Assessing Risk in the Hazard Mitigation Plan**



*Source: Local Mitigation Planning Handbook, FEMA, 2013*

FEMA's Local Mitigation Planning handbook describes four recommended steps for performing a risk assessment (Figure 7). The desired outcomes of these steps are an evaluation of each hazard's potential impacts on the people, economy, and built and natural environments in the planning area, as well as an understanding of each jurisdiction's overall vulnerability and most significant risks. These potential impacts and the overall vulnerability can be used to create problem statements and identify mitigation actions to reduce risk.

**Figure 7. Steps to Conduct a Risk Assessment**



*Source: Local Mitigation Planning Handbook, FEMA, 2013*

Hazus has separate models for earthquake, flood, tsunami, and hurricane hazards. However, Hazus can also be used to perform GIS analyses for hazards not included in the software. For instance, if a map of areas susceptible to landslides is available, Hazus can be used to overlay those areas with the provided inventory (i.e., buildings, critical facilities, and lifelines) to reveal the components vulnerable to landslides. Similarly, wildfire-prone areas close to developed areas can be used to determine wildfire vulnerability. For hazards other than floods, earthquakes, tsunamis, and hurricanes, Hazus inventory information can be combined with reliable historical loss and probability data to help estimate probable losses using techniques not included in the software.

### 3.1 Step 1: Describe Hazards

<b>Requirement</b> <b>§201.6(c)(2)(i)</b>	[The risk assessment shall include a] description of the type, location and extent of all natural hazards that can affect the jurisdiction. The plan shall include information on previous occurrences of hazard events and on the probability of future hazard events.
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The first step in the risk assessment process is to begin identifying and profiling the hazards that affect the study region. The type and number of hazards will depend on the size of the area analyzed.

Several case studies using Hazus are described throughout this job aid to explain the risk assessment process. Once Hazus is run and analysis outputs are produced, these can be viewed in tabular, map, or printed report formats.

#### 3.1.1 Hazard Identification

Hazard identification is the first step in risk assessment. Details about how to identify hazards can be found in FEMA's Local Mitigation Planning Handbook. Once the community, preparing its hazard mitigation plan, has identified the hazards that affect them, it is useful to know the extent to which Hazus can be used for each hazard's risk assessment.

### 3.1.2 Profile Hazards

After potential hazards are identified, each hazard that affects the community or study region must be profiled. The main elements needed to prioritize hazards for each jurisdiction, as required by DMA 2000, in a mitigation plan include: location, extent, history, and future probability. Also, in a multi-jurisdiction plan, the plan must describe any hazards that are unique and/or varied from those affecting the overall area.

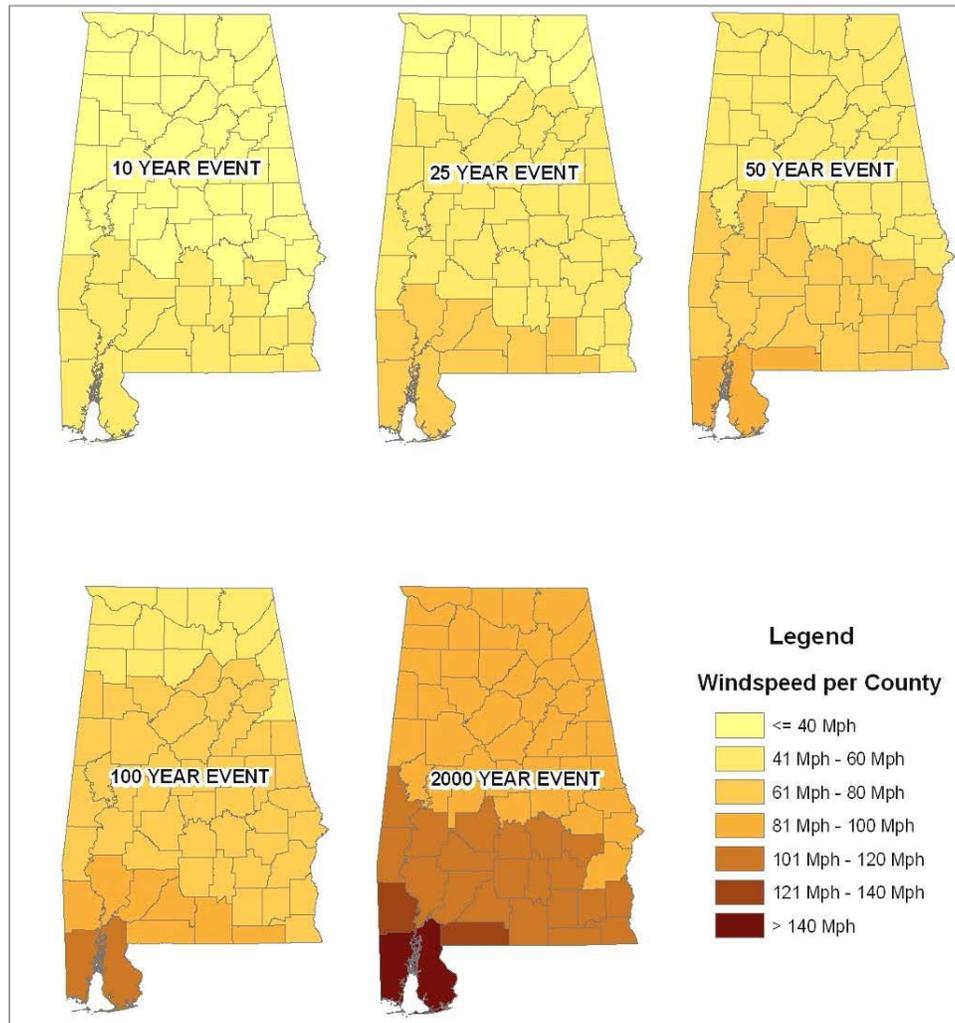
Hazus can assist in profiling hazards in the study region (identified in the base map) by providing the history of hazard occurrences, as well as the location, frequency, and magnitude of an event. Hazus can also be used to identify any differences in risk between multiple communities. If needed, a data gap analysis can be done to verify Hazus data with other locally available data; there might be certain data that is either not included or incomplete in Hazus. In this case, more research needs to be done through searching the Web; acquiring local data from various agencies, newspapers, other historical records, reports, or existing plans; or talking to other experts in the field.

Graphic information produced by Hazus will help stakeholders and decision makers to devise mitigation actions to protect different structures. Mitigation actions will be discussed later in the job aid, but these might include acquiring floodprone structures, elevating residential structures, restricting building on or near hazard areas, etc.

The maps on the following page illustrate case examples that have been or can be incorporated into hazard mitigation plans using Hazus. As it will be seen throughout this job aid, maps in Hazus can be created in different ways with different layouts and color schemes, the user is not restricted to a single template. However, maps for different hazards in a single plan document should be similar in layout and color scheme for easy comparison and understanding.

For the State of Alabama, the effects of high winds are considered very severe and can happen throughout the entire area. Figure 8 shows the maximum expected one-minute, open terrain, sustained wind speeds from hurricanes in Alabama for 10-, 25-, 50-, 100-, and 2,000-year return periods. This analysis helped the State to conclude in the hazard profile that it had a high probability of experiencing high winds (except for a few northern counties, the State has at least a 1 percent chance of experiencing hurricane winds every year).

**Figure 8. Probabilistic Maximum Sustained Wind Speeds for Alabama**



Source: 2007 Alabama State Hazard Mitigation Plan

Figure 9 shows the 100-year flood hazard areas and buildings in the floodplain for Crown Pointe, Indiana based on Hazus data. Maps generated in Hazus can be incorporated into the mitigation plan to identify the location (geographic area) that can be affected by each identified natural hazard.

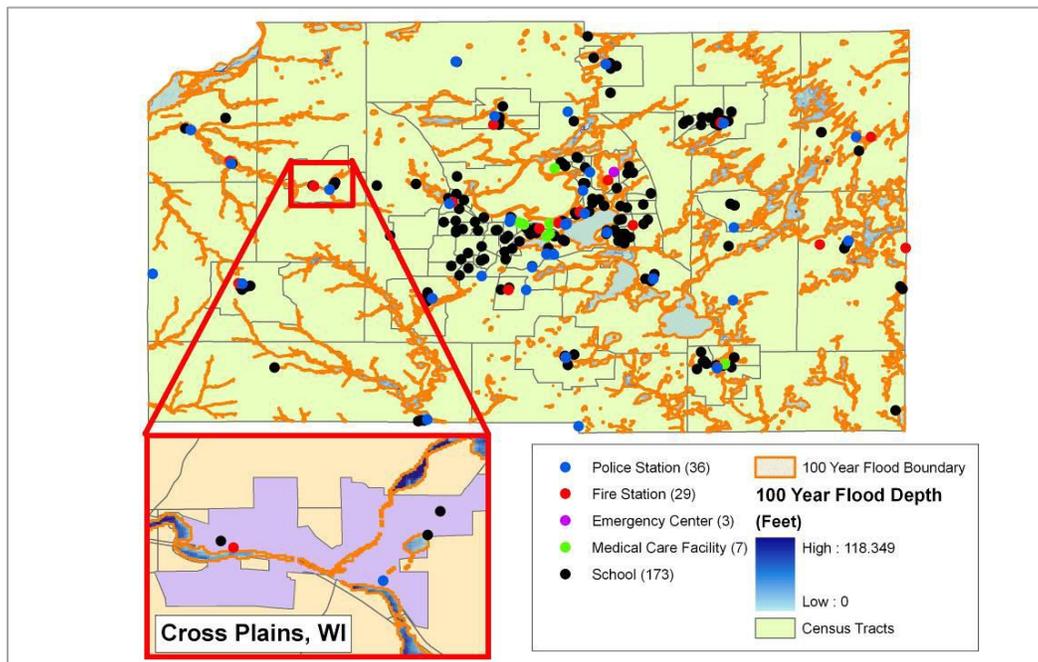
**Figure 9. 100-Year Flood Hazard Boundary and Buildings in Floodplain, Crowne Pointe**



Source: 2010 Lake County Multi-Hazard Mitigation Plan

When using Hazus, the analysis can also be done for smaller areas such as a county or city. Figure 10 identifies the location of the flood hazard areas within the County. Additionally, this map includes existing facilities, which will help in the next step of identifying the structures vulnerable to flooding.

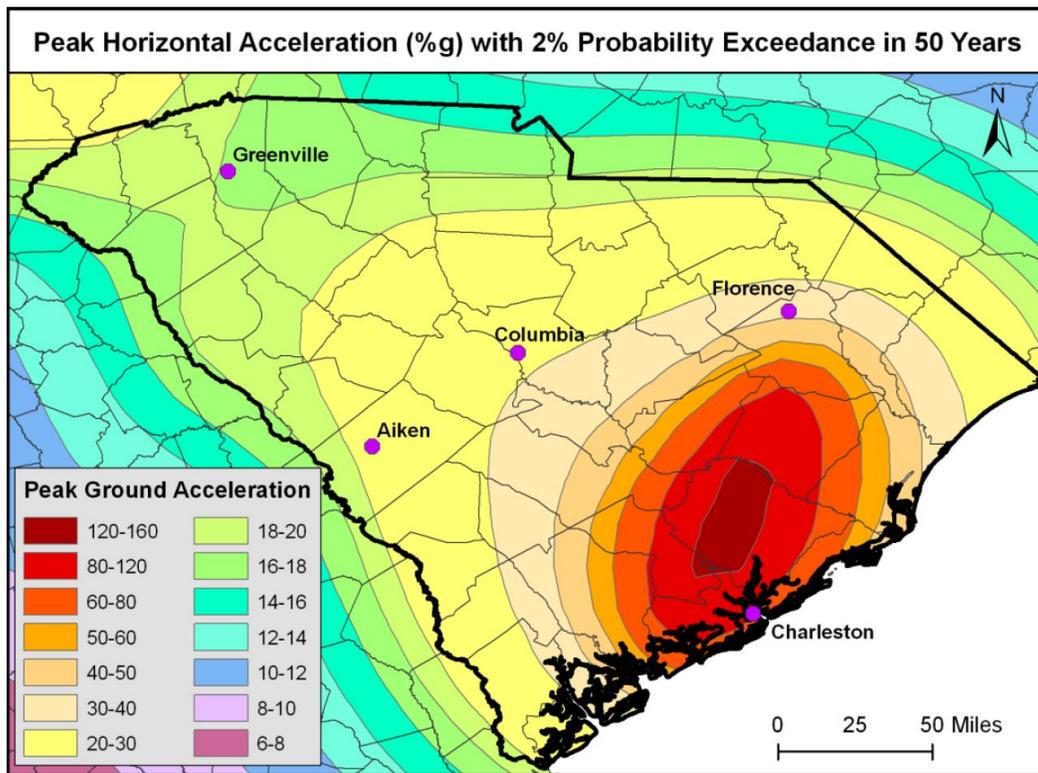
**Figure 10. 100-Year Flood Analysis, Dane County, Wisconsin**



Source: FEMA/Hazus

Figure 11 shows a map from the 2018 South Carolina State Hazard Mitigation Plan, illustrating anticipated ground movement generated by Hazus. This map helps identify existing or planned areas within the study region that might be at risk of damage or loss. Other user-supplied data, including fault locations, historic epicenters, liquefaction, or landslide maps, can also be helpful to incorporate into the analysis for later adoption of risk reduction measures.

**Figure 11. Ground Shaking by Census Tract**



Source: 2018 South Carolina State Hazard Mitigation Plan

### 3.2 Step 2: Identify Community Assets

<p><b>Requirement</b> <b>§201.6(c)(2)(ii)</b></p>	<p>[The risk assessment shall include a] description of the jurisdiction’s vulnerability to the hazards described in paragraph (c)(2)(i) of this section. This description shall include an overall summary of each hazard and its impact on the community.</p>
<p><b>§201.6(c)(2)(ii)(A)</b></p>	<p>The plan should describe vulnerability in terms of:</p> <p>(A) The types and numbers of existing and future buildings, infrastructure, and critical facilities located in the identified hazard areas;</p>

The second step in the risk assessment process is to inventory assets. These assets will be considered according to the prioritized hazards affecting the study region. The key elements required in a mitigation plan include information on natural assets, infrastructure, vulnerable structures, critical facilities, and populations in the hazard areas that can be affected.

Before incorporating any information into the hazard mitigation plan, the person writing the plan needs to become familiar with the inventory data in Hazus and how the data and results can be incorporated into the mitigation plan.

To generate the hazard mitigation plan's inventory of vulnerable assets, planners need to utilize the hazard profile information developed earlier in the planning process and overlay the data with the common inventory data for the study region included for all four models in Hazus (flood, hurricane, earthquake, and tsunami) to support the loss estimates and risk assessment.

The asset types may be as detailed as the Hazus occupancy type classes listed earlier or classified by asset construction dates, such as existing or new development or structures built to different building code standards.

### 3.2.1 General Building Stock

The General Building Stock (GBS) includes residential, commercial, industrial, agricultural, religious, government, and educational occupancy types. Buildings in Hazus are also classified to group similar structure valuation, damage, and loss characteristics. Refer to Hazus guidance documents for more information regarding the general occupancy types as well as the specific occupancy types included in Hazus.

Damages are estimated using building count and square footage by the census block or census tract, depending on which Hazus model is being viewed. The Flood Model displays the GBS data at the census block level, while the Hurricane and Earthquake Models display GBS data at the census tract level.

The main GBS databases include the following:

- **Square Footage by Occupancy:** These data are the estimated floor area by specific occupancy.
- **Full Replacement Value by Occupancy:** These data provide estimated replacement values by specific occupancy.
- **Building Count by Occupancy:** These data provide an estimated building count by specific occupancy.
- **General Occupancy Mapping:** These data are used to produce a map for the General Building Stock inventory data from the specific occupancy to general building type.
- **Demographics:** This table provides housing and population statistics for the area.

To satisfy mitigation planning requirements, the plan developers can use either Hazus classifications or a local classification system with a similar level of detail.

When using Hazus Flood, each study region is built using the dasymetric GBS data which removes areas without population based on the National Land Cover Land Use Dataset.

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### **3.2.2 Essential Facilities**

Essential facilities include medical care facilities, fire stations, police stations, emergency centers, and schools. These serve the health and welfare of the community and must function properly after a disaster.

### **3.2.3 High Potential Loss Facilities**

These facilities include nuclear power plants, dams, levees, and military installations; damage to these facilities would result in a high loss.

### **3.2.4 Hazardous Material Facilities**

These include storage facilities for hazardous materials, like corrosives, explosives, flammable materials, radioactive materials, and toxins.

### **3.2.5 Transportation Systems**

Transportation systems include highways (roadways, bridges, and tunnels.); railways (tracks, bridges, tunnels, stations, fuel, dispatch, and maintenance facilities.); light rail; bus (urban stations, fuel facilities, dispatch and maintenance facilities.); ports (waterfront structures, cranes/cargo handling equipment, warehouses and fuel facilities); ferries (waterfront structures, passenger terminals, warehouses, fuel facilities, and dispatch and maintenance facilities.); and airports (control towers, runways, terminal buildings, parking structures, fuel facilities, and maintenance and hanger facilities).

### **3.2.6 Lifeline Utility Systems**

Lifeline utility systems include potable water, wastewater, oil, natural gas, electric power, and communication systems.

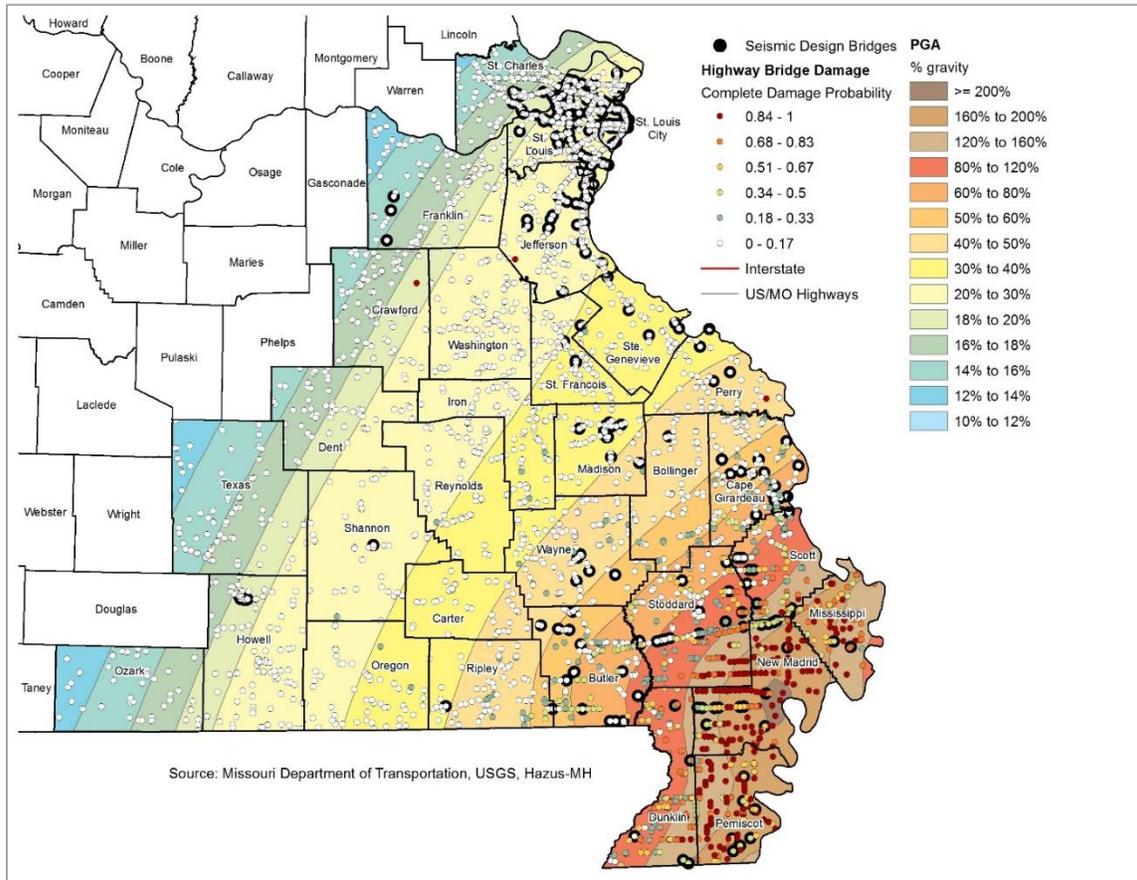
The entire inventory data included in Hazus will not indicate any vulnerability or loss until the software is run for a specific event or scenario. Once this is done, the results will be representative of potential loss to the degree of detail the user determines.

Some of the critical facilities in Hazus might not be considered “critical” by the community. On the other hand, there might be other key community assets that need to be included in the critical facilities inventory. These critical facility inventory data changes should happen during the planning process.

For data accuracy, location of structures and critical facilities mapped using Hazus need to be reviewed, corrected, and validated during planning meetings. Accurate location information that is not available in Hazus can be added and edited in Hazus software. The most current and accurate data, especially for infrastructure (such as bridges and pipelines), might be available from local and State agencies.

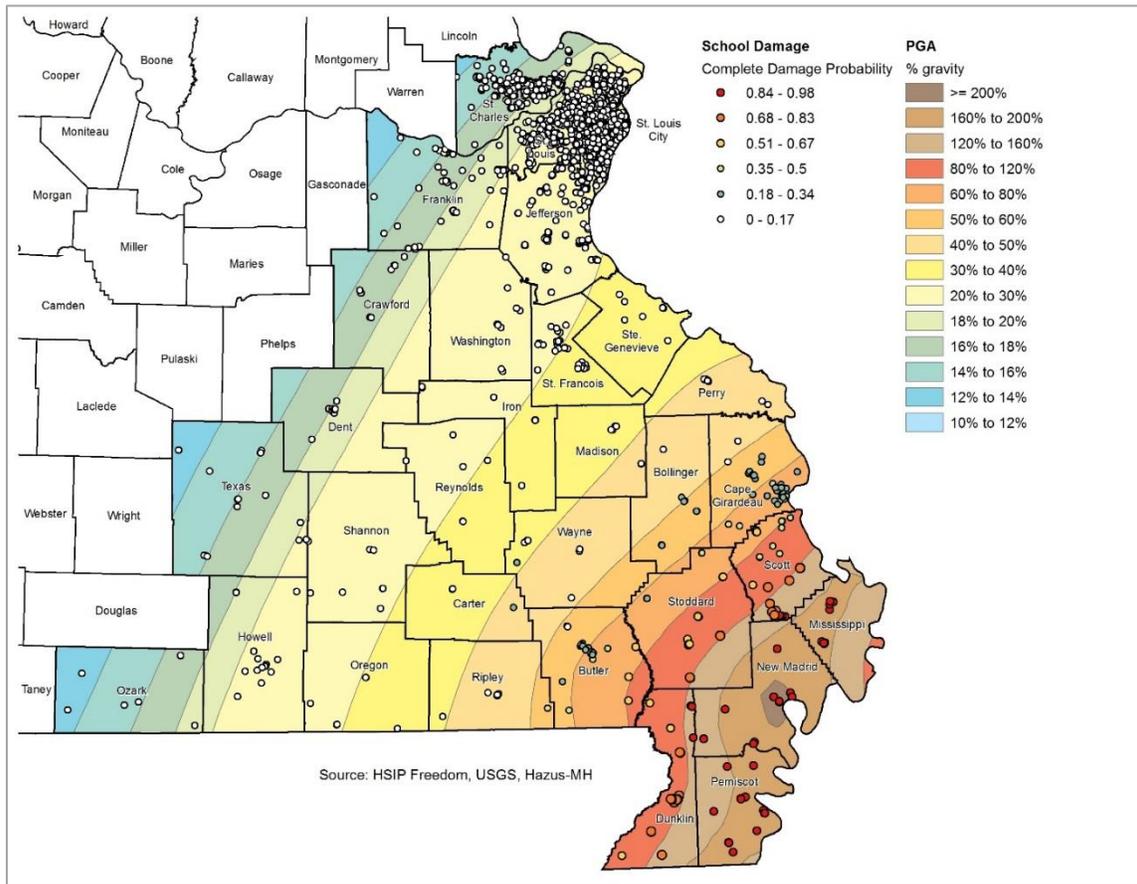
Figures 12 and 13 provide examples of how data generated in Hazus can be incorporated into the mitigation plan to represent asset inventory. Figure 12 illustrates bridges vulnerable to the earthquake hazard in Missouri, and Figure 13 identifies the school facilities vulnerable to the earthquake hazard. This kind of information can be included in the mitigation plan to describe vulnerability in terms of the types and numbers of existing and future buildings, infrastructure, and critical facilities located in the identified hazard area.

**Figure 12. Bridges Vulnerable to Earthquake**



Source: 2013 Missouri State Hazard Mitigation Plan

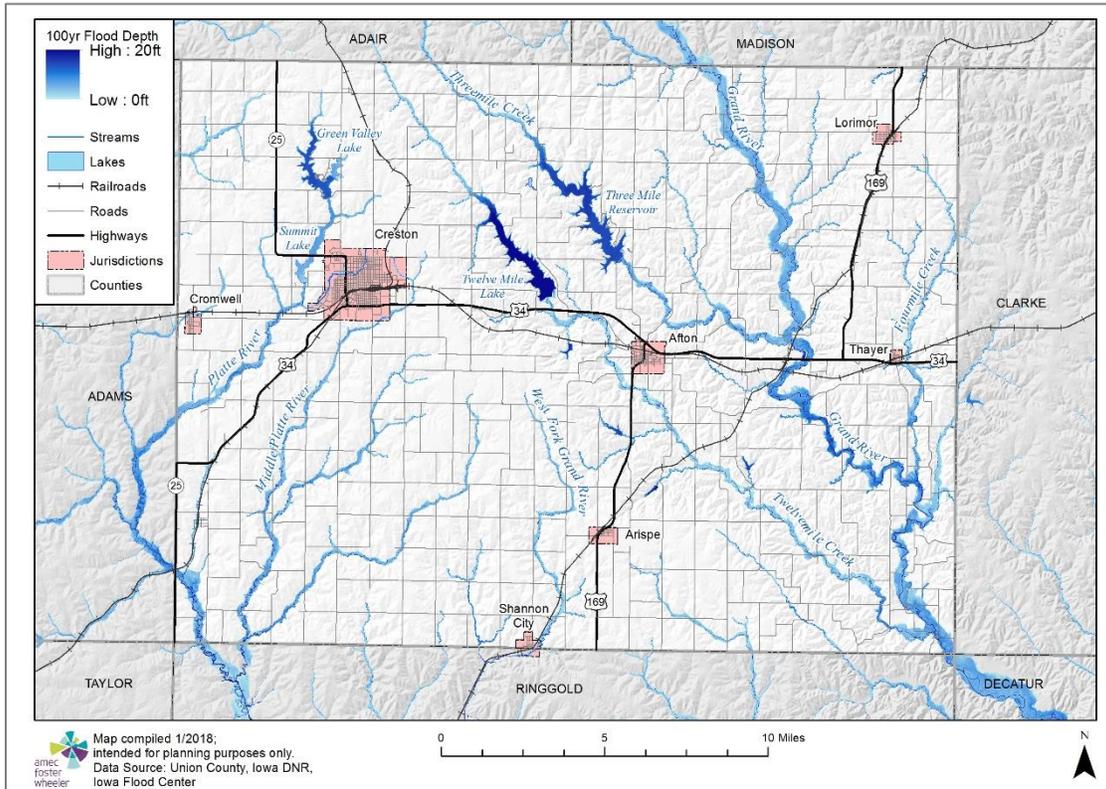
**Figure 13. Vulnerable Schools to Earthquake**



*Source: 2013 Missouri State Hazard Mitigation Plan*

Figure 14 illustrates the same information, but on the local level for Union County, Iowa. On a local level, it is sometimes possible to know the precise location of all the buildings within the study region. This detailed level of data assists the planning team in identifying the locations of the buildings that are susceptible to flooding. This county-wide map can then be used to identify areas for further investigation.

**Figure 14. 100-Year Flood Depths for Union County, Iowa**

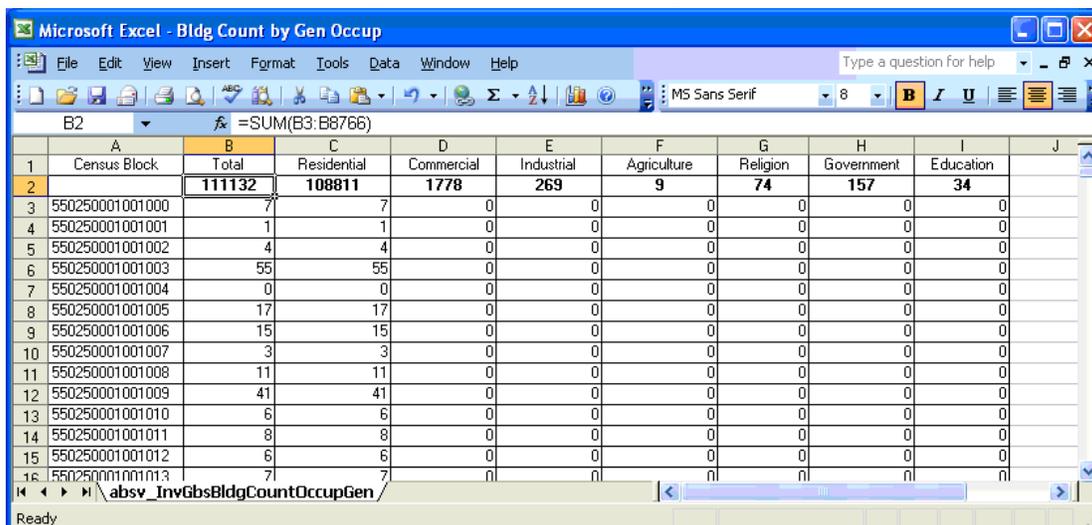


Source: 2018 Iowa State Hazard Mitigation Plan

### 3.2.7 Quantify Community Assets

Hazus can produce a table that counts all the assets in a county by census blocks, this is called “total building exposure” in Hazus. Plan preparers need to take the Hazus output, export the table into Excel, and add the counts to show totals by county (see Figure 15 example).

**Figure 15. Total Building Count**



	A	B	C	D	E	F	G	H	I	J
1	Census Block	Total	Residential	Commercial	Industrial	Agriculture	Religion	Government	Education	
2		<b>111132</b>	<b>108811</b>	<b>1778</b>	<b>269</b>	<b>9</b>	<b>74</b>	<b>157</b>	<b>34</b>	
3	550250001001000	7	7	0	0	0	0	0	0	0
4	550250001001001	1	1	0	0	0	0	0	0	0
5	550250001001002	4	4	0	0	0	0	0	0	0
6	550250001001003	55	55	0	0	0	0	0	0	0
7	550250001001004	0	0	0	0	0	0	0	0	0
8	550250001001005	17	17	0	0	0	0	0	0	0
9	550250001001006	15	15	0	0	0	0	0	0	0
10	550250001001007	3	3	0	0	0	0	0	0	0
11	550250001001008	11	11	0	0	0	0	0	0	0
12	550250001001009	41	41	0	0	0	0	0	0	0
13	550250001001010	6	6	0	0	0	0	0	0	0
14	550250001001011	8	8	0	0	0	0	0	0	0
15	550250001001012	6	6	0	0	0	0	0	0	0
16	550250001001013	7	7	0	0	0	0	0	0	0

Source: FEMA/Hazus

The asset inventory section of the plan needs only the total count of vulnerable structures, not the details of how much damage they will experience; that would be addressed in the loss estimation section.

### 3.3 Step 3: Analyze Risks

<b>Requirement</b> <b>§201.6(c)(2)(ii)</b>	[The risk assessment shall include a] description of the jurisdiction’s vulnerability to the hazards described in paragraph (c)(2)(i) of this section. This description shall include an overall summary of each hazard and its impact on the community.
<b>§201.6(c)(2)(ii)(B)</b>	The plan should describe vulnerability in terms of:  (B) An estimate of the potential dollar losses to vulnerable structures identified in ... this section and a description of the methodology used to prepare the estimate.

The third step in the risk assessment process is to analyze risks. This determines how the community’s assets are affected by the identified hazards. By this point, the study region has been identified, hazards have been profiled, and there is an inventory of assets. This step will bring all the information together to estimate losses due to hazard events.

Methods for analyzing risk include exposure analysis, historical analysis, and scenario analysis. Qualitative evaluations describe the types of impacts that might occur during a hazard event. Quantitative evaluations, such as Hazus, assign values and measure the potential losses to the assets at risk. The planning team will likely use a combination of methods for analyzing risk and express impacts both qualitatively and quantitatively, depending on the hazard and the available time, data, staff, and technical resources.

The following examples illustrate how the Yurok Tribe of Northern California and State of Missouri incorporated Hazus results into their mitigation plans.

#### 3.3.1 Example 1: Yurok Tribe of Northern California Tsunami Analysis

When the Yurok Tribe updated their hazard mitigation plan in 2013, Hazus was utilized to evaluate risk for earthquake, flood and tsunami. As stated in the plan, a UDF approach was used to model exposure and vulnerability. Building information for 892 structures was developed using best available tribal data, including building address points, aerial imagery, Parcel Quest data and tribal staff resources. Building and content replacement values were estimated using values from the tribe’s 2006 Hazard Mitigation Plan, as well as national replacement cost estimating guides. Emphasis was put on developing the most accurate representation of buildings using best available resources.

Tsunami inundation mapping for the planning area was collected where available. A user-defined facility model, specific to buildings, was developed and incorporated a GIS-produced depth grid, which has a level of accuracy acceptable for planning purposes. Where possible, the Hazus default data was enhanced using local GIS data from tribal, state and federal sources.

Figure 16 shows the exposure value of structures in the tsunami hazard area.

**Figure 16. Structures Exposed to Tsunami Inundation Zone**

	Assessed Value			% of AV
	Structure	Contents	Total	
Tribal Facilities	\$6,120,000	\$6,120,000	\$12,240,000	24.58%
Non-Tribal Government	\$626,864	\$626,864	\$1,253,728	9.20%
Non-Residential	\$3,519,154	\$2,780,831	\$6,299,985	27.67%
Residential	\$7,034,004	\$3,517,002	\$10,551,006	5.21%
<b>Total</b>	<b>\$17,300,022</b>	<b>\$13,044,697</b>	<b>\$30,344,719</b>	<b>10.52%</b>

Source: 2013 Yurok Tribe Hazard Mitigation Plan

Hazus results indicate that Highway 101 and Highway 169, as well as numerous arterial roads and streets, may be impacted by tsunami events. The analysis also identifies 12 bridges that would be exposed to the tsunami scenario event.

The generated loss estimates for the estimated tsunami hazard areas are reflected in Figure 17. It is estimated that there would be up to \$5.2 million of loss from a scenario tsunami hazard event.

**Figure 17. Loss Estimates for Tsunami**

	Structures Impacted <sup>a</sup>	Estimated Loss			% of Total Value
		Structure	Value	Total	
Tribal Facility	1	\$1,530,000	\$1,080,000	\$2,610,000	5.24%
Government Non-Tribal	0	\$0	\$0	\$0	0.00%
Non Residential	9	\$672,388	\$766,070	\$1,438,458	6.32%
Single Family Residential	8	\$815,489	\$387,746	\$1,203,236	0.59%
<b>Total</b>		<b>\$3,017,878</b>	<b>\$2,233,816</b>	<b>\$5,251,694</b>	<b>1.82%</b>

a. Impacted structures are those structures expected to receive measurable damage from the scenario tsunami event because they have lowest floor elevations below the projected tsunami inundation height.

Source: 2013 Yurok Tribe Hazard Mitigation Plan

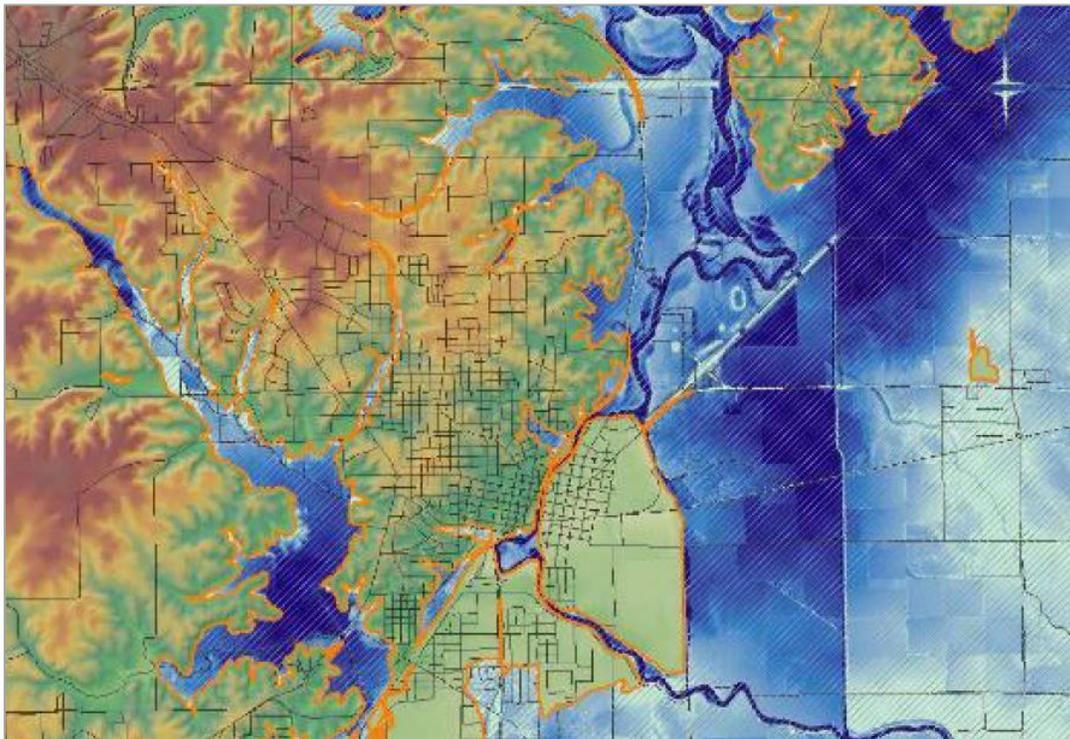
### 3.3.2 Example 2: State of Missouri Flood Analysis

The vulnerability of Missouri to flooding is significant. For the 2018 State Plan Update, the Missouri State Emergency Management Agency (SEMA) used Hazus to model flood vulnerability and estimate flood losses for all 114 counties and the City of St. Louis. Additional hazard data inputs were utilized, as available, to perform Level 2 analyses. This included the extensive use of the FEMA special flood hazard area data and Risk MAP flood risk datasets.

When evaluating flood risk for the State of Missouri, it was recognized that digital FIRM and Risk MAP datasets were more comprehensive and could assess risk at a more refined level of detail than the floodplains produced entirely by Hazus. While Hazus models are accurate, default analysis is conducted at the 10 sqm scale, whereas the digital FIRM (DFIRM) and Risk MAP data utilizes a 1 sqm scale. Flood analysis was therefore conducted using the latter datasets, in conjunction with available LiDAR data from the Missouri Spatial Data Information Service (MSDIS) and the US Army Corps of Engineers. When LiDAR was not entirely available, US Geological Survey (USGS) 10-meter digital elevation models were used to supplement any gaps.

To complete the state's user-generated DFIRM depth grid profile, ArcGIS Model-builder was utilized to create series of models using the DFIRM data and elevation data as inputs. The results are displayed in Figure 18, illustrating the depth grid generated by the model, which served as an input for the Hazus flood vulnerability and loss analysis.

**Figure 18. Example of a DFIRM Depth Grid in Detailed Areas – Butler County, MO**



*Source: 2018 Missouri State Hazard Mitigation Plan*

SEMA enhanced the Hazus analysis with a structure inventory dataset developed by the University of Missouri GIS Department (MSDIS) to indicate the number of structures exposed to the risk. MSDIS created a point and/or footprint dataset for every roof line in every county in the state of Missouri. This dataset is attributed with the type of structure such as Residential, Commercial, etc. For this risk assessment analysis, the MSDIS dataset was intersected with the existing depth grids from FEMA Risk MAP products, outside of the Hazus environment. This intersection provided an estimated number of structures, by type, that were exposed to the risk of flooding as well as the estimated depth of water for the twelve counties.

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Tables include both results:

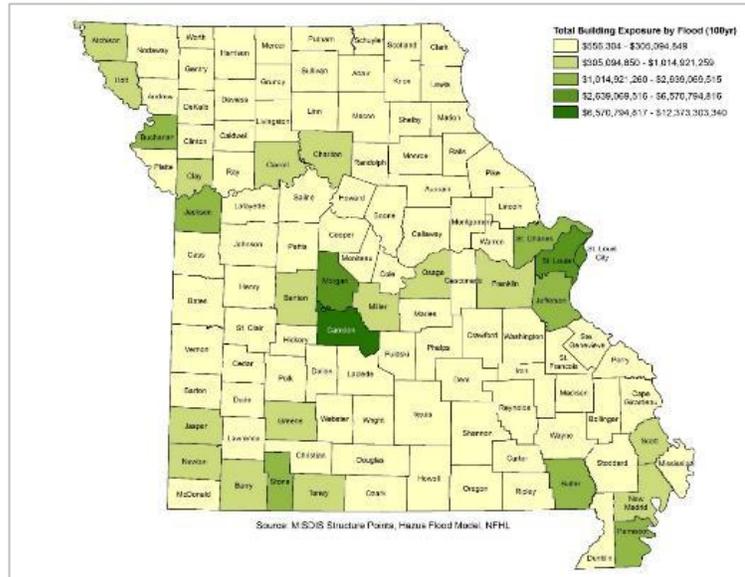
- Hazus building inventory with enhanced Level 2 essential facility data from the Homeland Security Infrastructure Program (HSIP) (2017) summarized to the census block level with a demographic/loss estimate ratio applied to reflect population changes from 2000 – 2010.
- MSDIS building inventory intersection with the floodplain summarized to the county level.

Hazus impact analyses were completed for all counties, and the City of St. Louis. Counties were then ranked based on these risk indicators and Hazus flood results were mapped to show flood loss potential and how it varies across the State. The primary indicators used to assess flood losses were:

- **Direct Building Losses:** Calculated within Hazus from US Census data.
- **Loss Ratio of the Direct Building Losses Compared to Overall Building Inventory:** The severity of impacts on community sustainability is indicated by the loss ratio of the direct building losses compared to overall building inventory. While a large urban area may have the greatest dollar losses, it may be able to absorb the impact better than a more rural area where a flood could impact a significant amount of the infrastructure in the entire county.
- **Count of Residential Buildings Exposed to Flooding (MSDIS):** To determine the number of residential buildings exposed to the 1-percent annual chance flood event, the MSDIS dataset was intersected with the depth grids outside of the Hazus environment. This provides an indication of the potential magnitude of a flood event.
- **Count of Residential Buildings Potentially Damaged by Flooding (Hazus):** Hazus analysis utilized US Census data to estimate the number of residential structures at risk of damage and the number of structures expected to receive substantial damage during a 1-percent annual chance flood event. Note, there are instances where the Hazus analysis predicted a greater number of damaged buildings than were identified with the exposed MSDIS points. This is due a fundamental premise of the Hazus Level 1 flood loss methodology that the buildings are uniformly distributed within census blocks.
- **Income Losses, Population Displaced by the Flood, and Shelter Needs:** Calculated within Hazus from US Census data.

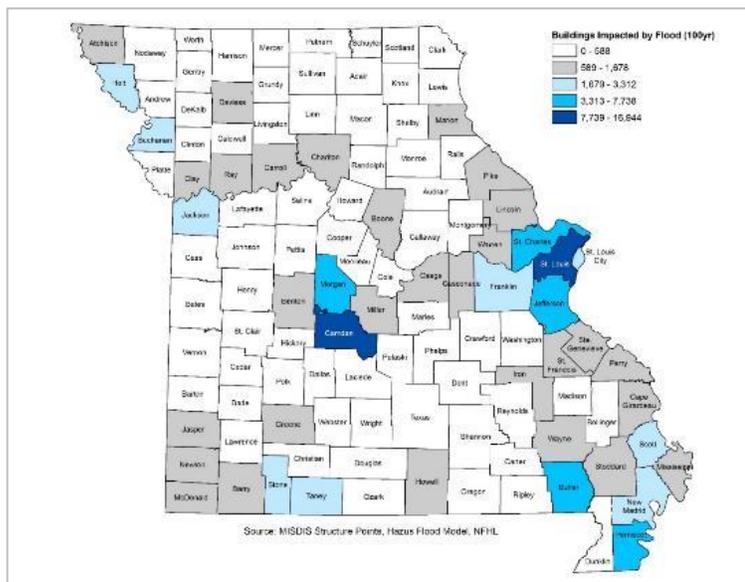
The figures that follow present the results of the primary indicators for each of Missouri's 114 Counties and the City of St. Louis.

**Figure 19. Hazus Countywide Base-Flood Scenarios: Building and Income Loss**



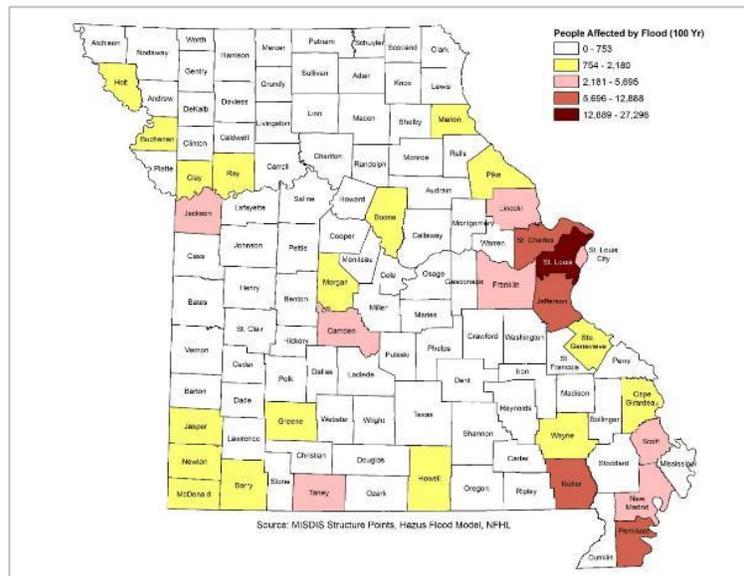
Source: 2018 Missouri State Hazard Mitigation Plan

**Figure 20. Hazus Countywide Base-Flood Scenarios: Building Loss Ratio**



Source: 2018 Missouri State Hazard Mitigation Plan

**Figure 21. Hazus Countywide Based-Flood Scenarios: Displaced People**



Source: 2018 Missouri State Hazard Mitigation Plan

Using the GIS Analysis with the FEMA special flood hazard areas and the MSDIS structure points described earlier, it is estimated that more than 43,486 Missouri households are within the special flood hazard area. In addition, thousands of other Missouri residents are at risk to the dangers of flash flooding from rapidly rising creeks and tributaries, storm water runoff, and other similar flooding events. Nationwide, most flood deaths are from flash floods, and nearly half of these fatalities are auto-related, according to the NWS.

Hazus analyzes loss estimates for critical infrastructure and facilities as well, including vehicle losses, utility system losses, essential facility impacts, transportation impacts, as well as agricultural losses. Hazus also provides the results in more detail, and some results, spatially. Project files for each county are available for use by local governments from SEMA.

### 3.4 Step 4: Summarize Vulnerability

<p><b>Requirement</b> <b>§201.6(c)(2)(ii)</b></p>	<p>[The risk assessment shall include a] description of the jurisdiction’s vulnerability to the hazards described in paragraph (c)(2)(i) of this section. This description shall include an overall summary of each hazard and its impact on the community.</p>
<p><b>§201.6(c)(2)(ii)(A)</b></p>	<p>The plan should describe vulnerability in terms of:</p> <p>The types and numbers of existing and future buildings, infrastructure, and critical facilities located in the identified hazard areas;</p>

To use Hazus to illustrate which community assets are vulnerable to a hazard, the following steps may be followed using the Hazus outputs:

### 3.4.1 Calculate the Percentage of Vulnerable Community Assets

Hazus software loss estimation methodology provides users with a decision support software for estimating potential losses from floods, hurricane, earthquake, and tsunami scenario events. This loss estimation capability enables users to calculate the percent of vulnerable community assets and develop plans and strategies for reducing risk. The total amount of buildings within a defined study area are used within the loss estimation methodology to identify the amount of vulnerable buildings to the identified hazard. The amount of vulnerable buildings will be dependent on the hazard identified (flood, hurricane, earthquake, or tsunami) and the General Building Stock data used.

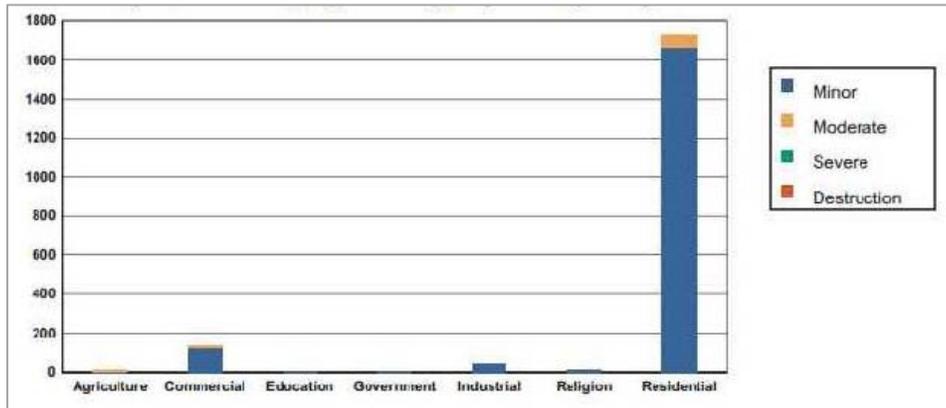
Plan authors can calculate how much of the community is vulnerable and evaluate the asset inventory. The results of the assessment should include a table outlining the distribution vulnerability across different structural types and locations. The Commonwealth of Virginia Multi-Hazard Mitigation Plan evaluates vulnerability for non-rotational winds hazard using the Hazus earthquake model. Analysis is conducted for seven regions defined by the Virginia Department of Emergency Management (VDEM). Figure 22 and 23 show expected building damage by occupancy type for the 100-year hurricane event for VDEM Region 1.

**Figure 22. Expected Building Damage by Occupancy Results Table  
(100-Year Probabilistic Event)**

Occupancy	None		Minor		Moderate		Severe		Destruction	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Agriculture	1,498	99.49	7	0.48	0	0.02	1	0.01	0.00	0.00
Commercial	23,730	99.46	126	0.53	4	0.01	0	0.00	0.00	0.00
Education	1,111	99.44	6	0.56	0	0.00	0	0.00	0.00	0.00
Government	991	99.35	6	0.64	0	0.00	0	0.00	0.00	0.00
Industrial	6,661	99.39	40	0.6	1	0.01	0	0.00	0.00	0.00
Religion	3,005	99.54	14	0.46	0	0.00	0	0.00	0.00	0.00
Residential	427,209	99.6	1670	0.39	60	0.01	0	0.00	0.00	0.00
<b>Total</b>	<b>464,205</b>		<b>1,870</b>		<b>65</b>		<b>1</b>		<b>-</b>	

Source: 2018 Commonwealth of Virginia Hazard Mitigation Plan

**Figure 23. Expected Building Damage by Occupancy (100-Year Probabilistic Event)**



Source: 2018 Commonwealth of Virginia Hazard Mitigation Plan

This type of information can be incorporated into the mitigation plan to show the types of structures that are vulnerable to identified hazards. Hazus can also be used to evaluate damage to essential facilities and services. Hazus will produce a report that details impacted resources and anticipated community needs following the probabilistic event. The hurricane scenario run for the Commonwealth of Virginia estimated the expected damages to all critical facilities in the region as provided in Figure 24.

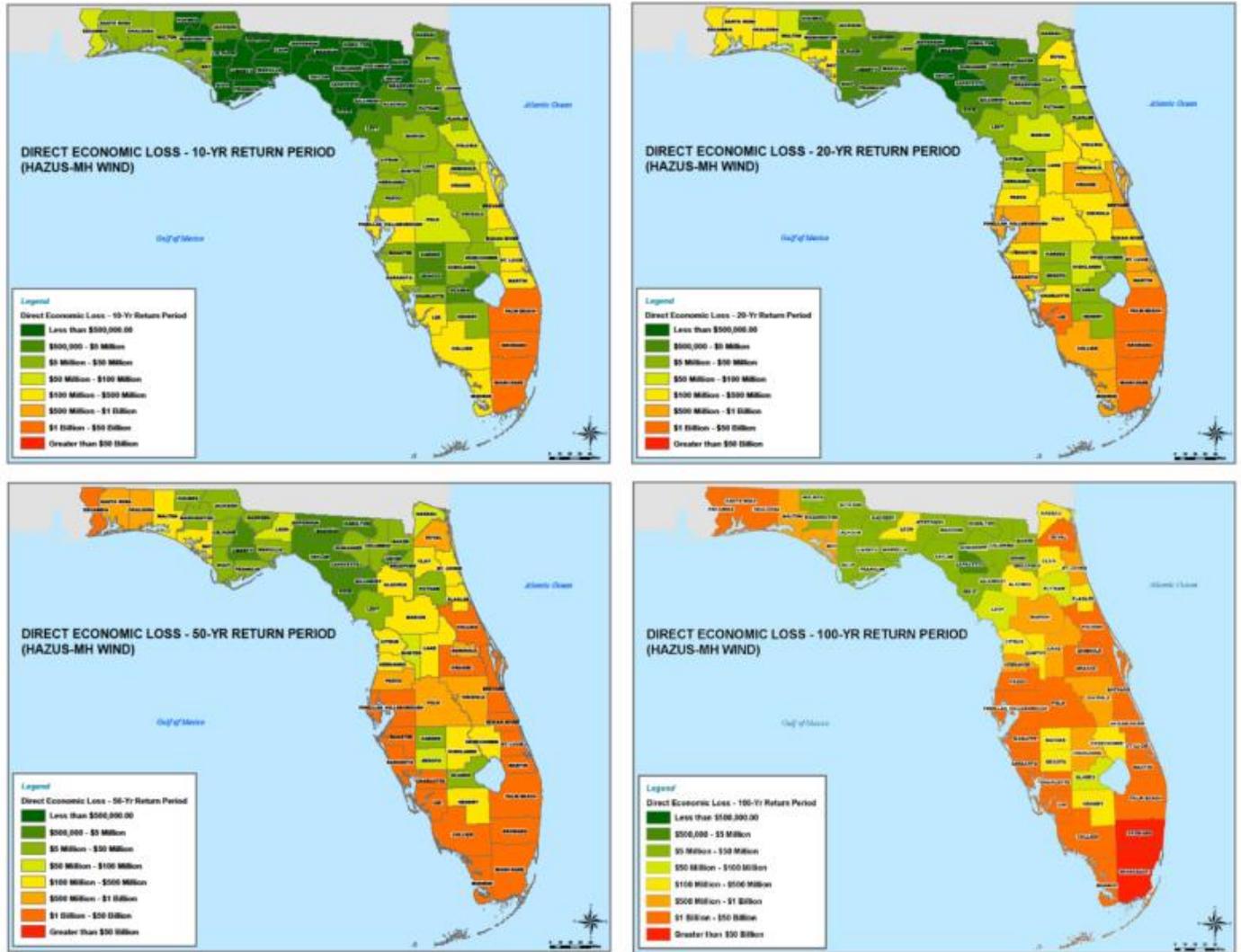
**Figure 24. Expected Damage to Essential Facilities (100-Year Probabilistic Event)**

Classification	Total	# Facilities		
		Probability of at Least Moderate Damage > 50%	Probability of Complete Damage > 50%	Expected Loss of Use <1 day
EOCs	3	0	0	3
Fire Stations	55	0	0	55
Hospitals	28	15	0	28
Police Stations	57	0	0	57
Schools	410	0	0	410

Source: 2018 Commonwealth of Virginia Hazard Mitigation Plan

In addition to generating information to understand estimated structural damages, Hazus users can also create maps to geospatially illustrate direct economic losses. The State of Florida experiences significant risk to tropical cyclones and during the 2018 Enhanced State Plan update, the Hazus wind model was utilized to evaluate losses across the state for the 10-, 20-, 50-, 100-, -200, -500, and 1000-year events. Direct economic losses refer to the sum of capital stock losses (cost building damage, cost contents damage, and inventory loss) and income losses (cost of relocation, capital related loss value, wages lost, rental income lost). The losses for the 10-, 20-, 50-, and 100-year events are illustrated in Figure 25.

**Figure 25. Hazus Wind Model Direct Economic Loss**



Source: 2018 Florida State Hazard Mitigation Plan

#### 4.0 Evaluating and Prioritizing Mitigation Actions

<p><b>Requirement</b> <b>§201.6(c)(3)</b></p>	<p>[The plan shall include the following:] A <i>mitigation strategy</i> that provides the jurisdiction’s blueprint for reducing the potential losses identified in the risk assessment, based on existing authorities, policies, programs, and resources, and its ability to expand on and improve these existing tools.</p>
<p><b>§201.6(c)(3)(i)</b></p>	<p>[The hazard mitigation strategy shall include a] description of mitigation goals to reduce or avoid long-term vulnerabilities to the identified hazards.</p>

After the risk assessment is complete, the next step in the mitigation planning process is developing the mitigation strategy and actions. This includes reviewing the risk assessment results and hazard profiles, formulating goals, objectives and actions, obtaining public input,

finalizing the mitigation strategy, and developing a process to implement and verify that the proposed actions are being accomplished.

Hazus results can play an important role when considering mitigation options. Hazard mitigation plans at the State and local level take different approaches to conceptualize goals, objectives, and actions. FEMA's Local Mitigation Planning Handbook defines goals, objectives, and actions as:

- **Goals:** Goals are general guidelines that explain what you want to achieve. They are usually broad policy statements, long-term in nature.
- **Objectives:** Objectives define strategies or implementation steps to attain the identified goals. Unlike goals, objectives are specific and measurable.
- **Actions:** Activities, measures, or projects that help achieve the goals and objectives of a mitigation plan.

The following sections provide example of different ways that the mitigation options can be structured and how Hazus results can be used to aid the process.

## 4.1 Identify Preliminary Mitigation Strategies and Actions

### 4.1.1 Risk Assessment Review

FEMA recommends that, before identifying preliminary mitigation strategies, planners should review the risk assessment findings for causes of hazards, hazard characteristics, critical assets, specific characteristics of assets in hazard areas, and high-risk areas of the composite map. Many of these findings can come from Hazus for flood, earthquake, tsunami, and hurricane wind.

One basic evaluation of Hazus results is whether there is regional variation or similar hazard risks and losses throughout the region covered by the study. For example, in an area where the hazard type has a medium or low occurrence, such as hurricane wind in the western United States or earthquake in many regions in the eastern United States, there is likely little hazard severity and loss variation in a region, because the hazard risk is relatively low. Therefore, mitigation strategies in these regions would NOT focus on specific regions with higher relative risks but would rather have region-wide options.

For regions with higher risk of earthquake, tsunami or hurricane, and for flood nationwide, there will be regional variation in the hazard risk and losses. Evaluation of the Hazus results should ask the following questions:

- What areas in a region have higher hazard vulnerability?
- Do these same regions have higher hazard losses?
- What base data differences might contribute to regional variation?

For example, Hazus results for flood may show the eastern portion of a region having higher flood risks, due to being in the floodplain of a major river. However, only a portion of the high-risk area may have had higher flood losses, due to the higher density of older housing stock for this portion of the region. Therefore, different mitigation options would focus on higher flood risk areas, the higher flood loss portion, and the strategies that would address the older housing stock issue.

Another consideration of the risk assessment review is evaluating the Hazus results and considering the limitations of Hazus and what the risk assessment analysis did NOT show. For example, if a Level 1 data analysis from Hazus is used for the critical facilities evaluation and an elementary school with a history of flooding does not show up, then mitigation strategies would need to address this issue by evaluating both the floodplain modeling and the critical facilities location information.

Information gained through the risk assessment should inform the development of problem statements that can be used to guide the development of the mitigation strategy. These statements help describe the results of the risk assessment and how mitigation actions can fix the problem. For example, a plan could state that “there is high fire risk in the northern part of our county where two elementary schools are located”. Group the problem statements by themes, such as hazards, assets at risk, or location to highlight key issues. Several problem statements or groups may lead to a single mitigation goal.

The way that the preliminary goals are developed and structured for a specific mitigation plan will be highly dependent upon the planning committee developing the plan. Usually, goals are structured according to mitigation option categories, hazard types, or asset types (such as structure use or utility type). FEMA’s Local Mitigation Planning Handbook lists the following four broad mitigation option categories: Local Plans and Regulations; Structure and Infrastructure Projects; Natural Systems Protection; and Education and Awareness Programs. Example goals for actual local mitigations plans will be used to contrast the different ways that goals can be structured and how these mitigation options might be included in these plans.

## 4.2 Evaluate Mitigation Actions

<p><b>Requirement</b> <b>§201.6(c)(3)(ii)</b></p>	<p>[The hazard mitigation strategy shall include a] section that identifies and analyzes a comprehensive range of specific mitigation actions and projects being considered to reduce the effects of each hazard, with particular emphasis on new and existing buildings and infrastructure.</p>
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Once the initial goals and objectives have been developed to form the preliminary mitigation strategies, these strategies need to be evaluated based on several different considerations. Public input is needed to refine the strategies and account for local experience. Factoring the capability of local, State, and Federal agencies to implement these strategies, these strategies need to be prioritized. For each of these considerations, Hazus results can play a role.

### 4.2.1 Obtain Public Input

Hazus results can play a very important role in facilitating public input. When the public meetings are held to review the risk assessment results and preliminary mitigation options, the maps from Hazus can provide a means to solicit public input. For example, Hazus flood analysis

results maps may show the high flood loss areas as predicted by Hazus. However, the public may be able to mark on the map other areas that have had flood damages for certain historical events. Critical facilities maps can also be shown to the public for refinement. The public's site-specific experience often goes beyond the detail level available in Hazus.

As planning areas vary, public input would be expected to vary. For a region with the greatest population and growth, multiple public meetings might be needed but historical knowledge of site-specific hazards might be limited due to more newer residents. Multiple sets of Hazus maps may be needed for these meetings, possibly focusing on a portion of the region such as an individual county or city. For a region that is more rural and may have a higher number of long-term residents, Hazus maps for the whole region might be sufficient. For a region with a mix of urban, suburban, and rural areas, a mixed approach with some regional and "zoom-in" maps of the higher population density areas may be beneficial.

#### **4.2.2 Prioritize Options**

The final important consideration in reviewing the mitigation actions is developing priorities. One tool that is commonly used (detailed in the Local Mitigation Planning Handbook) is the STAPLEE criteria: Social, Technical, Administrative, Political, Legal, Economic, and Environmental. For each mitigation action, the mitigation planning committee would look at issues and considerations for each of these criteria and establish a method to compare the relative importance of each criterion. This often is done by ranking each criterion on a scale of 1 to 10, establishing some relative weights, and then calculating a final priority score for each mitigation action.

Hazus results from the risk assessment can be used as a more objective way to assign these weights for certain criteria, especially the Technical and Economic criteria. For example, when establishing the score for the technical criteria, the options that mitigate high-risk hazards, such as greater hurricane wind speeds, would receive a higher score. This could be formalized by establishing a scoring scale ranging from 0 for the lowest observed value to 10 for the highest observed value from Hazus.

Still, FEMA acknowledges the way that priorities are usually set is very dynamic from community to community. Often capability, both in terms of local staff and available funding, will override most other considerations. Therefore, another important component is prioritizing options at the community level. When a local plan is multi-jurisdictional, each community needs to establish its own list of priorities based on capability. For State plans, each major State agency may also develop its own priority list based on disciplines that an agency covers.

Hazus results can be used as part of the priority ranking, but community-specific issues can inform the priority ranking and approach may vary by community. This shows the importance of involving a broad group of stakeholders in the plan development process and obtaining public input to make use of local, site-specific experience to supplement Hazus results.

### 4.2.3 Benefit Cost Review

<p><b>Requirement</b> <b>§201.6(c)(3)(iii)</b></p>	<p>[The hazard mitigation strategy shall include an] action plan, describing how the action identified in paragraph (c)(3)(ii) of this section will be prioritized, implemented, and administered by the local jurisdiction. Prioritization shall include a special emphasis on the extent to which benefits are maximized according to a cost benefit review of the proposed projects and their associated costs.</p>
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The evaluation and prioritization process must include benefit-cost review to consider the benefits that would result from a mitigation action versus the cost. This does not mean a full benefit-cost analysis (BCA), such as the FEMA BCA Module used for Hazard Mitigation Assistance projects, but a planning level assessment of whether the costs are reasonable compared to the probable benefits. Cost estimates do not have to be exact but can be based on experience and judgment.

Benefits include losses avoided, which include Hazus outputs such as the number and value of structures and infrastructure protected by the action and the population protected from injury and loss of life. Qualitative benefits, such as quality of life and natural and beneficial functions of ecosystems, can also be included in the review.

For specific guidance on how Hazus can be used in the FEMA BCA process for flood projects, see Section 5 in FEMA's Supplement to the Benefit-Cost Analysis Reference Guide (June 2011).

### 4.2.4 Example Mitigation Actions

Some example mitigation actions that might be used in the mitigation plan as a result of Hazus analysis could include:

- Collect building footprint data
- Elevate homes in the Longview Gardens area that are prone to flooding
- Inspect schools to identify structural seismic mitigation needs
- Work with USGS to install a stream gage on Pluto Bridge at the Charlie River

Each of the four example mitigation strategies based on Hazus results would fit into different goals. For a more comprehensive list of mitigation action options by hazard, refer to the FEMA publication entitled: *Mitigation Ideas: A Resource for Reducing Risk to Natural Hazards*.

Similar Hazus findings and their resulting mitigation options may fit into different types of goals based on the way that the goals are structured or may depend on how the objectives under these goals are formulated. In many cases, the objectives will use one of the other goal structure methods. For example, if the goals vary by hazard type, then the objectives may differ by asset type or project type.

Hazus risk assessment results can inform the development of mitigation actions. Information gained through the risk assessment should inform the development of problem statements that can be used to guide the development of the mitigation strategy. Group the problem statements

by themes, such as hazards, assets at risk, or location. Several problem statements or groups may lead to a single mitigation goal.

#### 4.2.5 Review Final List of Mitigation Actions

For finalizing the mitigation actions, Hazus can help refine options. Hazus can be used for various what-if scenarios for the acquisition and hurricane strap options. For the school data option, an evaluation of how many schools are missing or in the wrong location can be used to determine how much potential effort (cost) will be needed to update the data.

#### 4.2.6 Develop Plan to Implement Mitigation Actions

<p><b>Requirement</b> <b>§201.6(c)(3)(iii)</b></p>	<p>[The hazard mitigation strategy shall include an] action plan, describing how the action identified in paragraph (c)(3)(ii) of this section will be prioritized, implemented, and administered by the local jurisdiction. Prioritization shall include a special emphasis on the extent to which benefits are maximized according to a cost benefit review of the proposed projects and their associated costs.</p>
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This final step of developing the mitigation actions focuses on implementing the mitigation actions after plan adoption. The specific organizations accept responsibility to pursue their various mitigation actions. When one of their actions is based on Hazus results, the plan needs to include a method for providing the detailed Hazus results and data files. In some cases, the organization may hire consultants to assist with implementing actions, so the detailed analysis results will need to be available to these organizations as well.

From the example plan, one region could hire a consultant to develop a grant application for the flood acquisition mitigation option. This consultant will need to have the Hazus results indicating the specific neighborhood where this option is proposed; therefore, the final implementation portion of the plan will need to address how Hazus data is stored, maintained, and transmitted to those organizations that may need to use the data in the future.

This also applies to State plans. One major requirement of updates to State plans is to summarize the results from local plans; therefore, State plans also need to identify the organizations that will receive local Hazus data and other data used as part of the risk assessment process. In some cases, the State may establish a standardized format and method to transmit this information.

## 5.0 Conclusion

As it has been discussed throughout this job aid, Hazus can be a helpful tool to assist the mitigation plan author in displaying result from the risk assessment and developing mitigation actions. This job aid will help users identify and understand types of reports, tables, and maps produced in Hazus that can be incorporated into a Hazard Mitigation Plan.

It is important to keep in mind that using the outputs generated by Hazus will assist in meeting some DMA 2000 requirements, but it will NOT completely fulfill the requirements for the plan to be approved.

In order to have better results using Hazus, it is important to determine what the community's data limitations are, and if possible, acquire more recent and accurate data. Additional



information based on local data and discussions during the planning process and public meetings can and should be incorporated to improve on the Hazus analysis. It is also recommended to keep track of data sources; improving and maintaining data will later assist in the plan update.

## 6.0 References

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## Appendix A. Resources

**FEMA's General Hazus Resources** can be found at <https://www.fema.gov/hazus>

**Hazus Technical Guidance Documents and User Guidance Documents** can be found at <https://www.fema.gov/media-library/assets/documents/24609>. These documents are undergoing updates in 2018, with newer versions posted as they are finalized.

- [Hazus Hurricane Model User Guidance](#)
- [Hazus Hurricane Model Technical Guidance](#)
- [Hazus Tsunami Model User Guidance](#)
- [Hazus Tsunami Model Technical Guidance](#)
- [Hazus Hurricane Model Technical Manual](#)
- [Flood Model User Guidance](#)
- [Hazus Flood Model Technical Guidance](#)
- [Hazus Earthquake Model User Guidance](#)
- [Hazus Earthquake Model Technical Guidance](#)
- [Hazus Flood Information Tool \(FIT\) User Manual](#)
- [Hazus Advanced Engineering Building Module \(AEBM\) User Manual](#)
- [Hazus CDMS Data Dictionary](#)

**FEMA's Mitigation Planning Resources** can be found at <https://www.fema.gov/hazard-mitigation-planning-resources>

- [FEMA Local Mitigation Planning Handbook](#)
- [Local Mitigation Plan Review Guide](#)
- [State Mitigation Plan Review Guide](#)
- [Tribal Mitigation Plan Review Guide](#)
- [Developing the Mitigation Plan: Identifying Mitigation Actions and Implementation Strategies](#)
- [Hazard Mitigation: Integrating Best Practices into Planning](#)
- [Hazard Mitigation Planning Toolkit](#)
- [Mitigation Ideas: A Resource for Reducing Risk to Natural Hazards](#)
- [Integrating Hazard Mitigation into Local Planning: Case Studies and Tools for Community Officials](#)