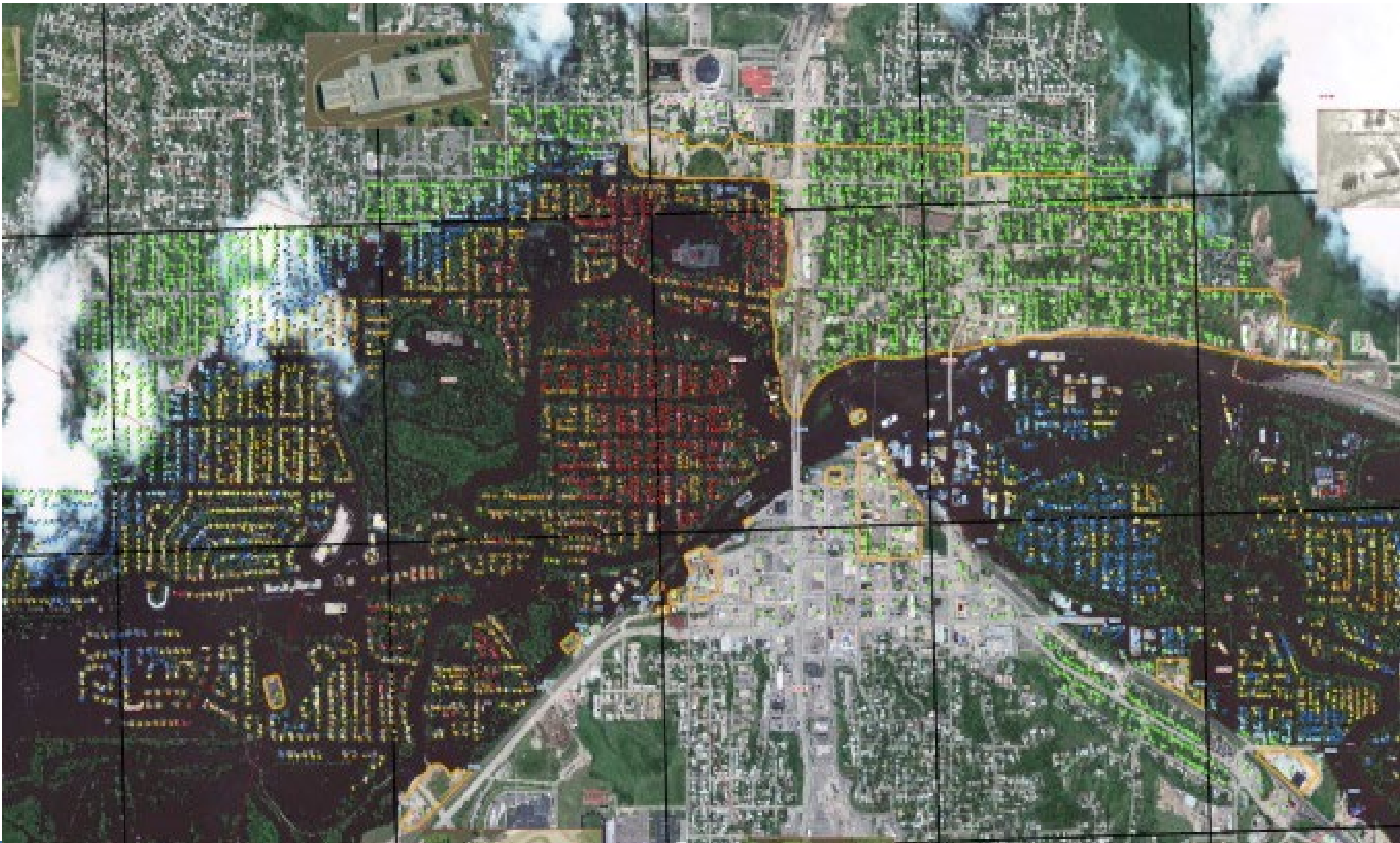

Using Hazus for Mitigation Planning

October 2021

FEMA

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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.

Acronyms and Abbreviations

Acronym	Definition
AAL	Average Annualized Loss
BCA	Benefit-Cost Analysis
CDMS	Comprehensive Data Management System
DFIRM	Digital Flood Insurance Rate Map
DMA 2000	Disaster Mitigation Act of 2000
FAST	Flood Assessment Structure Tool
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
GAT	Great Aleutian Tsunami
GBS	General Building Stock
GIS	Geographic Information System
HEC-RAS	Hydrologic Engineering Center's River Analysis System
HSIP	Homeland Security Infrastructure Program
LiDAR	Light Detection and Ranging
MSDIS	Missouri Spatial Data Information Service
NHRAP	Natural Hazard Risk Assessment Program
NRI	National Risk Index or The Index
NWS	National Weather Service
PDC	Pacific Disaster Center
SEMA	State Emergency Management Agency
UDF	User-Defined Facility
USGS	United States Geological Survey
VDEM	Virginia Division of Emergency Management

1. Introduction

Hazard mitigation planning reduces loss of life and property by minimizing the impact of disasters. It is most effective when implemented under a comprehensive, long-term mitigation plan. State, tribal, local and territorial 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 and reconstruction.

To facilitate the support for better mitigation, Congress enacted the Disaster Mitigation Act of 2000 (DMA 2000), which encourages state, tribal and local 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, tribal and local 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 document demonstrates how Hazus results can be incorporated into Hazard Mitigation Plans and assists with the development of hazard mitigation actions. It will 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. Section 2 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. Other publications and resources, such as Hazus User Guidance, Technical Manuals and the Hazus YouTube playlist describe in depth how to use the software and 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.

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;
- Academic Instituions;
- Planning researchers and students;
- Consultants;
- Plan reviewers; and
- State, tribal and local officials, including contract officers

This document assumes users have Geographic Information Systems (GIS) and Hazus software, or can access these resources through their organization, or by hiring a consultant who can run the program.

1.1. What Is Hazus?

Hazus is a nationally standardized risk modeling methodology that can be used to estimate potential damage, economic loss, and social impacts from earthquake, flood, tsunami and hurricane hazards. The Hazus software, built on Esri ArcGIS for Desktop technology, includes nationwide general GIS datasets, and a model for each of the four natural hazards below. The model results can support the risk assessment piece of mitigation planning.

Earthquake Model: Evaluates the probability of damages and losses to buildings, essential facilities, transportation, and utility systems 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.

Flood Model: Generates flood (riverine and coastal) 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.

Tsunami Model: 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.

Hurricane Model: 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 user-defined hurricanes, and it combines the wind and flood losses.

Hazus is packaged with datasets that include building inventories and infrastructure for the entire United States. The [Hazus Inventory Technical Manual] and [Hazus Factsheet] provide more detailed information on the baseline inventory data.

Losses estimated in Hazus are based on the accuracy of input data. A Basic analysis can be developed using the baseline data and parameter data provided within Hazus. Users can conduct more advanced analyses 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 1-1. For more information on data inputs, see Section 1.2.

- **Analysis Based on Baseline Information**: The basic level of analysis uses only the baseline databases built into the Hazus software and Methodology for building area and value, population characteristics, costs of building repair, and certain basic economic data. This level of analysis is commonly referred to as a Level 1 analysis. In a basic analysis (Level 1), hazard data is uniformly applied or generated from minimal input data and applied to the baseline inventory data with little to no user modification. Direct economic and social losses associated with the GBS and essential facilities are computed. Baseline data for transportation and utility systems are included; thus, these systems are considered in the basic level of analysis. However, there is a significant level of uncertainty pertaining to the estimates and this basic analysis is only available in certain hazard models. This level of analysis is suitable primarily for preliminary evaluations and crude comparisons among different Study Regions with a Census tract as the smallest regional unit. A basic Level 1 analysis could be used for comparisons and preliminary evaluations to assist in identifying potential mitigation actions within a community, which could be useful if evaluating funding priority for projects.
- **Analysis with User-Supplied Inventory:** Results from an analysis using only baseline inventory can be improved upon greatly with at least a minimum amount of locally developed input. These improved results are highly dependent on the quality and quantity of the improved inventory data. The significance of the improved results also relies on the user's analysis priorities. This level of advanced analysis is commonly referred to as a Level 2 or Level 3 analysis. The following inventory improvements impact the accuracy of Level 2 and Level 3 advanced analysis results:
    - Use of locally available data or estimates of the square footage of buildings in different occupancy classes.
    - Use of local expertise to modify (primarily by professional judgment) the databases that determine the percentages of specific building types associated with different occupancy classes.
    - Preparation of a detailed inventory of all essential facilities.
    - Collection of detailed inventory and cost data to improve evaluation of losses and lack of function in various transportation and utility systems.
    - Use of locally available data concerning construction costs or other economic parameters.
    - Compilation of information concerning high potential loss facilities.

FEMA's Natural Hazard Risk Assessment Program (NHRAP) encourages users to conduct Advanced 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) as well as local datasets for mitigation planning.

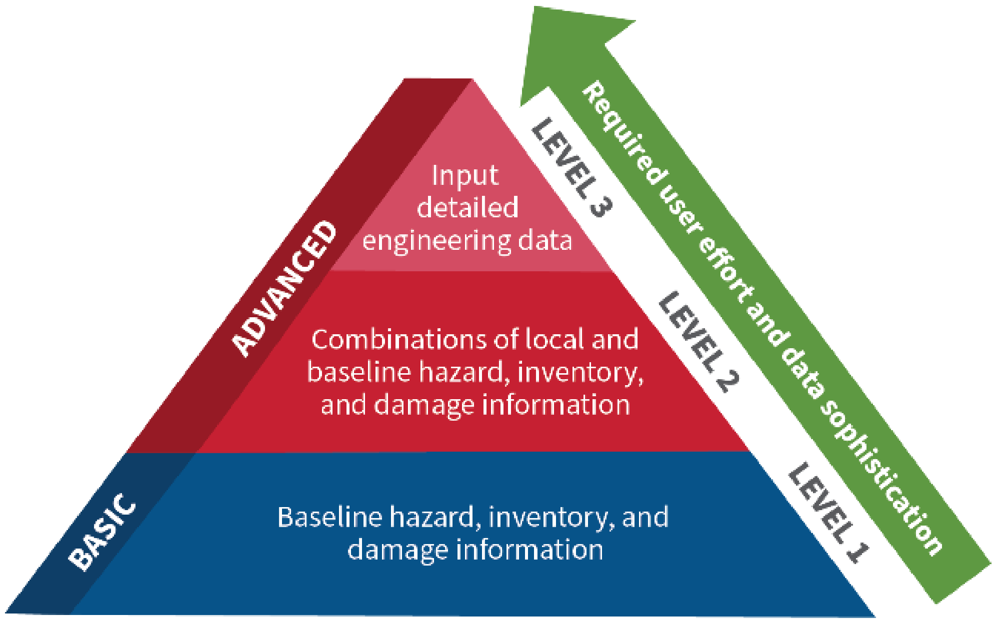


Figure 1-1 Hazus Analysis Levels

1.2. Hazus Inputs

Three types of input datasets are included in Hazus:

- Baseline (Aggregated)
- Site-specific
- Hazard-specific

The *baseline* data represents a collection of information that is common across all hazard models. There are six inventory data categories that are included in the Hazus-provided inventory dataset: General Building Stock, essential facilities, high potential loss facilities, transportation systems, utility systems and demographics. For more details on these datasets, refer to Section 2.2.1.

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 (see Table 1 below). 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 depict a specific hazard scenario more accurately. It is always recommended that users import hazard data from authoritative sources.

Table 1. Hazus Hazard-Specific Data Inputs

Model	Input
Flood	▪ Depth Grids (arcgrid, tiff, fgdb, img)* ▪ DFIRM data ▪ DEM ▪ Hydrologic Engineering Center's River Analysis System (HEC-RAS)
Hurricane	▪ Hurrevac import* ▪ .dat Census tract data file
Earthquake	▪ USGS ShakeMap* ▪ Deterministic Event ▪ USGS Probabilistic Seismic Hazard Maps ▪ User-Supplied Ground Shaking Maps
Tsunami	▪ Depth and momentum flux grids* ▪ Limited Risk MAP data available

**Preferred hazard data import*

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 regarding hazard data for loss estimation methodology can be found in FEMA's Hazus User Guidance for Flood, Hurricane, Earthquake, and Tsunami.

1.2.1. INTEGRATING USER-PROVIDED DATA

Much of the information in the Hazus supplied baseline 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. For example, the earthquake model is enhanced by user-provided hazard maps (soils, elevation, liquefactions), the hurricane model is enhanced by Hurrevac data, while the flood model is enhanced by user-defined depth grids.

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, or 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 Hazus CDMS User Guidance or check out the YouTube playlist on Managing Inventory Data.

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. Once imported into CDMS, the data will be aggregated during the Study Region creation. If the data includes points and an occupancy class, Hazus will generate a UDF layer based on the baseline data.

Once imported into the statewide datasets, CDMS will allow users to query, sort, and export 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 Excel or Microsoft Access. FEMA's Flood Assessment Structure Tool (FAST) is an open source tool available to analyze structure-level flood risk. For more information on FAST refer to Section 5.1.

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

Task	Estimated Labor Hours
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)*
Advanced hazard analysis with imported user-defined hazard input	3 Hours/County (could be longer for large counties with high resolution depth grids)
Advanced 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	1-2 Minutes/Study Region
Flood Assessment Structure Tool (FAST)	10,000 Structures/Second once formatted structure data and flood depth grid is available

**estimated labor hours dependent upon amount of data available at the building footprint and/or parcel level*

***development of both UDF and flood hazard data using an Advanced Hazus Analysis*

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, and data can also be exported from Hazus for additional geospatial processes and analysis. 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 Table 3: 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.

Table 3. Hazus Outputs

Hazus Capabilities	Earthquake Ground Shaking Ground Failure	Flood Frequency | Depth Riverine | Coastal Surge	Hurricane Wind | Surge	Tsunami Depth | Momentum Flux | Runup | Velocity
Inputs				
Historic	✓		✓	
Deterministic	✓	✓	✓	✓
Probabilistic	✓	✓	✓	
User-supplied	✓	✓	✓	✓
Other Supported Inputs	Real-time & scenario USGS Shakemaps	User-supplied depth grids (ArcGRID, GeoTIFF, IMAGINE), HEC-RAS (.FLT)	Hurrevac, User-supplied wind files (.dat)	NOAA PMEL SIFT, State models
Direct Damage				
General Building Stock	✓	✓	✓	✓
Essential Facilities	✓	✓	✓	
Transportation Systems	✓	✓		
Utility Systems	✓	✓		
User-Defined Facilities	✓	✓	✓	✓
Induced Damage				
Fire Following	✓			
Debris Generation	✓	✓	✓	
Direct Losses				
Cost of Repair	✓	✓	✓	✓
Income Loss	✓	✓	✓	✓
Casualties	✓			✓

Hazus Capabilities	Earthquake Ground Shaking Ground Failure	Flood Frequency | Depth Riverine | Coastal Surge	Hurricane Wind | Surge	Tsunami Depth | Momentum Flux | Runup | Velocity
Shelter and/or Evacuation Needs	✓	✓	✓	✓
Averaged Annualized Loss (AAL)	✓	✓	✓	

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. 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.

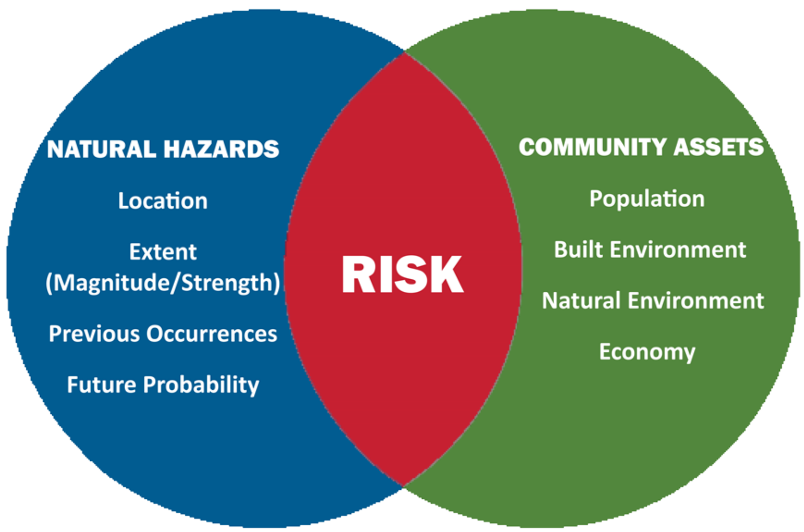
Hazus allows the user to define the planning area by creating a Study Region. A Study Region is the geographic area Hazus will use to conduct the various flood, hurricane, tsunami, and earthquake scenarios, and can be defined at the Census block, Census tract, county, or state level in the Flood and 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. The Study Region boundaries can then be brought into GIS to create maps of the study area, overlain with transportation networks, bodies of water, and buildings such as schools, police and fire stations, and hospitals. All of these layers can be mapped within Hazus; however, this is not recommended, and the preferred method is to either export the layers from Hazus and add to a GIS map, or bring them into GIS using a database connection.

Data used to create the basemap may include baseline 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 are 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.

2. 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 2-1 illustrates the concept of risk as the relationship, or overlap, between hazards and community assets. The smaller the overlap, the lower the risk.



Note: Modified from U.S. Geological Survey and Oregon Partnership for Disaster Resilience Models.

Figure 2-2 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 2-2). 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 2-3. 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 data can be used outside of Hazus for GIS analyses related to other hazards, and this can be done by creating a database connection to Hazus to access its data. For instance, if a map layer of areas susceptible to landslides is available, Hazus baseline inventory data can be used to overlay those areas with the provided inventory (i.e., buildings, critical facilities, and utilities) 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, tsunami, and hurricanes, Hazus inventory information can be combined with other reliable historical loss and probability data, including FEMA's National Risk Index (The Index), to help estimate probable losses using techniques not included in the software.

2.1. Step 1: Describe Hazards

> Requirement §201.6(c)(2)(i) [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 (Local Mitigation Plan Review Guide).

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 document to explain the risk assessment process. Once Hazus is run and analysis outputs are produced, results can be viewed in tabular, map, or report formats.

2.1.1. 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, and FEMA's National Risk Index can also be used to identify hazards in the area. 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.

2.1.2. 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 in a mitigation plan, as required by DMA 2000, 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 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 in Section 3, but these might include acquiring flood prone structures, elevating residential structures, restricting building on or near hazard areas, etc.

> Did you know that Hazus can be used to model future conditions, including climate change? Future conditions can be modeled in Hazus by incorporating updated inventory and hazard data. Population growth and built environment projections can be used to modify Hazus inventory databases to better reflect demographics and infrastructure conditions of the future. Hazard data representative of future climate scenarios (for example, a depth grid accounting for climate-driven riverine flooding) can also be brought into Hazus and modeled; however, these results are best estimated when paired with updated future inventory datasets. Check out this Coral Reef Conservation study in Hawaii to see how FEMA/USACE used site-specific and future hazard data to show the mitigation benefits of a nature-based solution.

The maps on the following pages illustrate case examples that have been or can be incorporated into Hazard Mitigation Plans using Hazus. As it will be seen throughout this document, 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.

Figure 2-3 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.

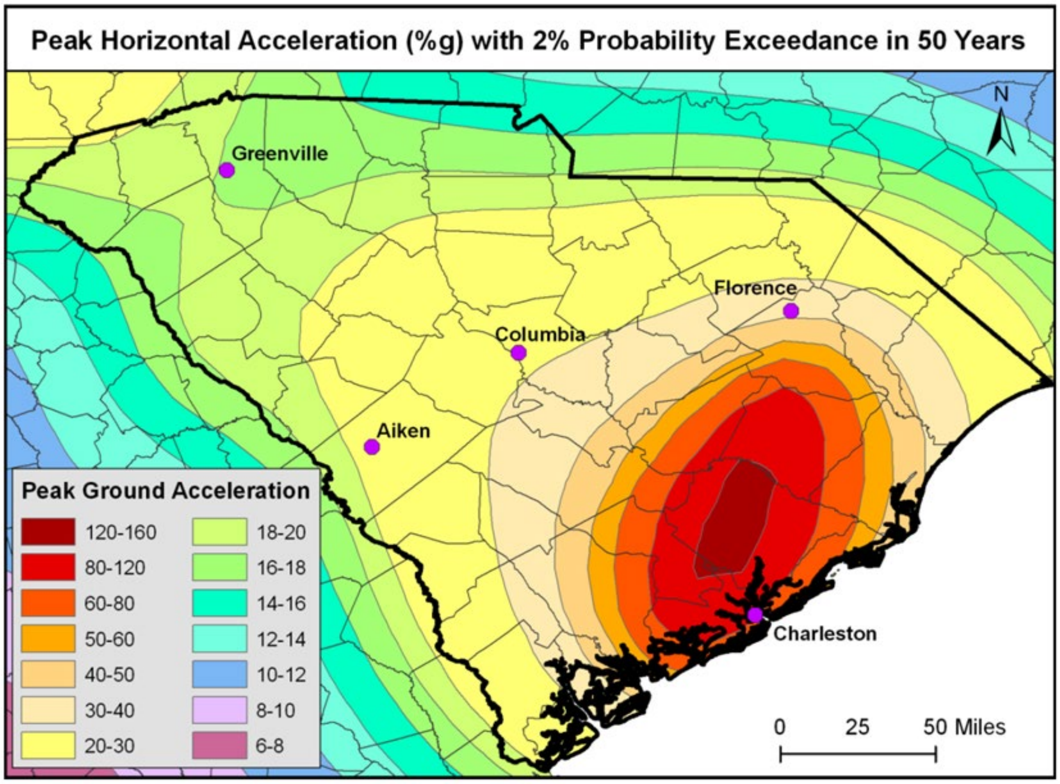


Figure 2-4. Ground Shaking by Census Tract
(Source: 2018 South Carolina State Hazard Mitigation Plan)

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. When using Hazus, the analysis can also be done for smaller areas such as a county or city. For Larimer County in Colorado, earthquake risk is considered to be low to moderate but is important enough to profile in the plan. Figure 2-4 shows the estimated peak ground acceleration expected for a 2500-year event to provide an overview of seismic risk that could result in damage. This analysis helped the County to conclude in the hazard profile that it is a low probability, high-impact hazard.

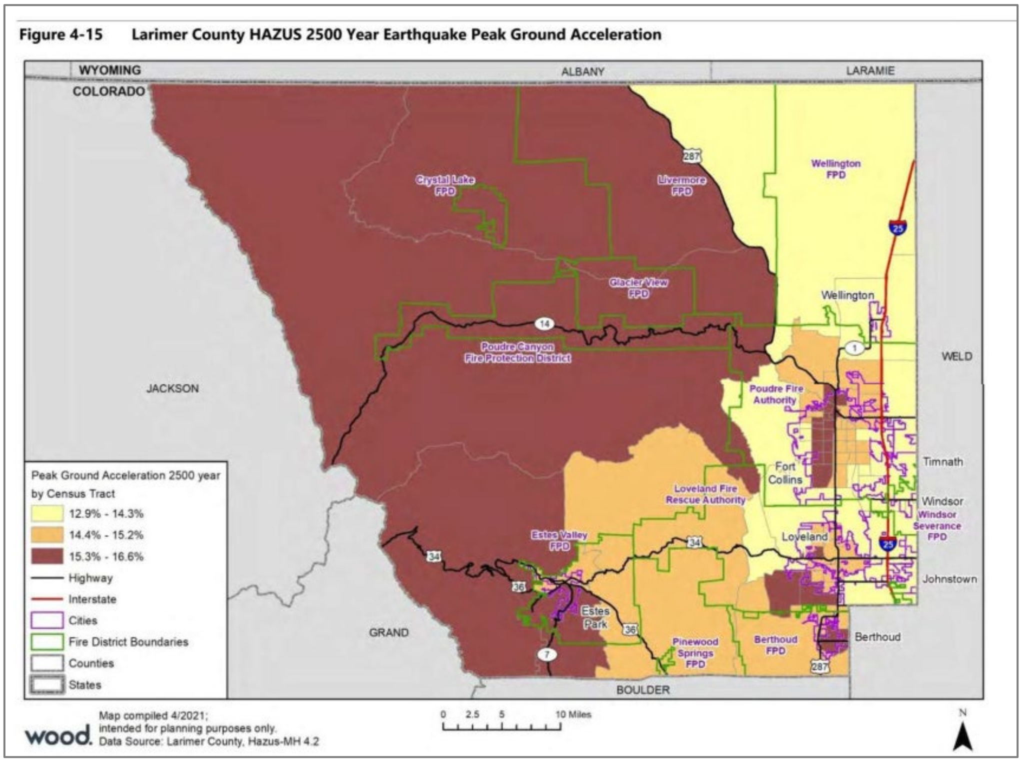


Figure 2-5. Peak Ground Acceleration in Larimer County, Colorado (Source: 2021 Draft Larimer County Hazard Mitigation Plan)

2.2. Step 2: Identify Community Assets

Requirement §201.6(c)(2)(ii)

[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.

The plan should describe vulnerability in terms of:

§201.6(c)(2)(ii)(A)

(A) The types and numbers of existing and future buildings, infrastructure, and critical facilities located in the identified hazard areas; (Local Mitigation Plan Review Guide).

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.

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.

Figure 2-5 and Figure 2-6 provide examples of how data generated in Hazus can be incorporated into the mitigation plan to represent asset inventory. Figure 2-5 illustrates critical facilities vulnerable to the flood hazard in the West Maui Community Planning Area of Maui County, Hawaii, and Figure 2-6 identifies the Hazus results for potential building losses across the county. 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. 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.

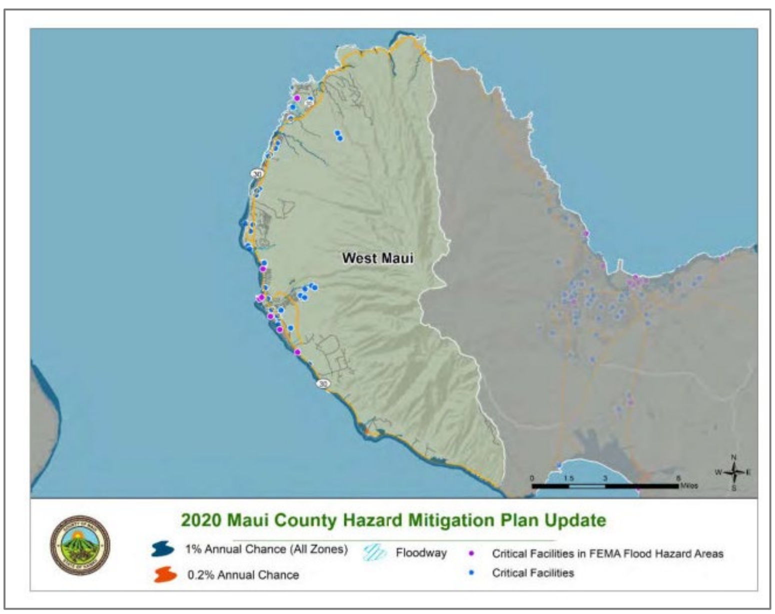


Figure 2-6. Vulnerable Critical Facilities in West Maui Community Planning Area (Source: 2020 Maui County Hazard Mitigation Plan)

1% Annual Chance Flood

	Building Loss	Content Loss	Total Loss
Hāna	$100,053	$50,723	$150,776
Kīhei-Mākena	$105,948,425	$53,432,335	$159,380,760
Lāna'i	$541,995	$270,192	$812,187
Makawao-Pukalani-Kula	$0	$0	$0
Moloka'i	$14,759	$7,505	$22,264
Pā'ia-Ha'ikū	$5,763,711	$3,203,519	$8,967,230
Wailuku-Kahului	$3,202,440	$1,626,929	$4,829,369
West Maui	$268,960,293	$134,929,911	$403,890,203
Total	**$384,531,676**	**$193,521,114**	**$578,052,790**

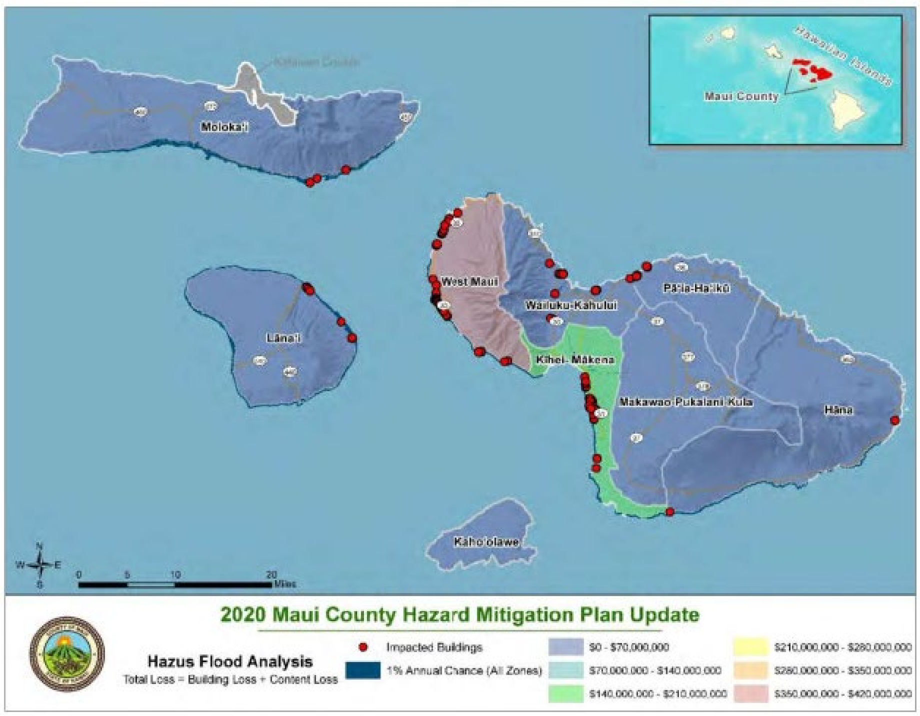


Figure 2-7. Hazus Flood Analysis Results
(Source: 2020 Maui County Hazard Mitigation Plan)

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 Hazus General Building Stock inventory data for the Study Region to support the loss estimates and risk assessment. For more information on inventory data please see Section 2.2.1 below.

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.

2.2.1. HAZUS INVENTORY DATA

Hazus data include statewide baseline inventories for buildings, essential facilities, and infrastructure.

2.2.1.1.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 the Hazus Inventory Technical Manual 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 and Tsunami Models display 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.

2.2.1.2. Essential Facilities

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

2.2.1.3.Transportation Systems

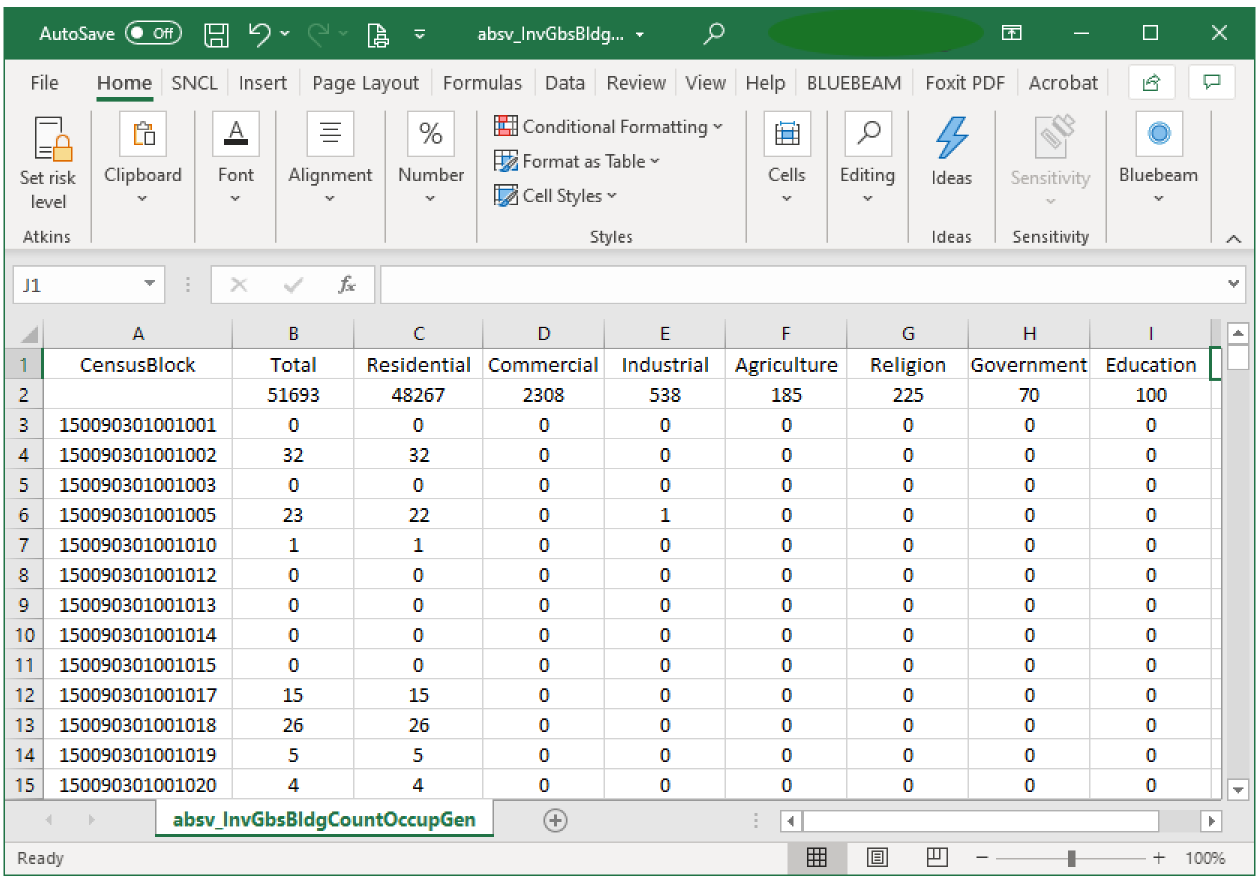
Transportation systems include highways (roadways, bridges, and tunnels.); railways (tracks, bridges, tunnels, stations, fuel, dispatch, and maintenance facilities.); light rail; bus (urban stations, fuel facilities, dispatch and maintenance facilities.); ports (waterfront structures, cranes/cargo handling 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).

2.2.1.4. Utility Systems

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

2.2.2. QUANTIFY COMMUNITY ASSETS

Hazus can produce a table that counts all the assets in a county by Census blocks, which 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 2-7 example).



CensusBlock	Total	Residential	Commercial	Industrial	Agriculture	Religion	Government	Education
	51693	48267	2308	538	185	225	70	100
150090301001001	0	0	0	0	0	0	0	0
150090301001002	32	32	0	0	0	0	0	0
150090301001003	0	0	0	0	0	0	0	0
150090301001005	23	22	0	1	0	0	0	0
150090301001010	1	1	0	0	0	0	0	0
150090301001012	0	0	0	0	0	0	0	0
150090301001013	0	0	0	0	0	0	0	0
150090301001014	0	0	0	0	0	0	0	0
150090301001015	0	0	0	0	0	0	0	0
150090301001017	15	15	0	0	0	0	0	0
150090301001018	26	26	0	0	0	0	0	0
150090301001019	5	5	0	0	0	0	0	0
150090301001020	4	4	0	0	0	0	0	0

Figure 2-8. Total Building Count (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, which would be addressed in the analyzing risks and loss estimation section.

2.3. Step 3: Analyze Risks

Requirement §201.6(c)(2)(ii)

[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.

The plan should describe vulnerability in terms of:

§201.6(c)(2)(ii)(B)

(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 (Local Mitigation Plan Review Guide).

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 state of Hawaii and state of Missouri incorporated Hazus results into their mitigation plans.

2.3.1. EXAMPLE 1: STATE OF HAWAII TSUNAMI SCENARIO ANALYSIS

When the State of Hawaii updated their Hazard Mitigation Plan in 2018, Hazus was utilized to evaluate risk for earthquake, flood, hurricane and tsunami. For the tsunami hazard, the Pacific Disaster Center (PDC) provided inundation area data for the Great Aleutian Tsunami (GAT) and ran the Hazus v4.2 Tsunami Model for the GAT scenario to estimate potential losses in the state. In addition, the PDC. A statewide spatial analysis was conducted using the GAT inundation area to determine exposure to state assets, state roads and critical facilities. The impacts to population, buildings and economy were summarized using the Hazus reports provided by the PDC and included in the Plan.

A spatial analysis determined that there are 1,175 State buildings and critical facilities located in the GAT inundation area, with the greatest number located in the City and County of Honolulu. The Plan also noted that ports and harbors are especially vulnerable to the tsunami hazard, as well as airports located on the coast, so "damages and closures to these facilities will likely be long-term having cascading economic impacts statewide."

Figure 2-8 shows the exposure value of structures in the tsunami hazard area and loss estimates. It is estimated that there would be over $12 million of loss from a scenario tsunami hazard event, representing over 5% of the building stock.

Table 4.13-10. General Building Stock Exposure and Potential Losses to the GAT by County

County	Total Value	Replacement Cost Value in Hazard Area	Replacement Cost Value Exposed as % of Total	Estimated Building Potential Loss	
				Replacement Cost Value	Percent (%) of Total
County of Kaua'i	$13,287,882,000	$2,641,513,000	19.9%	$1,322,085,389	9.9%
City and County of Honolulu	$164,787,212,000	$43,010,342,000	26.1%	$6,082,130,961	3.7%
County of Maui	$31,320,693,000	$9,026,708,000	28.8%	$3,513,021,920	11.2%
County of Hawai'i	$33,326,392,000	$3,595,732,000	10.8%	$1,951,209,483	5.9%
Total	$242,722,179,000	$58,274,295,000	24.0%	$12,868,447,753	5.3%

Source: FEMA Hazus 4.2; PDC 2017
Notes: GIS Geographic Information System
PDC Pacific Disaster Center

Figure 2-9. Structures Exposed to Tsunami Inundation Zone (Source: 2018 State of Hawaii Hazard Mitigation Plan)

2.3.2. EXAMPLE 2: STATE OF MISSOURI FLOOD EXPOSURE 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 Hazus 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 (Light Detection and Ranging) data from the Missouri Spatial Data Information Service (MSDIS) and the U.S. Army Corps of Engineers (USACE). When LiDAR was not entirely available, U.S. 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 2-9, illustrating the depth grid generated by the model, which served as an input for the Hazus flood vulnerability and loss analysis.

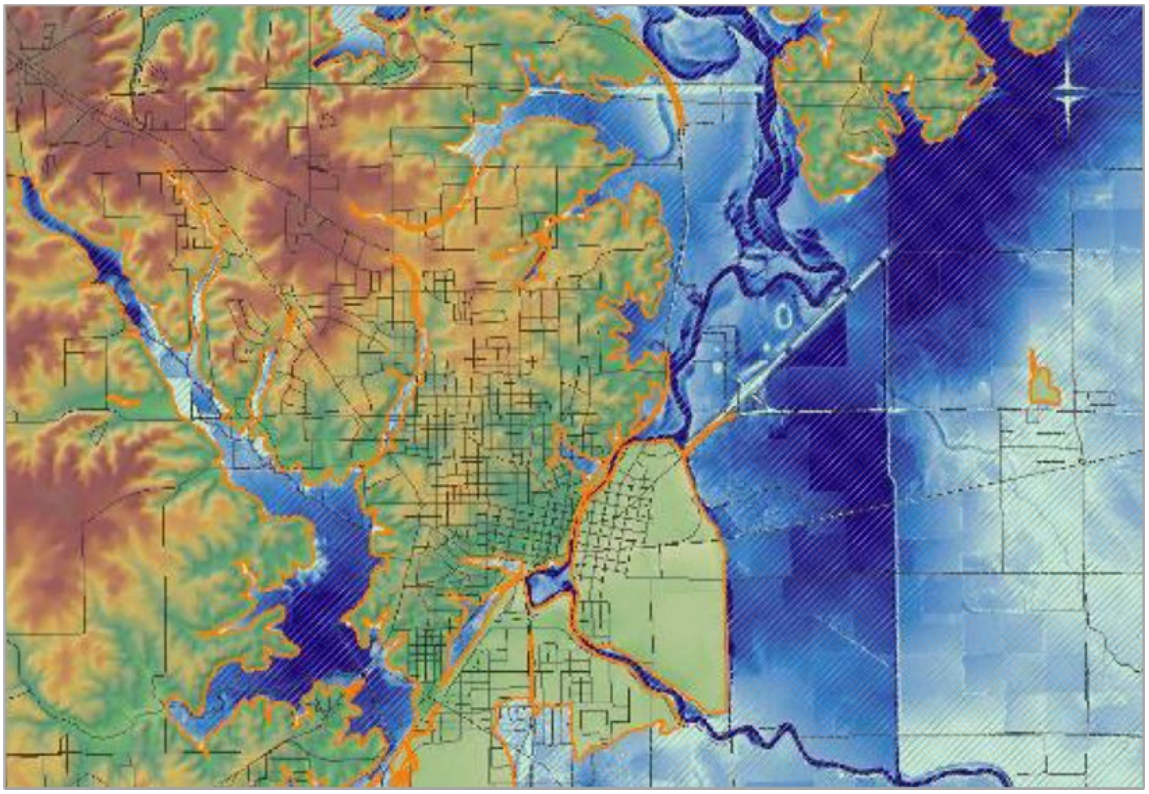


Figure 2-10. Example of a DFIRM Depth Grid in Detailed Areas – Butler County, MO (Source: 2018 Missouri State Hazard Mitigation Plan)

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.

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 U.S. 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 U.S. 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 U.S. 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.

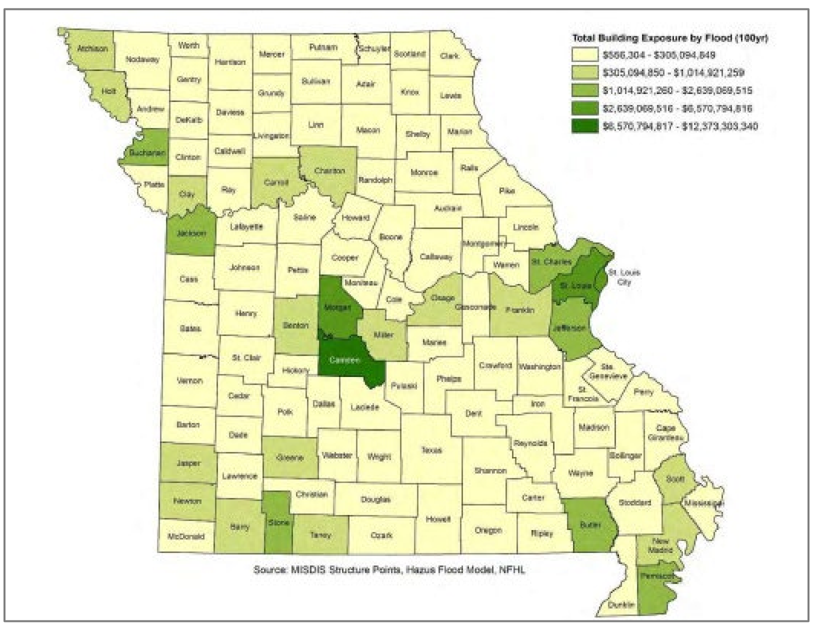


Figure 2-11. Hazus Countywide Base-Flood Scenarios: Building Exposure (Source: 2018 Missouri State Hazard Mitigation Plan)

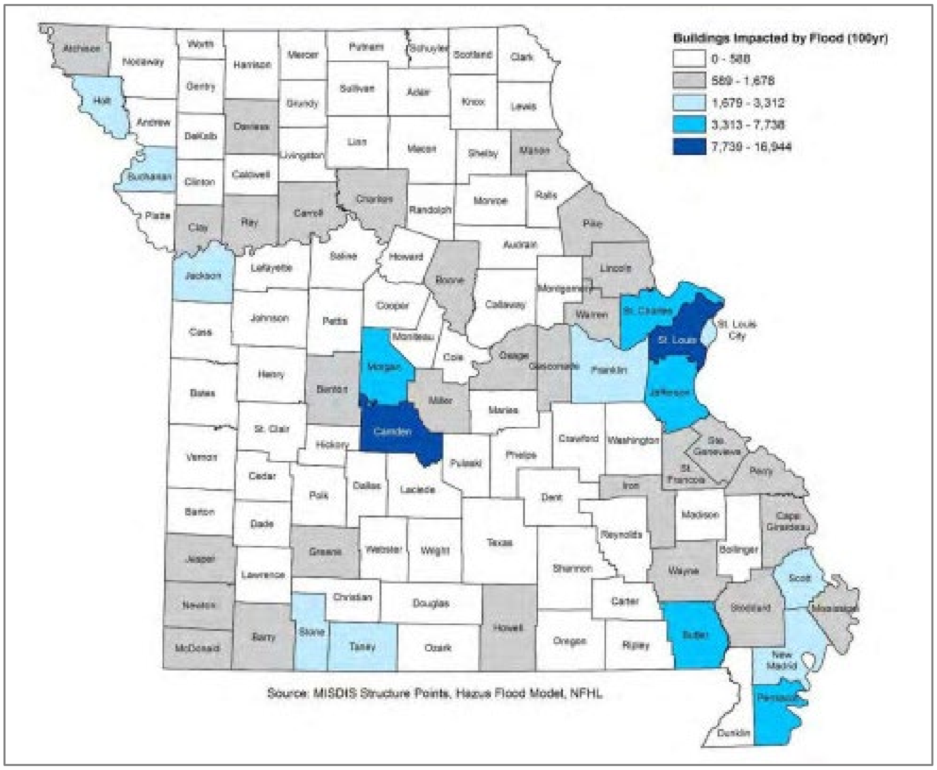


Figure 2-12. Hazus Countywide Base-Flood Scenarios: Ratio of Buildings Impacted (Source: 2018 Missouri State Hazard Mitigation Plan)

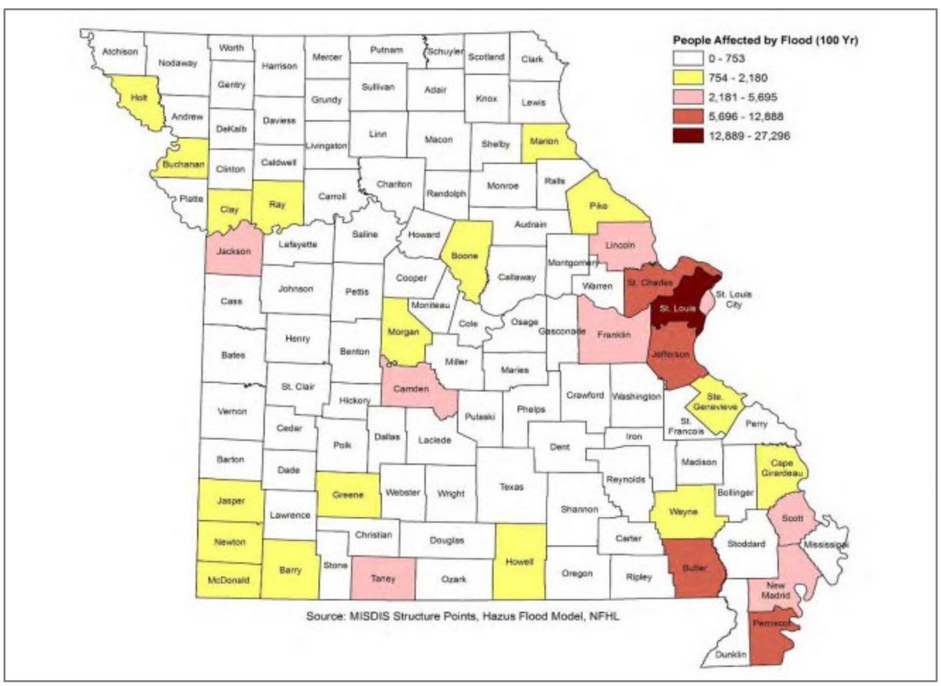


Figure 2-13. Hazus Countywide Based-Flood Scenarios: Displaced People (Source: 2018 Missouri State Hazard Mitigation Plan)

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 National Weather Service (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 the Missouri State Emergency Management Agency.

2.4. Step 4: Summarize Vulnerability

Requirement §201.6(c)(2)(ii)

[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.

The plan should describe vulnerability in terms of:

§201.6(c)(2)(ii)(A)

The types and numbers of existing and future buildings, infrastructure, and critical facilities located in the identified hazard areas; (Local Mitigation Plan Review Guide).

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

2.4.1. 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 number of vulnerable buildings to the identified hazard. The number 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 Hurricane

Model. Analysis is conducted for seven regions defined by the Virginia Department of Emergency Management (VDEM). Figure 2-13 and Figure 2-14 show expected building damage by occupancy type for the 100-year hurricane event for VDEM Region 1.

	None		Minor		Moderate		Severe		Destruction	
Occupancy	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
Total	**464,205**		**1,870**		**65**		**1**		**-**	

Figure 2-14. Expected Building Damage by Occupancy Results Table (100-Year Probabilistic Event) (Source: 2018 Commonwealth of Virginia Hazard Mitigation Plan)

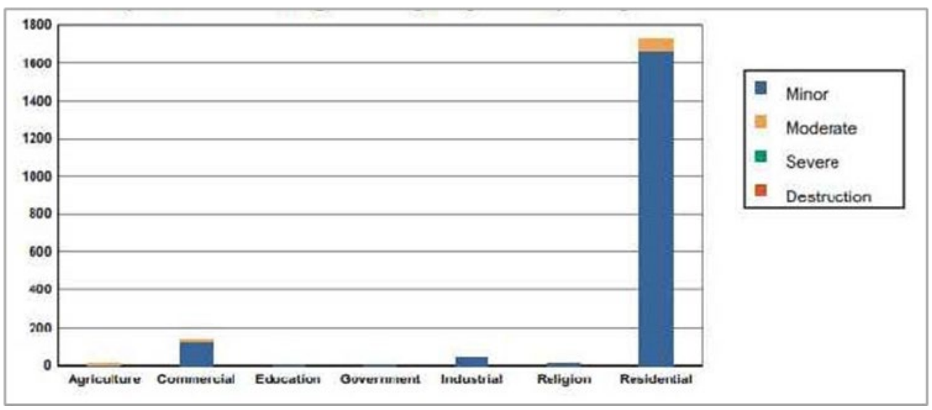


Figure 2-15. Expected Building Damage by Occupancy (100-Year Probabilistic Event) (Source: 2018 Commonwealth of Virginia Hazard Mitigation Plan)

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 2-15.

Classification	Total	# Facilities: Probability of at Least Moderate Damage > 50%	# Facilities: Probability of Complete Damage > 50%	# Facilities: 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

Figure 2-16. Expected Damage to Essential Facilities (100-Year Probabilistic Event) (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 Hurricane 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 2-16.

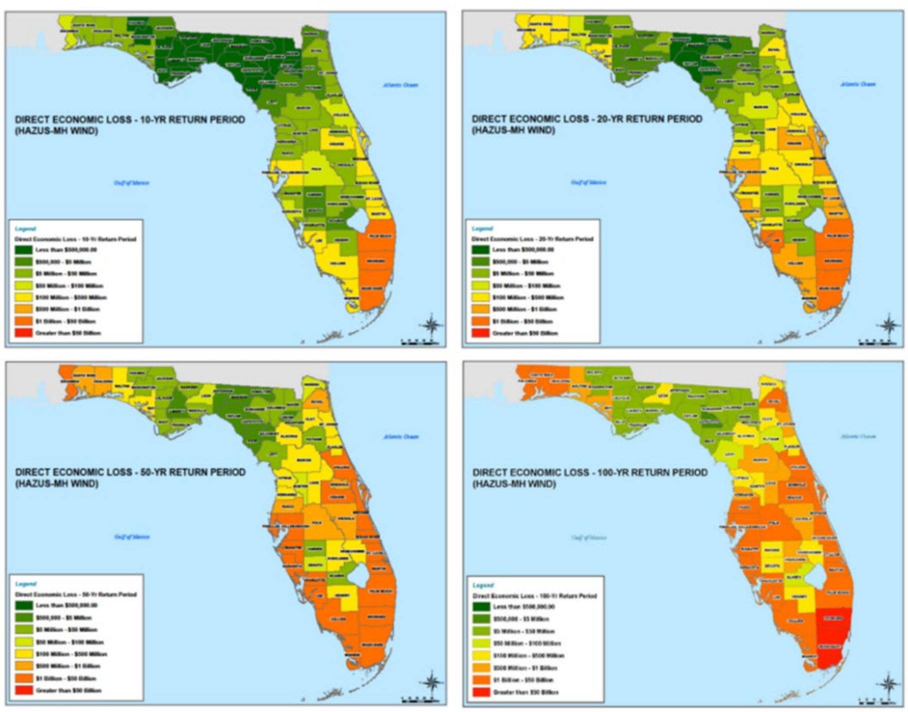


Figure 2-17. Hazus Hurricane Model Direct Economic Loss (Source: 2018 Florida State Hazard Mitigation Plan)

3. Evaluating and Prioritizing Mitigation Actions

Requirement §201.6(c)(3)

[The plan shall include the following:] A mitigation strategy 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.

§201.6(c)(3)(i)

[The hazard mitigation strategy shall include a] description of mitigation goals to reduce or avoid long-term vulnerabilities to the identified hazards (Local Mitigation Plan Review Guide).

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.

3.1. Identify Preliminary Mitigation Strategies and Actions and 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. Many of these findings can come from Hazus for Flood, Earthquake, Tsunami, and Hurricane wind models.

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.

3.2. Evaluate Mitigation Actions

Requirement §201.6(c)(3)(ii)

[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 (Local Mitigation Plan Review Guide).

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.

3.2.1. 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.

3.2.2. 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.

3.2.3. BENEFIT COST REVIEW

> Requirement §201.6(c)(3)(iii)
>
> [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 (Local Mitigation Plan Review Guide).

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).

3.2.4. 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.

3.2.5. 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.

3.2.6. DEVELOP PLAN TO IMPLEMENT MITIGATION ACTIONS

Requirement §201.6(c)(3)(iii)

[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 (Local Mitigation Plan Review Guide).

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.

4. Additional Data for Planning

Hazard Mitigation Plans help communities reduce future disasters' effects on lives, property, and the economy. Mitigation planning regulations require a risk assessment that describes each hazard identified by the community in terms of location, potential magnitude, past events, and future probability. The plan must also describe each hazard's impacts on the community. In addition to Hazus created data, there are additional datasets that can be used to enhance risk analysis for mitigation planning.

4.1. National Risk Index

The National Risk Index is an online mapping application that visualizes natural hazard risk metrics based on 18 natural hazards, expected annual losses from natural hazards, social vulnerability, and community resilience. With this tool, you can discover a holistic view of community risk to natural hazards.

Hazard Mitigation Plans help communities reduce future disasters' effects on lives, property, and the economy. The National Risk Index helps communities beginning the planning process by illustrating which hazards pose a risk, and the community's current level of resilience. It can also inform community outreach during the planning process.

Mitigation planning regulations require a risk assessment that describes each hazard identified by the community in terms of location, potential magnitude, past events, and future probability. The plan must also describe each hazard's impacts on the community.

When writing a Hazard Mitigation Plan, the natural hazard risk data helps communities meet certain requirements by providing an efficient, standardized risk assessment methodology and free interactive web maps and geographic information system (GIS) services. The Index incorporates physical and social vulnerability data to identify communities more at risk to the adverse impacts of natural hazards. The information in The Risk Index also allows communities to look at risk from multiple hazards. This tool does not generate the risk assessment portion of the plan, but it supports its development with high quality, comprehensive data that can specifically be applied to mitigation plan requirements for Elements B1 and B3.

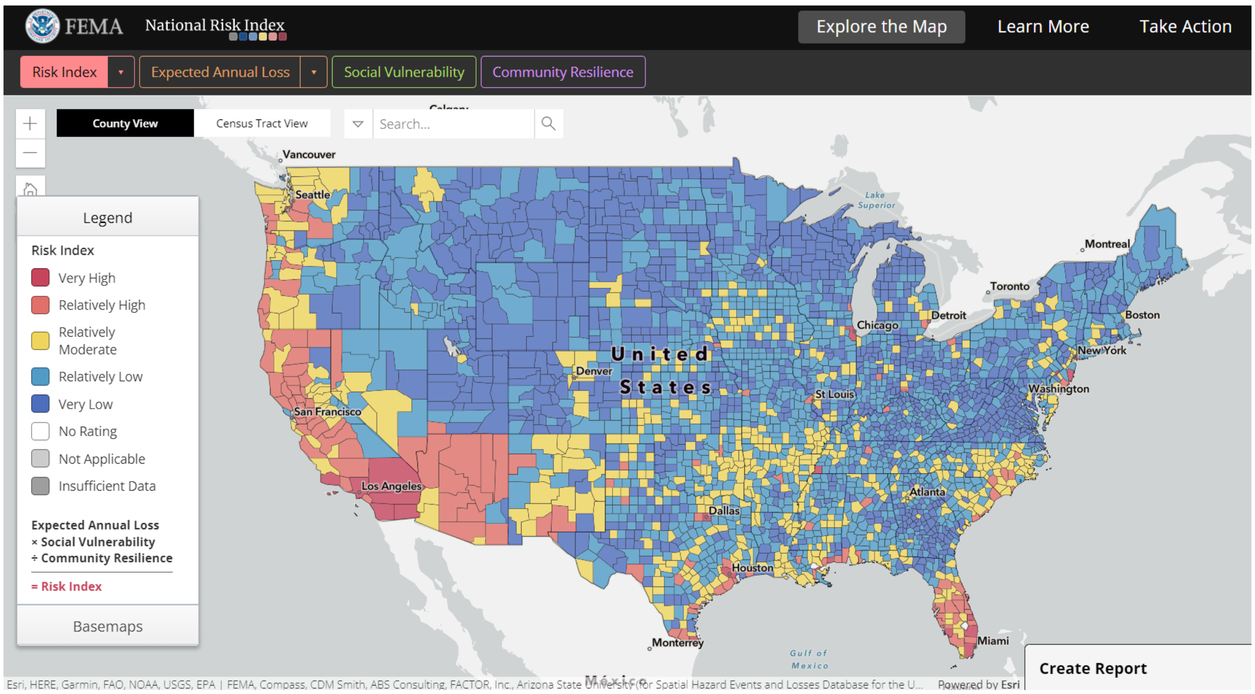


Figure 4-18 National Risk Index

4.2. Hazus Loss Library

The Hazus Loss Library is an online public collection of natural hazard risk information. The library is a collection of Hazus-generated risk assessments and loss modeling results for historic and probabilistic floods, hurricanes, earthquakes and tsunamis.

Curated by FEMA's Natural Hazards Risk Assessment Program, the Hazus Loss Library is the first open and authoritative collection of Hazus risk assessment studies to be shared publicly. Users can search for a historic event, planning scenario, or location and view previously performed analyses as well as downloadable results products and reports such as damage by building type, total economic losses, displaced households and more.

The Hazus Loss Library can aid in all phases of emergency management at the local, state and federal levels and improve mitigation strategies, strengthen planning exercises, and expedite recovery. The free platform is accessible for both technical and non-technical users.

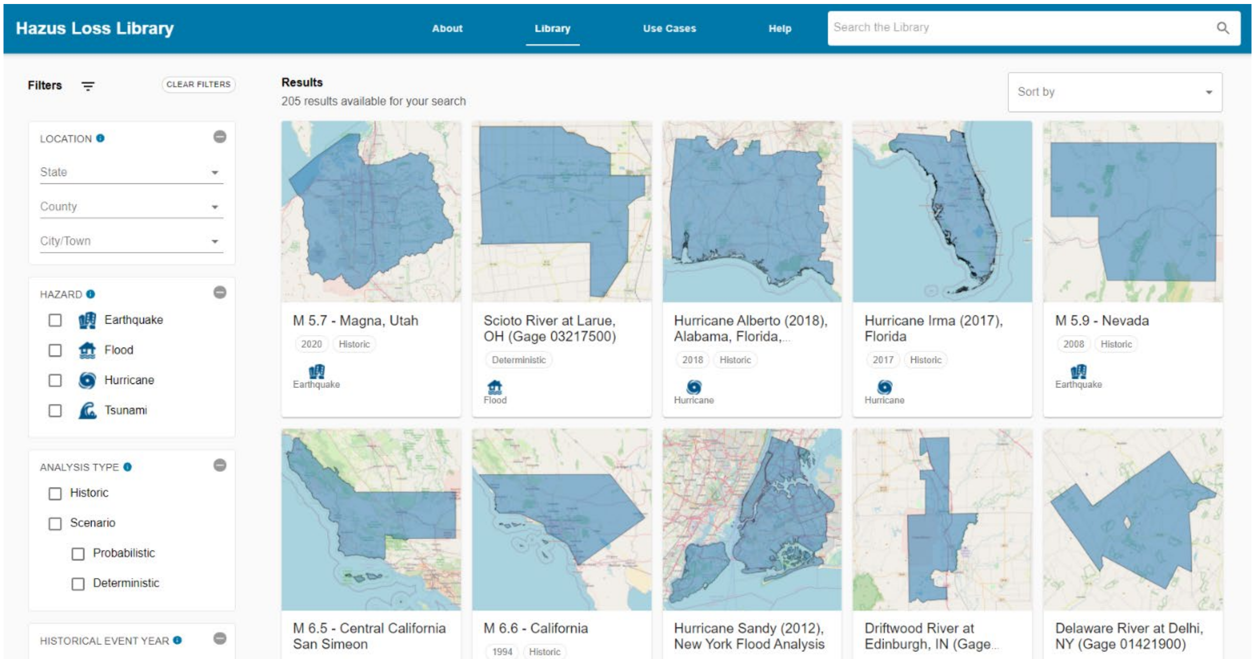


Figure 4-19. Hazus Loss Library

5. Hazus Open Source Tools

The Hazus program provides open source tools designed for a variety of risk analysis tasks that are available on the Hazus GitHub page. These tools are simple to use and do not require coding experience. However, they are developed using HazPy, the Hazus Python Package, which can be customized and extended by users with python coding experience to create new tools. The tools can aid planners and users in their analysis of vast amounts of risk assessment data.

5.1. Hazus Flood Assessment Structure Tool

The Hazus Flood Assessment Structure Tool (FAST) was designed to make flood risk assessments quicker, simpler, and more cost effective. FAST provides planners, analysts and policymakers with a free and user-friendly tool to characterize flood risk in their communities using completely open methods and technology. FAST helps drive strategic risk reduction initiatives across the U.S. by making flood risk assessments more accessible.

An example of the efficiency of the tool can be seen in a recent project with the U.S. Coral Reef Task Force, which mapped coastal flood losses avoided due to coral reef protection across Hawaii. The USGS documented the risk reduction benefits of coral reefs across Hawaii in 2019 using Census block exposure information to compare flood losses with full and reduced coral reef habitat. FEMA's Hazus Team built on this study by completing a detailed structure-level flood analysis using the FAST to identify areas where coral reef conservation would lead to the highest economic benefit for the five main islands of Hawaii.

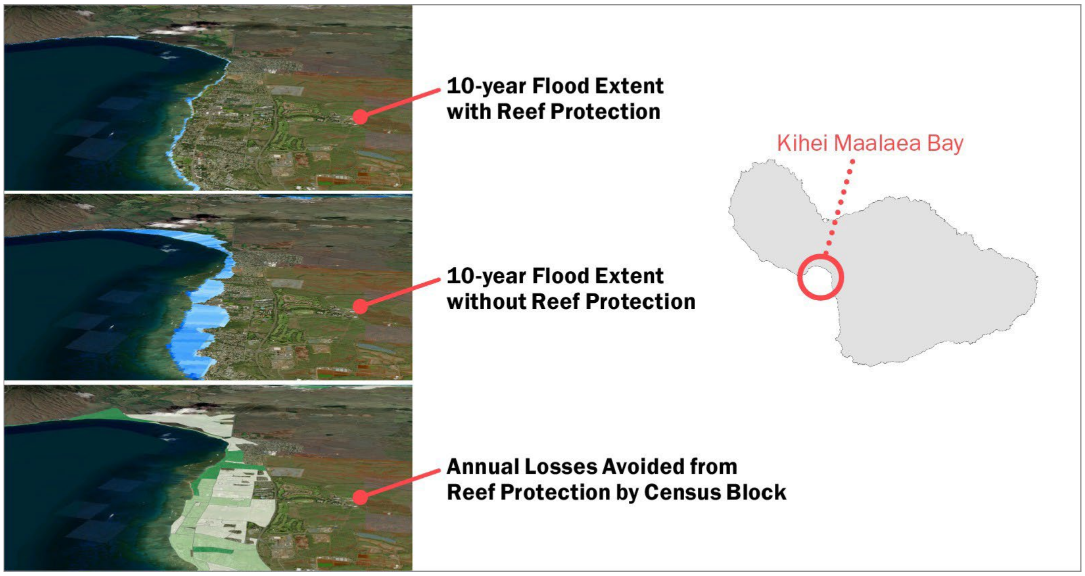


Figure 5-20. Risk Reduction Benefits of Coral Reefs on Maui – Kihei

(Changes in flood extent and annual flood losses avoided due to coral reef protection at Kihei Maalaea Bay identified as optimal for reef mitigation investment by a hot spot analysis)

5.2. Hurricane Hazard Import Tool

The Hurricane Hazard Import Tool (HHIT) is an open source tool that downloads, prepares, and imports Hurrevac hurricane data into a user's local Hazus database for hurricane loss modeling. Hurrevac is a storm tracking decision support tool jointly developed by the Federal Emergency Management Agency, the U.S. Army Corps of Engineers, and the National Oceanic and Atmospheric Administration. Hurrevac storm data include the location, direction, and speed of tropical storm winds for previous, current, and forecasted storm information produced by NOAA's National Hurricane Center advisories.

5.3. Hazus Export Tool

The open-source Hazus Export Tool can be used to produce simplified results tables and a one-page graphical report summarizing risk assessment results. The Hazus Export Tool is developed using the Hazus Python Package, HazPy. HazPy tools automatically check for updates each time they are opened.

6. Conclusion

As has been discussed throughout this document, Hazus can be a helpful tool to assist the mitigation plan author in displaying results from the risk assessment and developing mitigation actions. This document 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.

7. References

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8. Resources

More information on FEMA's Hazus and available resources can be found at https://www.fema.gov/hazus. For the Hazus Technical Manuals and User Guidance (listed below), SOPs, and other technical documentation, please visit https://www.fema.gov/flood-maps/tools-resources/flood-map-products/hazus/user-technical-manuals.

- Hazus Hurricane Model User Guidance
- Hazus Hurricane Model Technical Manual
- Hazus Tsunami Model User Guidance
- Hazus Tsunami Model Technical Manual
- Hazus Flood Model User Guidance
- Hazus Flood Model Technical Manual
- Hazus Earthquake Model User Guidance
- Hazus Earthquake Model Technical Manual
- Hazus Inventory Technical Manual
- Hazus CDMS Data Dictionary

Additional Hazus resources include the Hazus Youtube Playlist and the Hazus GitHub. Sign up for Risk Assessment Guidance here, and contact the Hazus team at fema-hazus-support@fema.dhs.gov with questions.

FEMA's National Risk Index can be found at https://www.fema.gov/flood-maps/products-tools/national-risk-index

FEMA's Mitigation Planning Resources (listed below) can be found at https://www.fema.gov/emergency-managers/risk-management/hazard-mitigation-planning

- 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