Hazus Tsunami Model User Guidance

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FEMA

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1.0 Introduction

The Hazus Tsunami loss estimation model provides local, state, and regional officials with a state-of-the-art decision support software for estimating potential losses from tsunami scenarios. This loss estimation capability will enable users to anticipate the consequences of future tsunamis and to develop plans and strategies for reducing risk. The GIS based software can be applied to study small or large geographic areas with a range of population characteristics and can be implemented by users with varying technical and subject expertise.

The methodology was originally developed for the Federal Emergency Management Agency (FEMA) by the National Institute of Building Sciences (NIBS) to provide a tool for developing earthquake loss estimates. Hazus has been expanded to perform similar loss evaluations for wind, floods, and tsunamis.

The Hazus Tsunami Model allows practitioners to estimate economic and social losses from tsunamis. The information provided by the model will assist state and local officials in evaluating, planning for, and mitigating the effects of tsunamis. The Hazus Tsunami Model provides practitioners and policy makers with a tool to help reduce tsunami damage, reduce disaster payments, and make wise use of the nation's emergency management resources.

If the Hazus Tsunami Model is applied for areas of tsunami risk across the nation, estimates also will help guide the allocation of federal resources to stimulate risk mitigation efforts and to plan for federal tsunami response. The Hazus Tsunami Model is currently available for the five (5) Very High Risk U.S. states and the five (5) High Risk U.S. territories.

1. Alaska
2. Washington
3. Oregon
4. California
5. Hawaii
6. Northern Mariana Islands (Tsunami only)
7. American Samoa (Tsunami only)
8. Guam (Tsunami only)
9. Puerto Rico
10. U.S. Virgin Islands (Tsunami only)

This *Hazus Tsunami Model User Guidance* document provides the background and instructions for developing an inventory to complete a tsunami loss estimation study using Hazus. It also provides information on running the software, and how to interpret and report model outputs.

The *Hazus Tsunami Model Technical Guidance,* separate accompanying document, details the default data and documents the methods of calculating losses. Together, these documents provide a comprehensive overview of this nationally applicable loss estimation methodology.

1.1 Uses for Hazus

Hazus can be used by various types of users with varying data needs. Local or state government officials may be interested in the costs and benefits of specific mitigation strategies, and thus may want to know the expected losses if mitigation strategies have (or have not) been applied. Emergency response teams may use the results of a loss study in planning and performing emergency response exercises. In particular, they might be interested in the operating capacity of emergency facilities such as fire stations, emergency operations centers, and police stations. Emergency planners may want to know how much temporary shelter will be needed and for how long. Utility company representatives, as well as community planners, will want to know about the locations and lengths of potential utility outages.

Federal and state government officials may require an estimate of economic losses (both short term and long term) in order to direct resources toward affected communities. In addition, government agencies may use loss studies to obtain quick estimates of impacts in the hours immediately following a tsunami so as to best direct resources to the disaster area. Insurance companies may be interested in monetary losses so they can assess asset vulnerability.

Loss estimation studies based on tsunami scenarios have a variety of uses for various departments, agencies, and community officials. As users become familiar with the loss estimation methodology, they will determine which Hazus methodologies are most appropriate for their needs, and how to interpret the study results.

The products of Hazus Tsunami Model analyses have several pre-tsunami and/or post-tsunami applications in addition to estimating the scale and extent of damage and disruption.

Examples of pre-tsunami applications of the outputs may include:

- *Development of tsunami hazard mitigation strategies* that outline policies and programs for reducing tsunami losses and disruptions indicated in the initial loss estimation study. Strategies can involve upgrading existing buildings and the adoption of new building codes.
- *Anticipation of the nature and scope of response and recovery efforts* including: identifying short-term shelter requirements and safe zones.
- *Development of community awareness plans* to increase preparedness levels.

Post-event applications of the outputs may include:

- *Projection of immediate economic impact assessments for state and federal resource allocation and support* including supporting the declaration of a state and/or federal disaster by calculating direct economic impact on public and private resources, local governments, and the functionality of the area.
- *Activation of immediate emergency recovery efforts* including provision of emergency housing shelters and initiating clean-up efforts.
- *Application of long-term reconstruction plans* including the identification of long-term reconstruction goals, the institution of appropriate wide-range economic development plans for the entire area, allocation of permanent housing needs, and the application of land use planning principles and practices.
- *Improvement of community-awareness plans* to increase preparedness levels

Once inventory has been collected, making modifications and running new analyses are simple tasks. The ease with which reports and maps can be generated makes the software useful for a variety of applications.

1.2 Assumed Level of Expertise of Users

Users can be broken into two groups: those who perform the study and those who use the study results. For some studies these two groups will consist of the same people, but generally this will not be the case. However, the more interaction there is between these two groups, the better the study will be. End users of the loss estimation study need to be involved from the beginning to make results more usable.

Those who are performing the study must, at minimum, have a basic understanding of tsunamis and their consequences. In many cases, the results will be presented to audiences (e.g., city councils and other governing bodies) that have little technical knowledge of the tsunami loss problem.

It is assumed that a loss study will be performed by a team consisting of tsunami experts, structural engineers or architects, economists, sociologists, emergency planners, and loss-estimate users. These individuals are needed to develop tsunami scenarios, develop and classify building inventories, provide and interpret economic data, provide information about the local population, and provide input as to what types of loss estimates are needed to fulfill the goals of the loss study. Because tsunamis often are the result of a local earthquake, the team should also include representatives from the earthquake modeling and analysis community.

If a local or state agency is performing the study, some of the expertise can be found in-house. Experts are generally found in several departments: building permits, public works, planning, public health, engineering, seismic and tsunami science, information technologies, finance, historical preservation, natural resources, and land records. Although internal expertise may be most readily available, participation of individuals from academic institutions, citizen organizations, and private industry cannot be underestimated.

1.3 When to Seek Help

The results of a loss estimation study should be interpreted with caution. If default input values are used, it must be recognized that there is a great deal of uncertainty associated with them. If the loss estimation team does not include individuals with expertise in the areas described above, then it is likely that one or more outside consultants may be required to assist with interpreting the results. It is also advisable to retain objective reviewers with subject expertise to evaluate and comment on map and tabular data outputs.

A seismic or tsunami engineer will be needed to provide deterministic scenario data, or to review each scenario’s parameters. Attention should be given to any differences in the methodology used to define documented scenarios.

If the user intends to modify the default inventory data or parameters, assistance will be required from an individual with expertise in the subject. For example, if the user wishes to change default percentages of model building types for the region, a structural engineer with knowledge of regional design and construction practices will be helpful. Modifications to defaults in the economic loss models will require input from an economist.

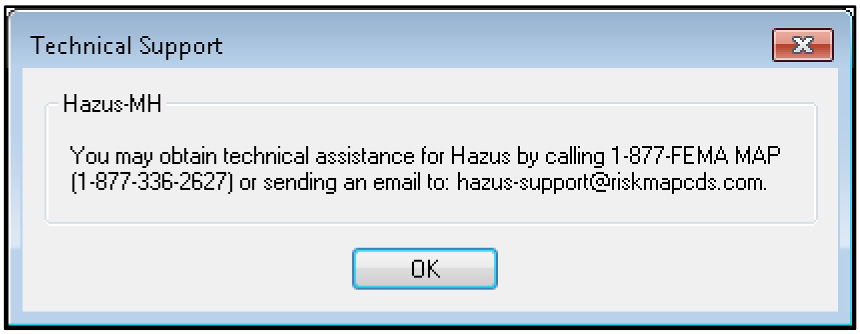
1.4 Online Help and Technical Support

Technical help for the users of Hazus has been established. Users should contact the technical support line at the email, or phone provided in this document or in the Hazus application (**Help | Technical Support**) for information on technical support. To access more information, including Frequently Asked Questions (FAQs), software updates, training opportunities, and User Group activities, visit: https://www.fema.gov/hazus.

Technical assistance is available via the Hazus Help Desk at hazus-support@riskmapcds.com. The **Help** menu references the help files for ArcGIS. Given that Hazus is built as an extension to ArcGIS functionality, knowing how to use ArcGIS and ArcGIS Help Desk assists in Hazus use.

To obtain technical support with any hazard modeled by Hazus, a dedicated link is available for getting help. Both an email and direct phone number are available and can be retrieved via the **Help | Obtaining Technical Support…** option **(Figure 1)**.

Figure 1: Hazus Technical Support



1.5 Uncertainties in Loss Estimates

Although the Hazus software offers users the opportunity to prepare comprehensive loss estimates, it should be recognized that, even with state-of-the-art techniques, uncertainties are inherent in any such estimation methodology. Any region or city studied will have an enormous variety of buildings and facilities of different sizes, shapes and structural systems constructed over years under diverse design codes. Similarly, many types of components with differing seismic and tsunami resistance will make up transportation and utility lifeline systems. Due to this complexity, relatively little is certain concerning the structural resistance of most buildings and other facilities.

Further, there simply are not sufficient data from past tsunamis or laboratory experiments to permit precise predictions of tsunami damage even for specific buildings and other structures. To deal with this complexity and lack of data, buildings and components of lifelines are combined into categories based upon key characteristics. Relationships between key features of water depth and velocity, and average degree of damage with associated losses for each building category are based on current data and available theories. While the Hazus software is state-of-the-art in terms of loss estimation, these relationships contain a certain level of uncertainty.

The results of a tsunami loss study should not be looked upon as a *prediction*. Instead, they only give an indication of what the future may hold.

2.0 Introduction to the Tsunami Loss Estimation Methodology

This brief overview of the tsunami loss estimation methodology is intended for local, regional, or state officials contemplating a tsunami loss study.

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. The following information can be obtained:

- *Quantitative estimates of losses* in terms of direct costs for repair and replacement of damaged buildings, direct costs associated with loss of function (e.g., loss of business revenue, relocation costs), casualties, and regional economic impacts.
- *Combined Earthquake and Tsunami scenario losses* (for near-source earthquake events)

To generate this information, the methodology includes:

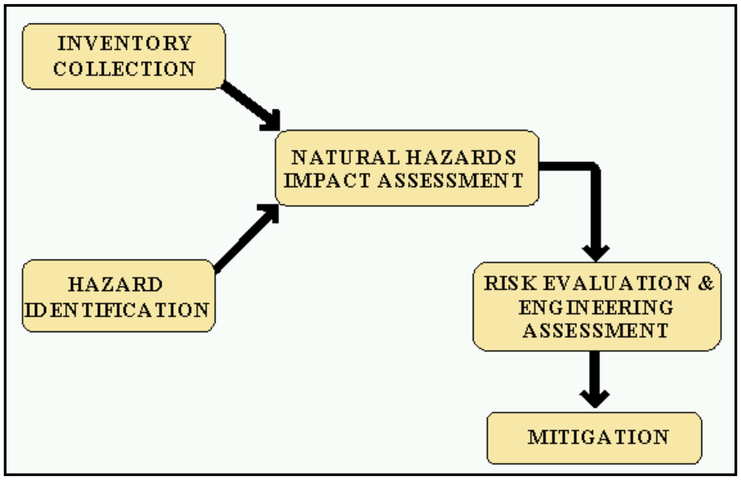
- Classification systems used in assembling inventory and compiling information on the building stock, as well as demographic and economic data.
- Standard calculations for estimating type and extent of damage, and for summarizing losses.
- National and regional databases containing information for use as default (built-in) data—in the absence of user-supplied data—useable in calculation of losses.

These systems, methods, and data have been combined in the development of user-friendly GIS software for this loss estimation application. GIS technology facilitates the manipulation of data on building stock, population, and the regional economy.

The software makes use of GIS technologies for displaying and manipulating inventory, and permits losses and consequences to be portrayed on applicable spreadsheets and maps. Collecting and entering the information necessary for analysis are the major tasks involved in generating a loss estimate. The methodology permits estimates to be made at several levels of complexity, based on the level of inventory entered for the analysis (e.g., default data versus locally enhanced data). The better and more complete the inventory information, the more accurate the results.

Figure 2 shows the steps that are typically performed in assessing and mitigating the impacts of a natural hazard such as a tsunami. The methodology incorporates inventory collection and hazard identification into the natural hazards impact assessment.

Figure 2: Steps in Assessing and Mitigating Losses due to Natural Hazards



In a simplified form, the steps include:

- Select the area to be studied. The region of interest is created based on Census block, Census tract, county, NFIP community, or state. The area could include a city, county, or group of municipalities. It is generally desirable to select an area that is under the jurisdiction of an existing regional planning group.
- Specify the hazard. In the Tsunami Model, the hazard can be specified as a Near Source or Distant Source tsunami. When a Near Source scenario is selected, the option of running a combined earthquake and tsunami damage scenario is available. The results of the earthquake shake damage can be fed into the Hazus Tsunami Model to produce combined earthquake and tsunami loss estimates for the General Building Stock (GBS) and User-Defined Facilities (UDF).
- Provide additional information describing the building inventory, essential facilities, and demographics, if available.
- Using formulas embedded in Hazus, damage probabilities, expected building losses, expected contents losses, and expected loss-of-use are computed for different classes of buildings.
- The results of the previous step are used to compute estimates of direct economic loss, evacuation times, and casualties.

The user plays a major role in selecting the scope and nature of the output of a loss estimation study. 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 tract or block, or may be aggregated by county or region.

2.1 Tsunami Hazards Considered by the Methodology

The tsunami-related hazards considered by the methodology in evaluating casualties, damage, and resultant losses include tsunami inundation depth, and velocity. When working with tsunami scenarios, it is recommended that tsunami experts be consulted to develop credible tsunami scenarios that are realistic for the study area. Consideration should be given to repeating loss calculations for several scenario tsunamis with different magnitudes and locations, since these factors are a major source of uncertainty.

2.2 Types of Buildings and Facilities Considered

The buildings, facilities and lifeline systems considered by the methodology are as follows:

- *General Building Stock*: Hazus Tsunami Model General Building Stock (GBS) does not directly use the aggregated Census Tract or Block data used by other models. Instead, the GBS is composed of the U.S. Army Corp of Engineers' (USACE) National Structure Inventory (NSI) point data (developed with FEMA). NSI point data creates notional structures, or "points," in the developed portion of each census block to represent the numbers and types of buildings that occur based on size, occupancy type, construction materials, etc. Although the Census Tract or Block geometries are used to display data, the modeling is conducted at the point level within that geometry.
- *Essential Facilities*: Essential facilities, including medical care facilities, emergency response facilities (police, fire, and emergency operation centers (EOC)), and schools, are those vital to emergency response and recovery following a disaster. School buildings are included in this category because of the key role they often play in housing people displaced from damaged homes. Generally, there are very few of each type of essential facility in a census tract, making it easier to obtain site-specific information for each facility. Thus, damage and loss-of-function are evaluated on a building-by-building basis for this class of structures, even though the uncertainty in each such estimate is high. *At this time, the tsunami loss model capability is not available for essential facilities, however, essential facilities are integrated into the GBS information and can be assessed using the UDF capability. Schools data in particular were used to estimate the population (students) in the inundation zones. Users can evaluate Essential Facilities by incorporating them as User-Defined Facilities.*
- *User-Defined Facilities*: User-defined facilities are buildings at specific locations that the user can add to the inventory. Damage is evaluated on a building-by-building basis for this class of structures, even though the uncertainty in each such estimate is high. Accurate location of these buildings may substantially reduce uncertainty regarding the intersection with the hazard input. Some communities have the coastal user-defined facility data already populated for their study region.

2.3 Casualties

The Hazus Tsunami Model makes use of a USGS methodology (see Chapter 6 of the *Tsunami Model Technical Guidance*) for estimating pedestrian evacuation times, incorporating travel and warning times to estimate potential loss of life and injuries. The Casualty analysis can be performed for two levels of data. As with other "Level 1" analyses, or Basic analysis, in Hazus, Casualty Level 1 is considered an estimation tool with minimal requirements for data input. The Hazus Tsunami Model creates the boundaries required for the Level 1 Casualty analysis: the Hazard Boundary and the Fatality Boundary. The Hazard Boundary is the inundation hazard boundary (depth > 0). The Fatality Boundary is the portion of the inundation hazard where the flood depths are expected to be 2 meters or greater in depth (Fatality Rate = 99%). This assumed fatality rate does not account for the potential that some people may find refuge in buildings that are strong and tall enough to survive the tsunami loads.

Casualty Level 2, or Advanced analysis, is more comprehensive, and utilizes the travel time results provided by the USGS Pedestrian Evacuation Analyst Tool. (See Chapter 11, below, for additional information.)

2.4 Levels of Analysis

To provide flexibility, losses are estimated based on the accuracy of input data. Basic analysis can be based on default data and parameter data provided within Hazus. Advanced analysis can be estimated using more accurate data that is specific to the region, hazard, population, etc. thus improving inventories and/or parameters with user-supplied data. The advanced level also incorporates data from third-party studies. The appropriate level of analysis must be determined to meet the needs and resources of the user.

2.4.1 Analysis Based on Default Information

The basic level of analysis uses the default GBS and demographic databases built into the model. These databases are derived from national-level data sources for building square footage, building value, population characteristics, costs of building repair, and economic data. Direct economic and social losses associated with the GBS are computed, as well as evacuation travel times and casualty estimates. Because the analysis involves only default data sources, the uncertainties are high.

Other than defining the study region, specifying the hazard, and making decisions concerning the extent and format of the output, an analysis based on default data requires minimal effort from the user. As indicated, however, since default rather than actual data are used to represent local conditions, the uncertainties in the estimated levels of damage and loss are high. This level of analysis is suitable primarily for preliminary evaluations and for comparisons among different regions.

2.4.2 Analysis with User-Supplied Inventory

Results from an analysis using only default inventory can be improved greatly with at least a minimum amount of locally developed input. This is generally the intended level of implementation. Improved results are highly dependent on the quality and quantity of improved inventories. The significance of the improved results also relies on the user’s analysis priorities. The following inventory improvements impact the accuracy of analysis provided by the tsunami model, as well as applications of the results:

- Use of locally available data or estimates concerning the square footage of buildings in different occupancy classes.
- Use of local expertise to modify, primarily by judgment, the databases concerning percentages of model building types associated with different occupancy classes.
- Preparation of a detailed inventory for all essential facilities.
- Collection of detailed inventory and cost data to improve evaluating exposure of various transportation and utility lifelines.
- Collection of detailed population and transportation data to improve the evacuation results.

- Use of locally available data concerning construction costs or other economic parameters.
- Gathering of information concerning high potential loss facilities and facilities housing hazardous materials.
- Synthesis of data for evaluating the economy of the study region used in assessing indirect economic impacts.

2.5 Methodology updates

The current version of the Hazus Tsunami Model, does not estimate the following:

- *Damage, loss, and functionality estimations for Essential Facilities and Lifeline Infrastructure*
- *Shelter Requirements*
- *Debris*
- *Indirect economic losses*
- *Note that, at this time, the standalone earthquake model analysis is not complete for the U.S. territories (except Puerto Rico) and will not run independent of the tsunami analysis. The functionality to run the standalone earthquake analysis is available for the territories, but the earthquake specific inventory tables have not been completed.*

For Combined Earthquake and Tsunami Losses Global Report:

- *Casualties are calculated and presented <u>separately</u> for earthquake and tsunami, at this time, so there is some potential for double counting. However, it is possible that injuries as a result of the earthquake would slow evacuation times for those persons and anyone who remains to assist them, which could result in an increase in casualties caused by the tsunami.*

3.0 Getting Started: Hazus Start-Up Screen

The start-up screen is the first screen the user sees when Hazus is launched. Before running a loss estimation analysis, users must define a study region. The Study Region, in Hazus terminology, is the geographic extent for which data are aggregated, the hazard defined and the analysis carried out. Hazus will prompt the user to create a new region or import a previously created region. Users can also open, delete, duplicate, backup, or export an existing region.

3.1 Hazus MH-Startup

The first option in the Hazus Startup (**Figure 3**) is to define a study region. For this example, we will be creating a new region. Clicking **OK** activates the window seen in Figure 4. In this Wizard, the user selects the study region's tsunami hazard type for the analysis.

Click **Next** to start. This will activate the window seen in Figure 5 where the user can name the Region and create a description. Click **Next**, which will activate the window in Figure 6. Select Tsunami and click **Next**.

For users who wish to create combined earthquake and tsunami results, Earthquake should also be selected.

Figure 3: Hazus Startup Menu – Create a New Region

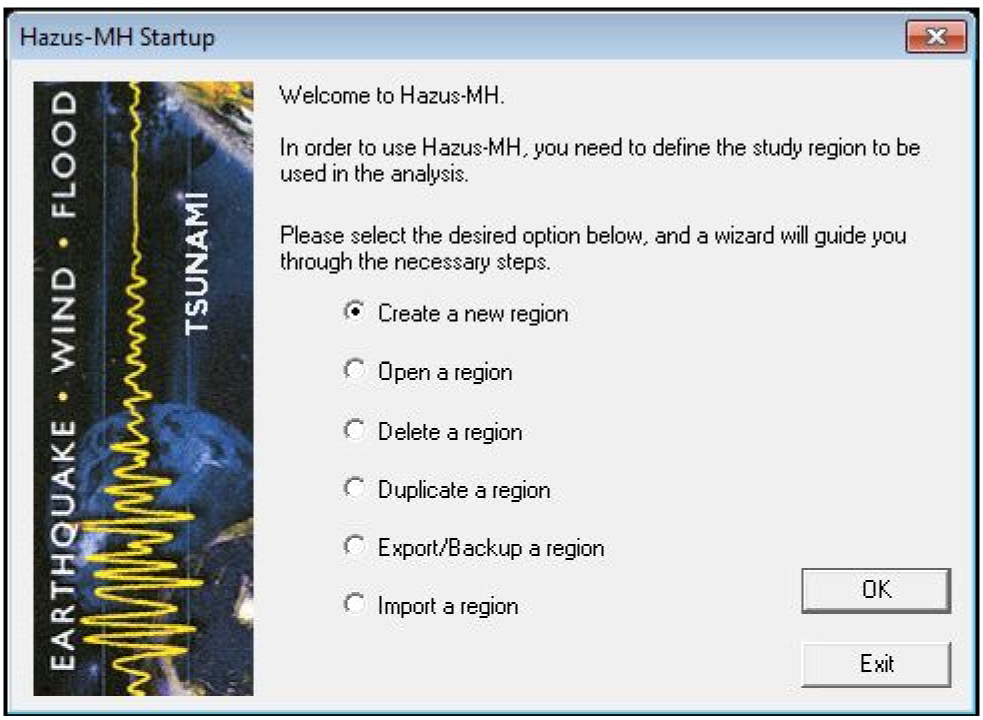


Figure 4: Create New Region Wizard

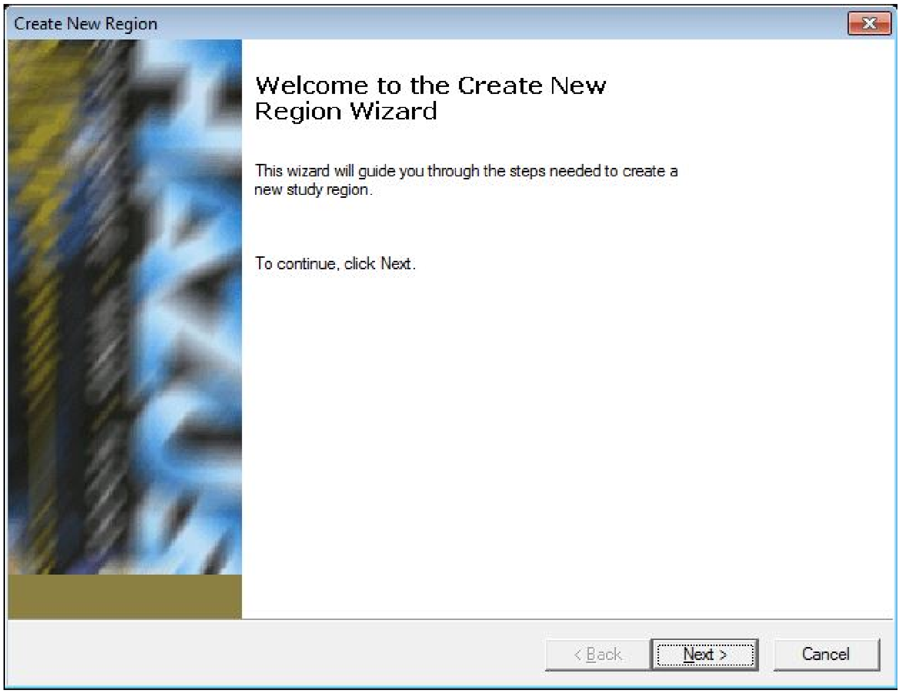


Figure 5: Study Region Name

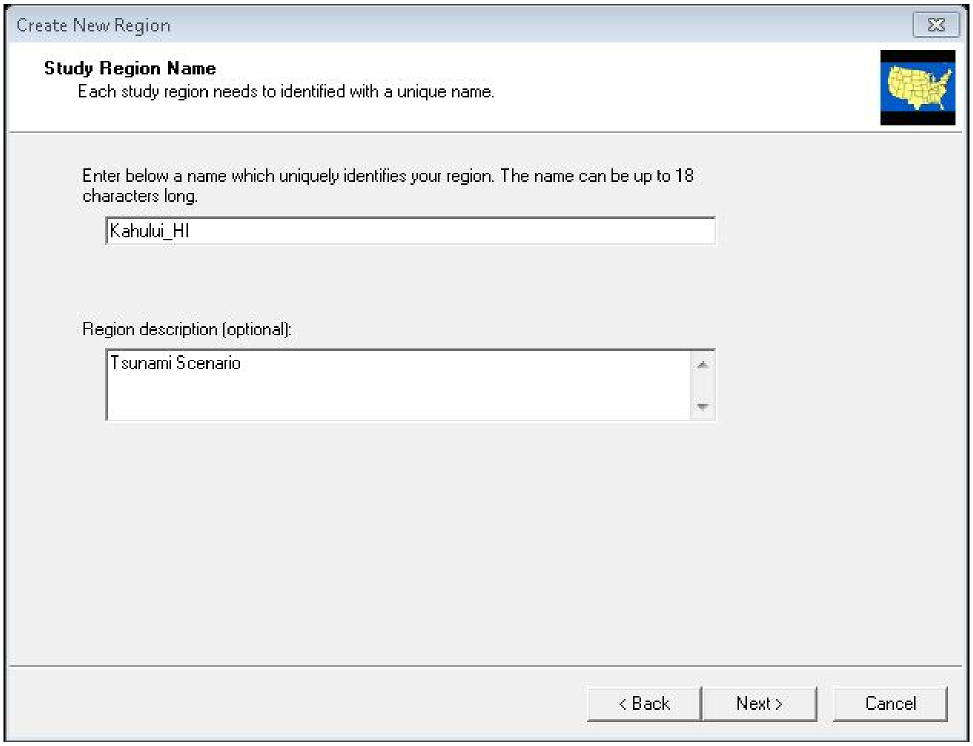
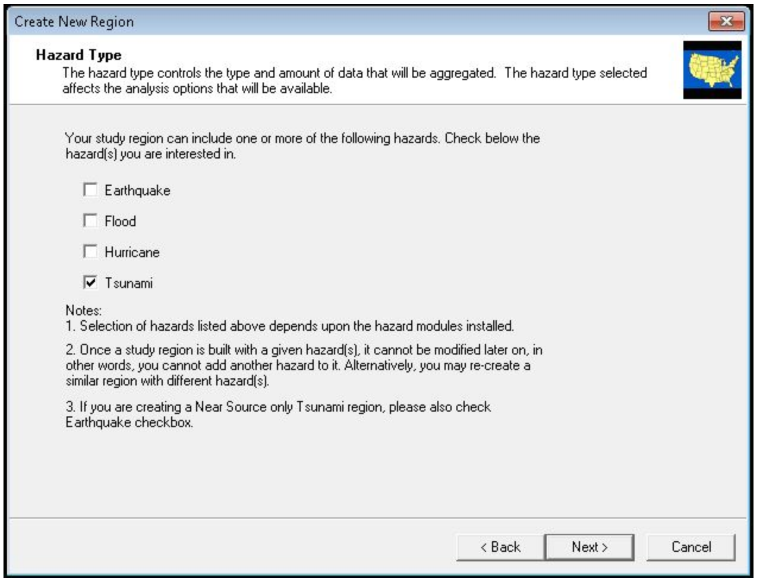


Figure 6: Hazard Type



3.2 Create New Region

Next, the user can create a new region by State, County, Census tract, Census block, or Community (NFIP) levels, as seen in **Figure 7.** To create a region at the county level, the user first selects the state of the new region found in **Figure 8.** This will prompt the County Selection window found in **Figure 9**. Once a county is selected, click **Finish**. The program will process until the region has been created. Click **OK**. The program will not automatically open the region at the end of this process.

Figure 7: Create New Region Selection

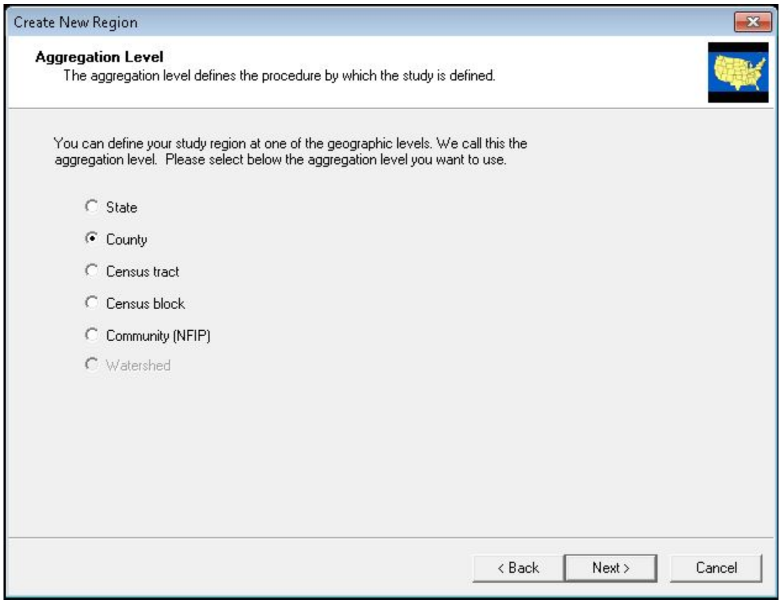


Figure 8: Create New Region State Selection

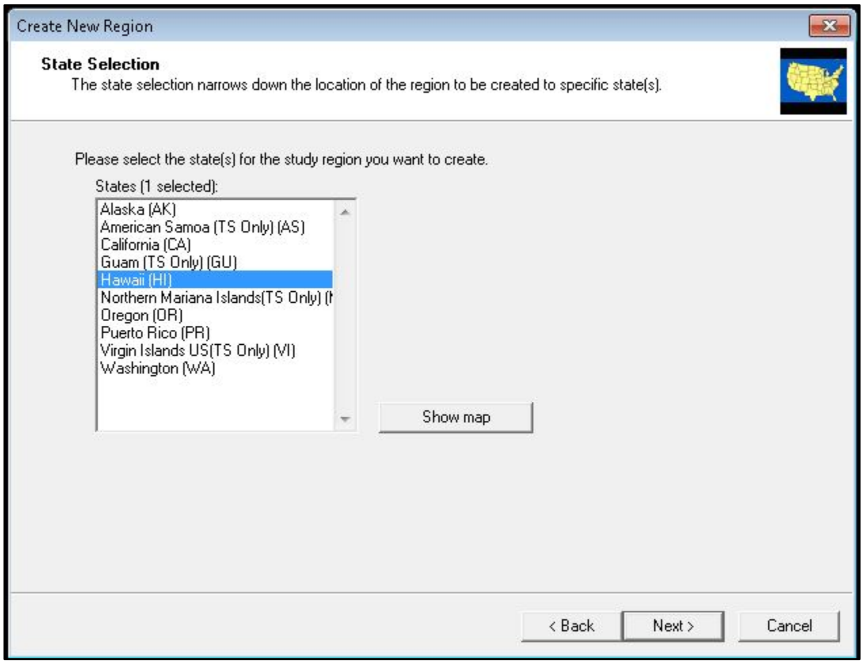
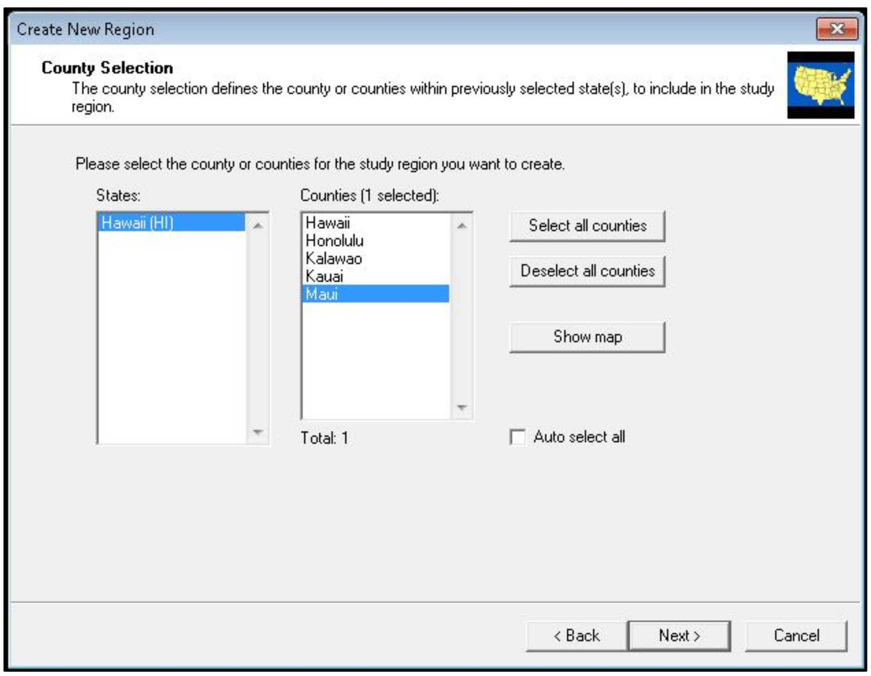


Figure 9: Create New Region County Selection



3.3 Open Region

Open the newly created Region under the Hazus Startup seen in Figure 10**.** This will allow the user to select the study created in the previous steps. Click **Next** at the Open Region window

(Figure 11). Select the region that was created in the previous section**.** Click **Next**. Then click **Finish**. The region will then open.

Figure 10: Hazus Startup Menu - Open a Region

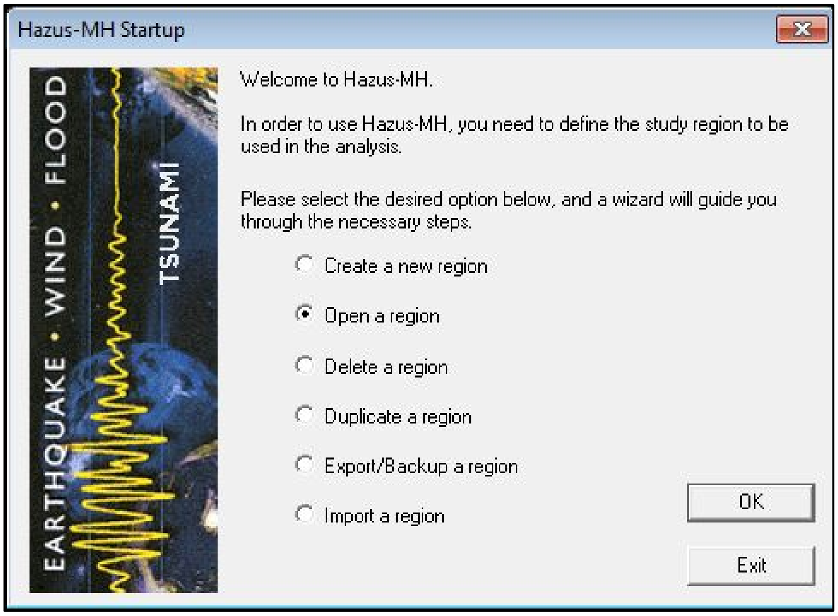
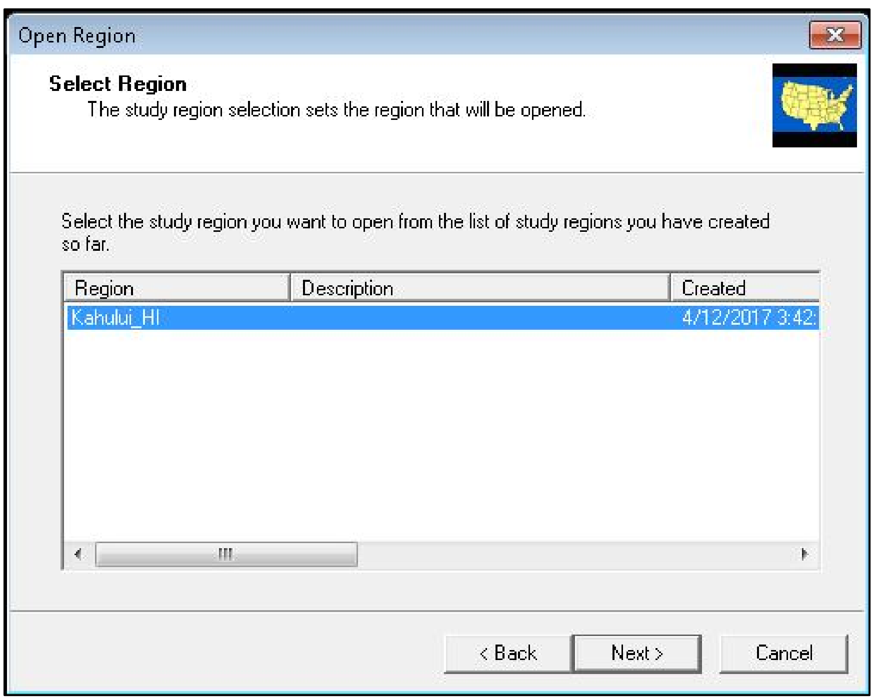


Figure 11: Select a Region



3.4 Delete Region

The **Delete a Region** option seen in Figure 12 will not be available until a region has been created or imported. Select Delete a Region and click **OK,** this will open the Delete a Region window seen in Figure 13. Click **Delete**.

Figure 12: Hazus Startup Menu - Delete a Region

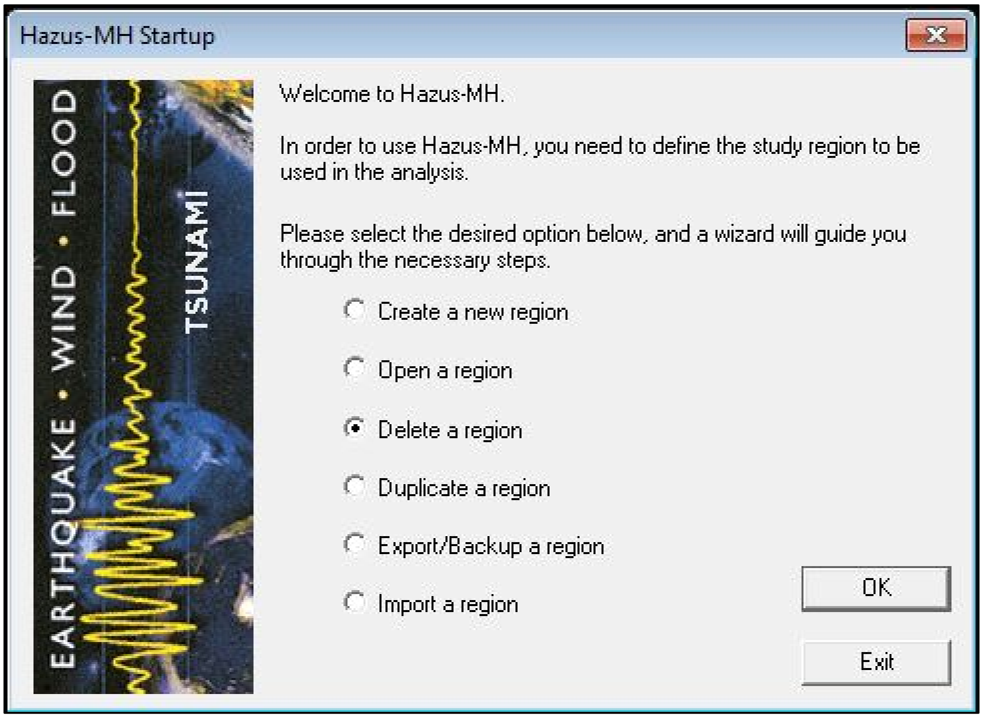
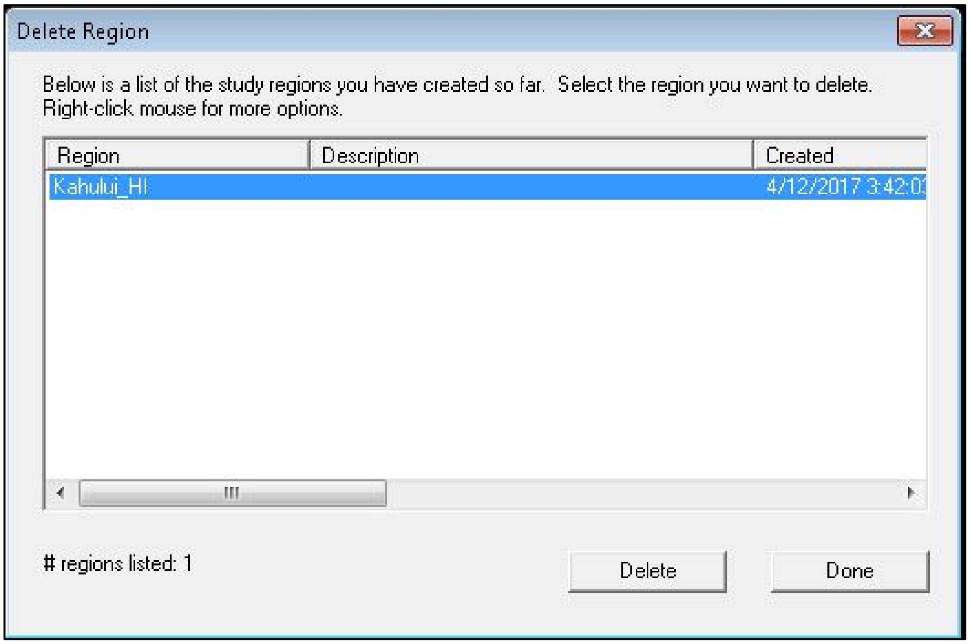


Figure 13: Delete a Region



3.5 Duplicate a Region

The **Duplicate a Region** option seen in Figure 14 will not be available until a region has been created or imported. Select Duplicate a Region and click **OK**. The selected region can be Duplicated as seen in Figure 15**.**

Figure 14: Hazus Startup Menu - Duplicate a Region

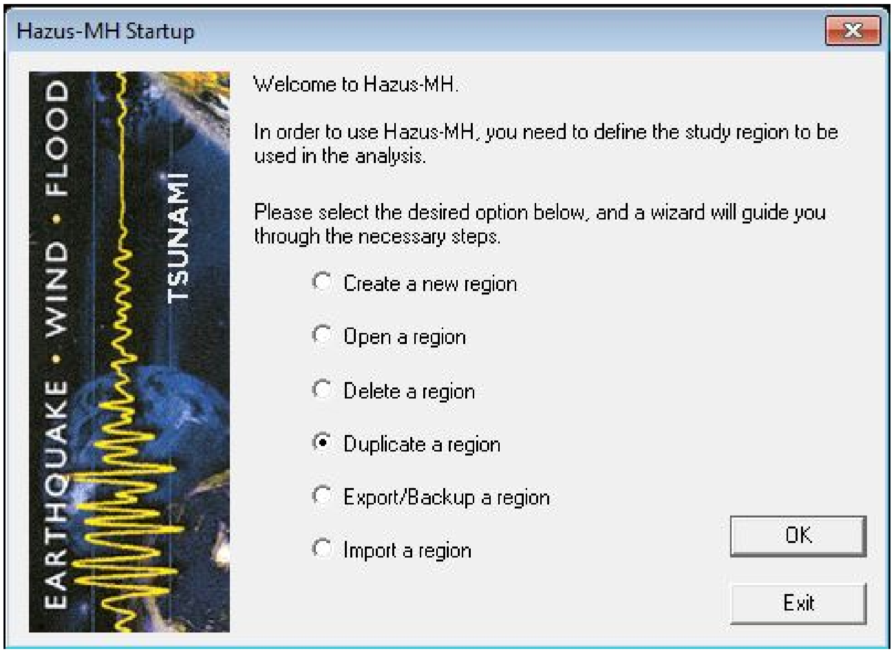
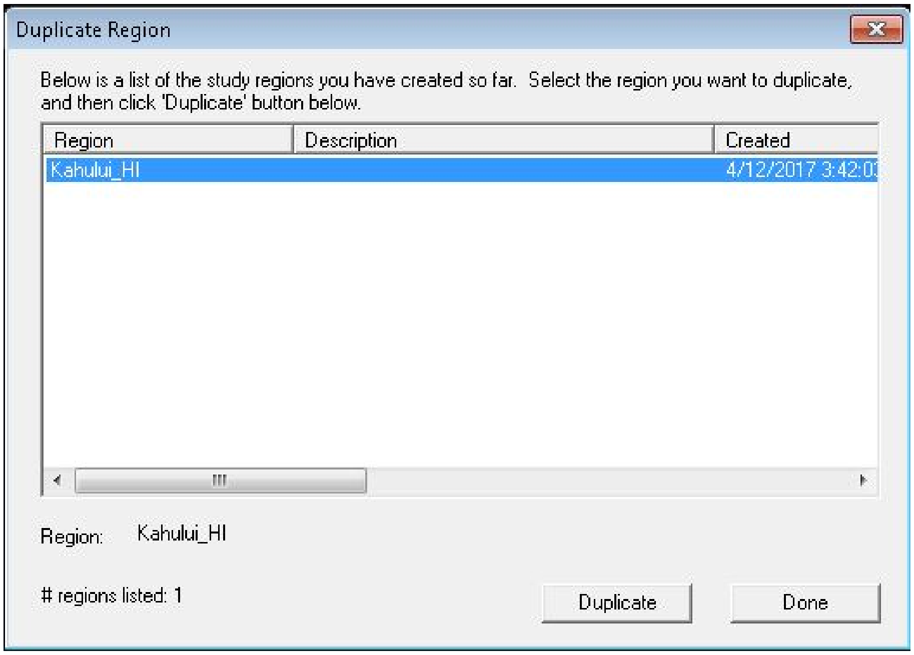


Figure 15: Duplicate a Region Selection

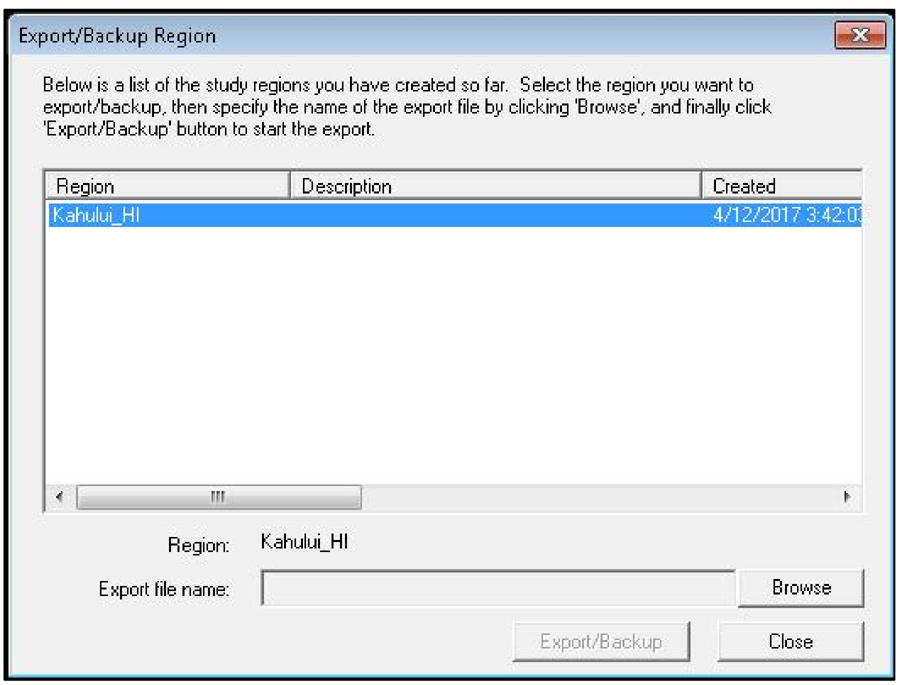


3.6 Export Region

The **Export/Backup** a Region option seen in Figure 16 will not be available until a region has been created or imported. Select Export/Backup a Region and click **OK**. The user can then Export/Backup a region by following the instructions at the top of the window seen in Figure 17.

Figure 16: Hazus Startup Menu - Export/Backup a Region

Figure 17: Export/Backup a Region



3.7 Import a Region

Select **Import a Region (Figure 18)** and click **OK**. File explorer will open. Select an export Hazus file (. hpr)**.** The Imported Region Name window will open, and prompt the user to name the imported region **(Figure 19).**

Figure 18: Hazus Startup Menu - Import a Region

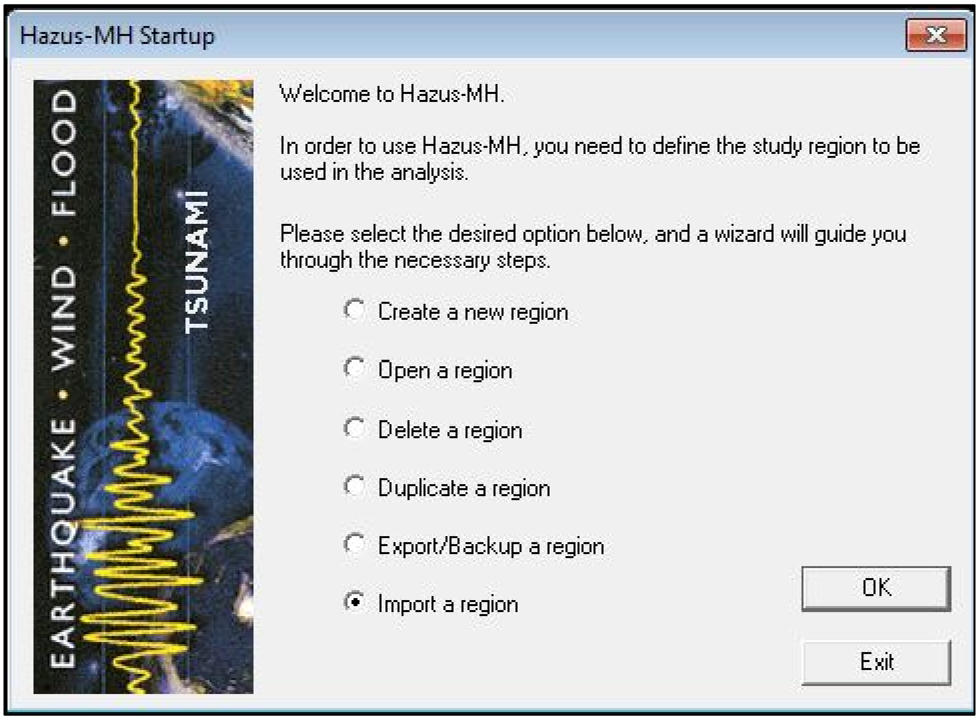
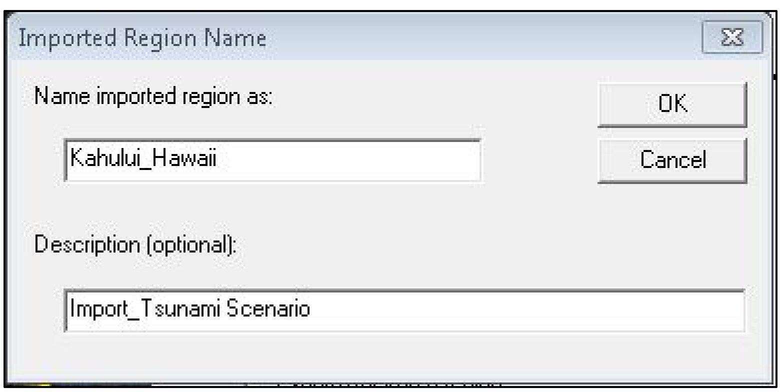


Figure 19: Imported Region Name



4.0 Tsunami Model: Basic Hazus Analysis

The Hazus Tsunami Model allows practitioners to estimate the economic and social losses from tsunami impacts. The information provided by the model will assist state and local officials in evaluating, planning for, and mitigating the effects of tsunami impacts. The Hazus Tsunami Model provides practitioners and policy makers with a tool to help reduce tsunami damage, reduce disaster payments, and make wise use of the nation's emergency management resources. The following example will allow the user to run a Basic Tsunami General Building Stock (GBS) Analysis and Basic Casualty Analysis.

4.1 Steps to Create and Run a Basic Tsunami GBS Analysis

Open Hazus (Figure 20). This section will involve opening a region. Information on all other options can be found in Chapter 3: Getting Started: Hazus Start-Up Screen. Select **Open a region** and click **OK**. This will open the Open a Region Wizard (Figure 21).

Figure 20: Open a Region

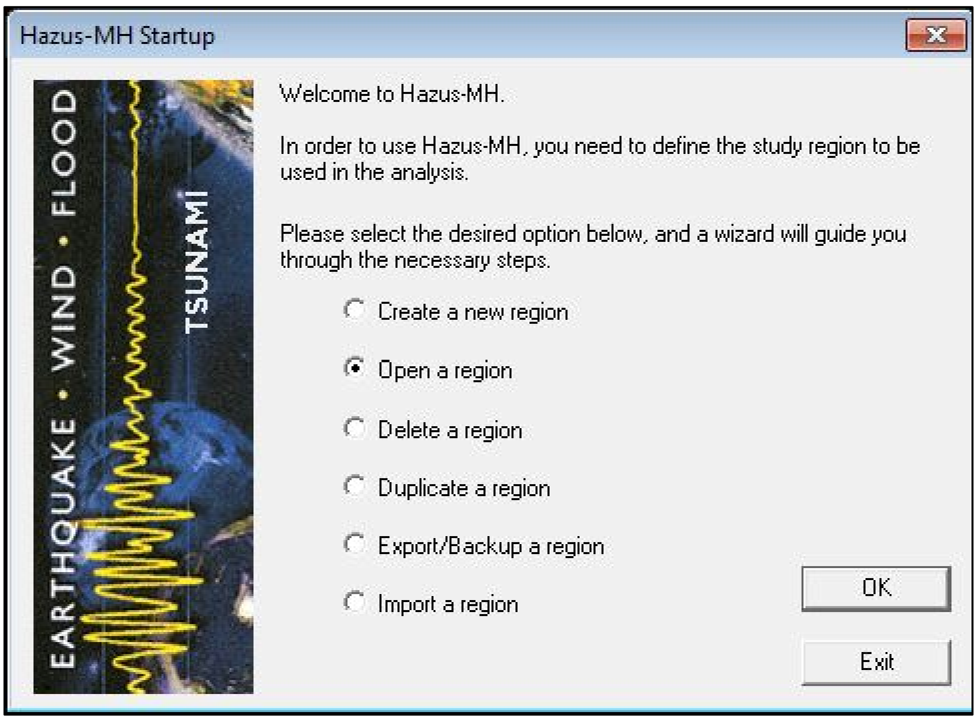
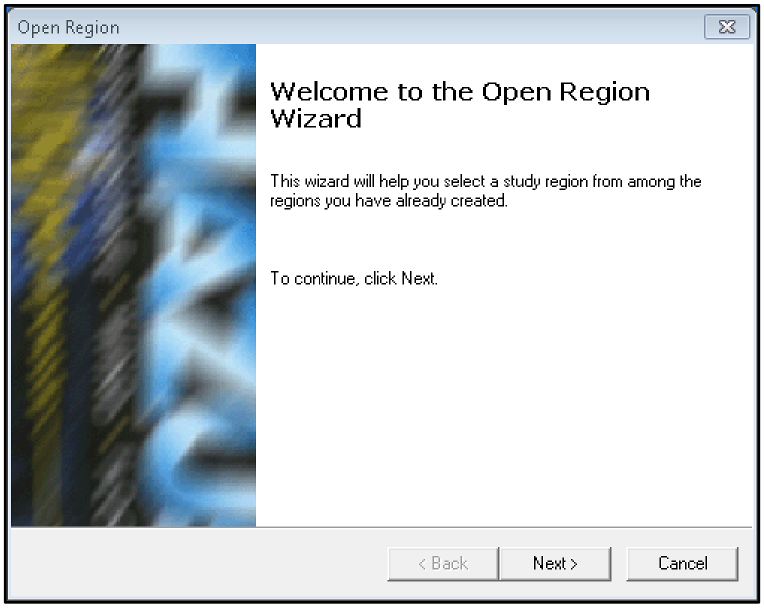
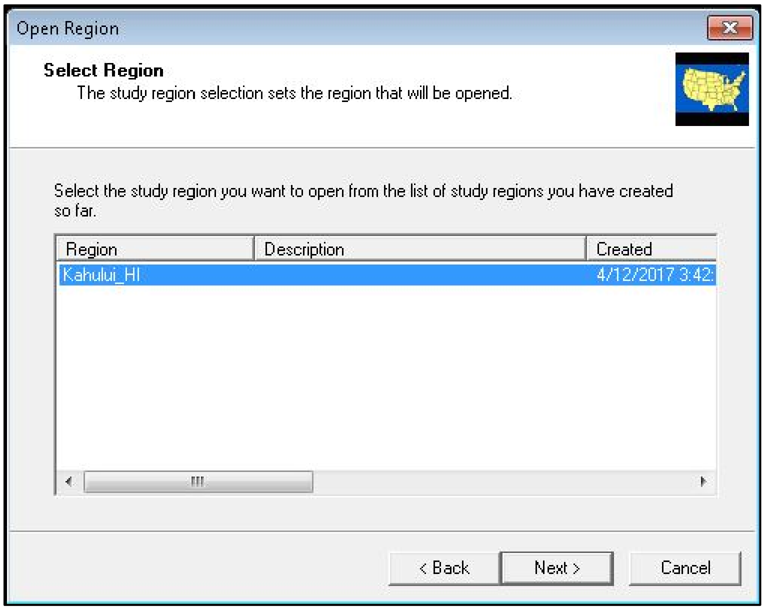


Figure 21: Open Region Wizard



Select **Next**. In the Open Region | Select Region window (Figure 22), the user can choose the Region. After choosing, click **Next**.

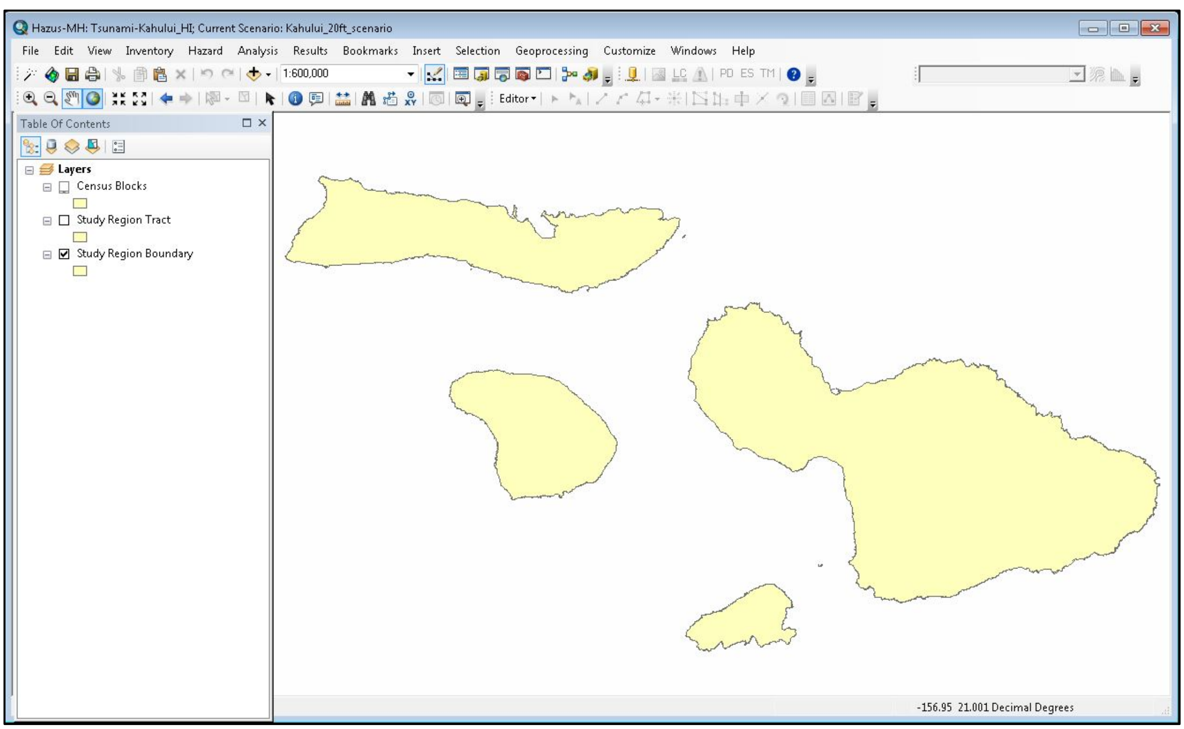
Figure 22: Select a Region



This will bring up a review window (Figure 23). Here the user can check that the region selected and hazard selected are as intended. Select **Finish**. ArcMap will open with the selected region, as seen in Figure 24.

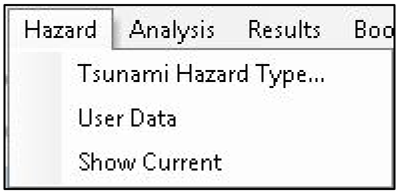
Figure 23: Region Review

Figure 24: ArcMap



Choose the Hazard drop-down menu from the toolbar, and select **Tsunami Hazard Type** (Figure 25).

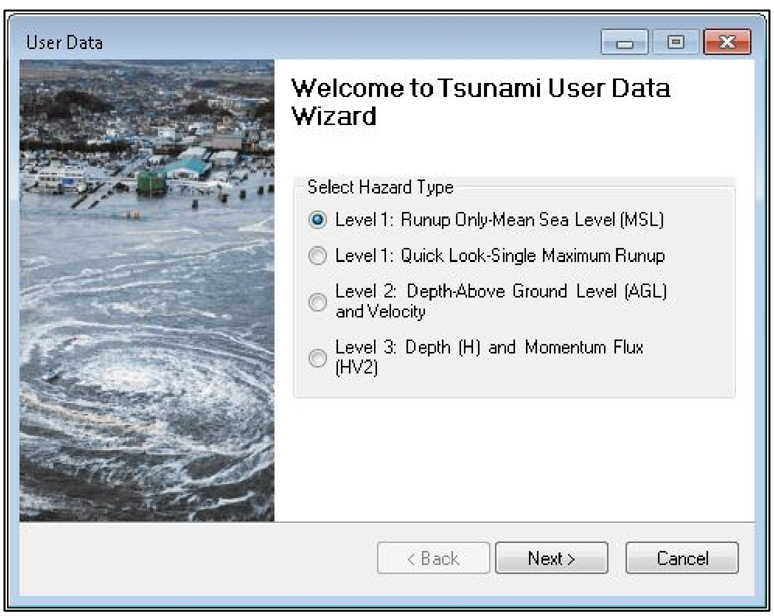
Figure 25: Hazard Menu



This opens the Tsunami Hazard Type dialog (Figure 26) where the user can choose between a Near Source (Tsunamigenic source nearby, Earthquake impacts may be expected) or Distant Source (Tsunamigenic source far away, no Earthquake impacts). Select and click **OK**. Return to the Tsunami Hazard Type drop-down menu and select User Data. This will open the User Data Wizard (Figure 27). Choose the Level 1: Runup Only-Mean Sea Level (MSL) option and click **Next**.

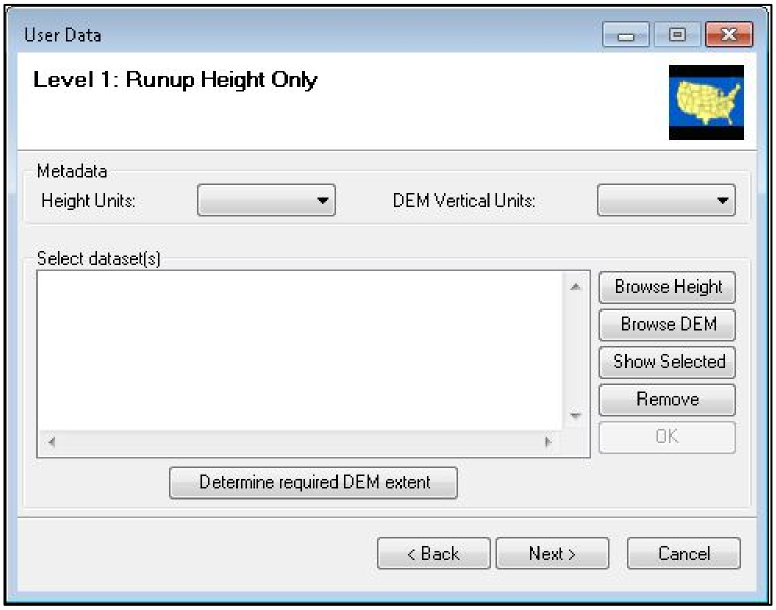
Figure 26: Tsunami Hazard Type

Figure 27: User Data Wizard



In the Level 1: Runup Height Only window (**Figure 28**), click the **Determine required DEM extent** button. This step will locate and extract a DEM for the study region. It may take a few moments.

Figure 28: Level 1: DEM Extraction



When the DEM Extent Window appears, click the Download and Unzip All option to save the DEMs (**Figure 29**). The NED Resolution menu allows the user to select the resolution of the DEMs (vertical units for NED data will be meters). When complete, a dialog will pop up with the location of the saved DEM (Figure 30).

Figure 29: DEM Extent

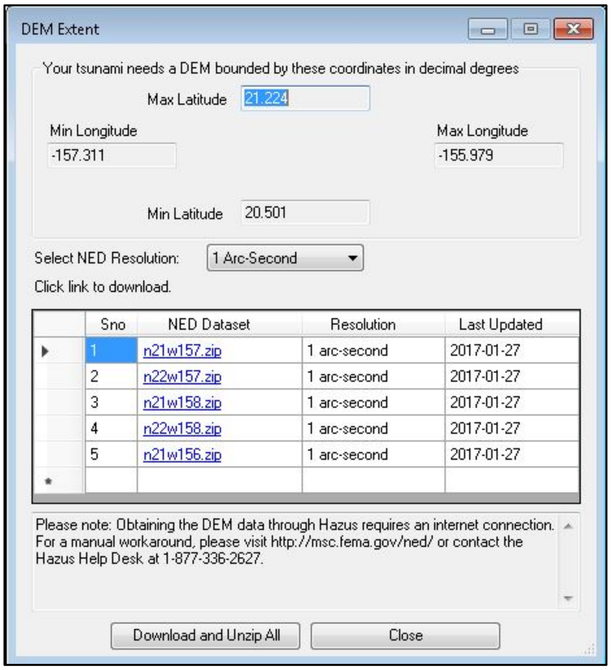
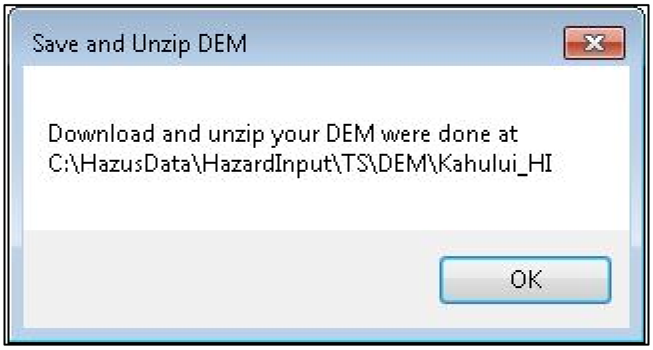


Figure 30: Save and Unzip DEM



The model works best if the DEM is clipped to the study region. This can be done using the Extract by Mask tool (Figure 31) under Geoprocessing on the toolbar (run a search under Search for Tools). Save the DEM to the same folder as the downloaded DEM. This step will help reduce processing time. The result should look similar to the example in Figure 32. Note: If more than one DEM intersects the study region, the user will have to merge the DEMs prior to clipping. This can be done in ArcGIS under Geoprocessing as well.

Figure 31: Extract by Mask Tool

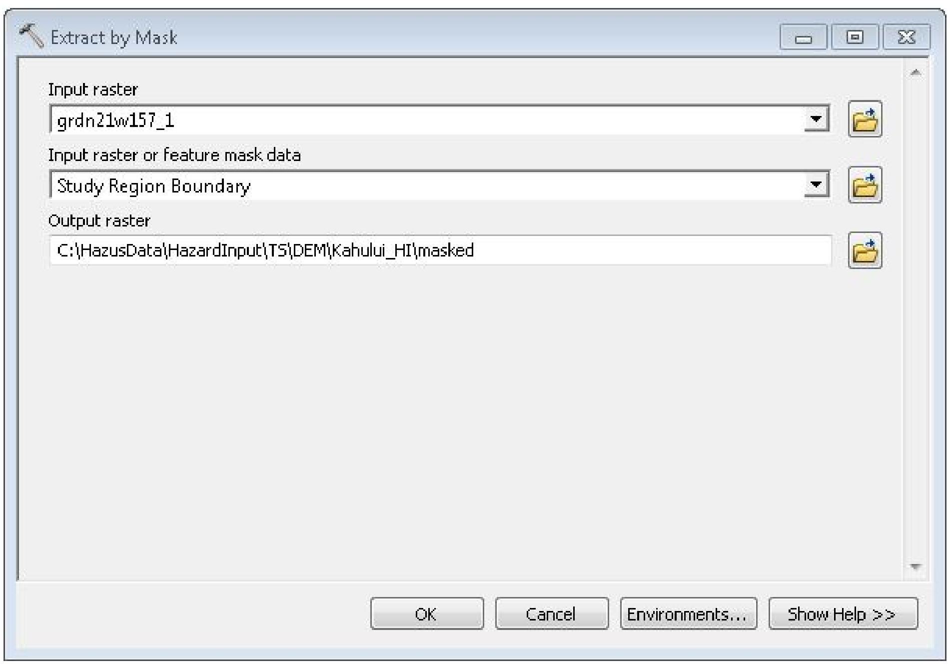
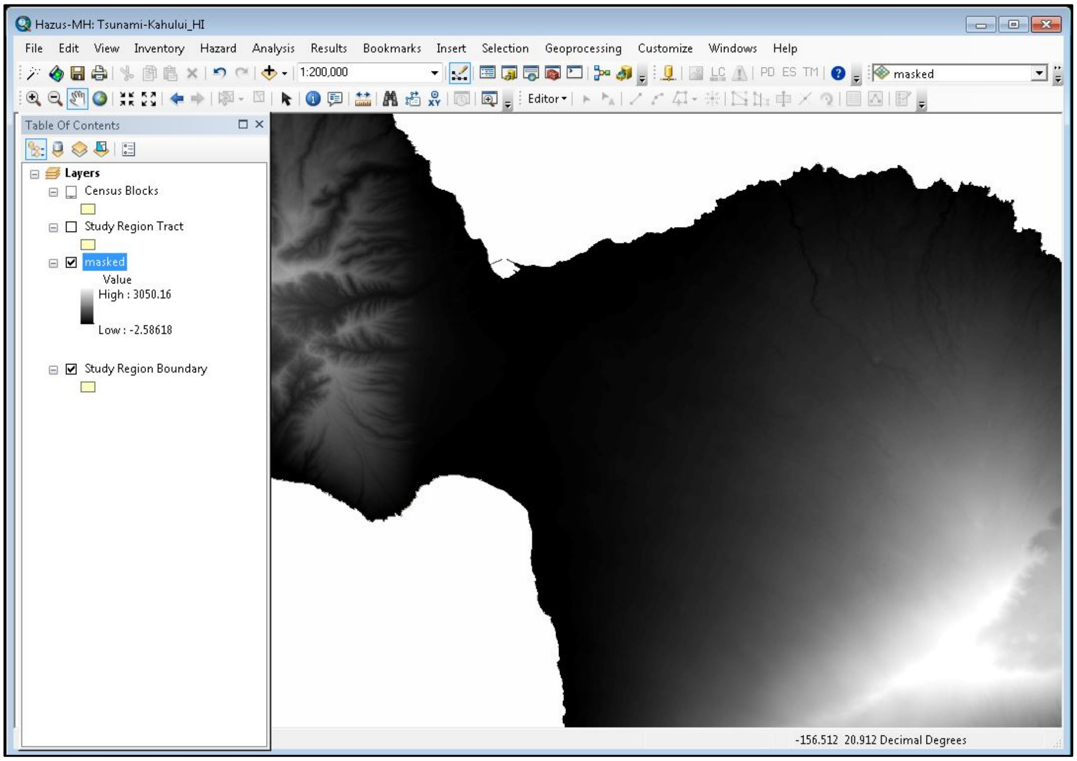
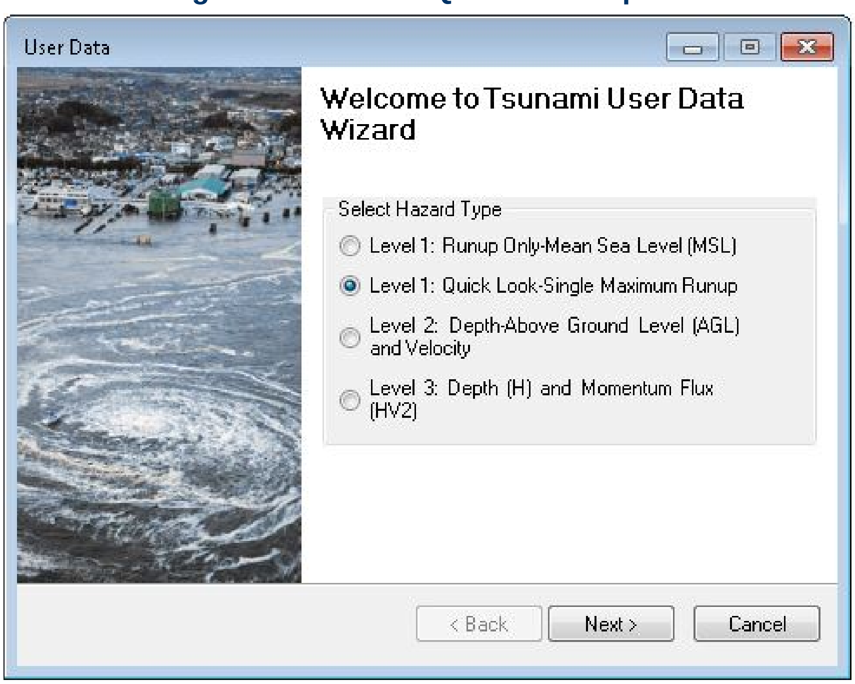


Figure 32: Mask DEM to Study Region



Return to the Hazard drop-down menu, select User Data again. Choose the Level 1: Quick Look-Single Maximum Runup option and click **Next** (Figure 33).

Figure 33: Level 1: Quick Look Option



In the Quick Look window (Figure 34), select the DEM Vertical Units and Maximum Runup Units from the dropdown menus. Enter a Maximum Runup Height Value (vertical elevation of the furthest inundation of the tsunami with respect to the initial sea level – see *Tsunami Model Technical Guidance* Chapter 4), and Browse DEM to select the masked DEM from Figure 32. Click **OK**. A Processing notification will popup (**Figure 35**). When it vanishes, click **Next**.

Figure 34: Quick Look Window

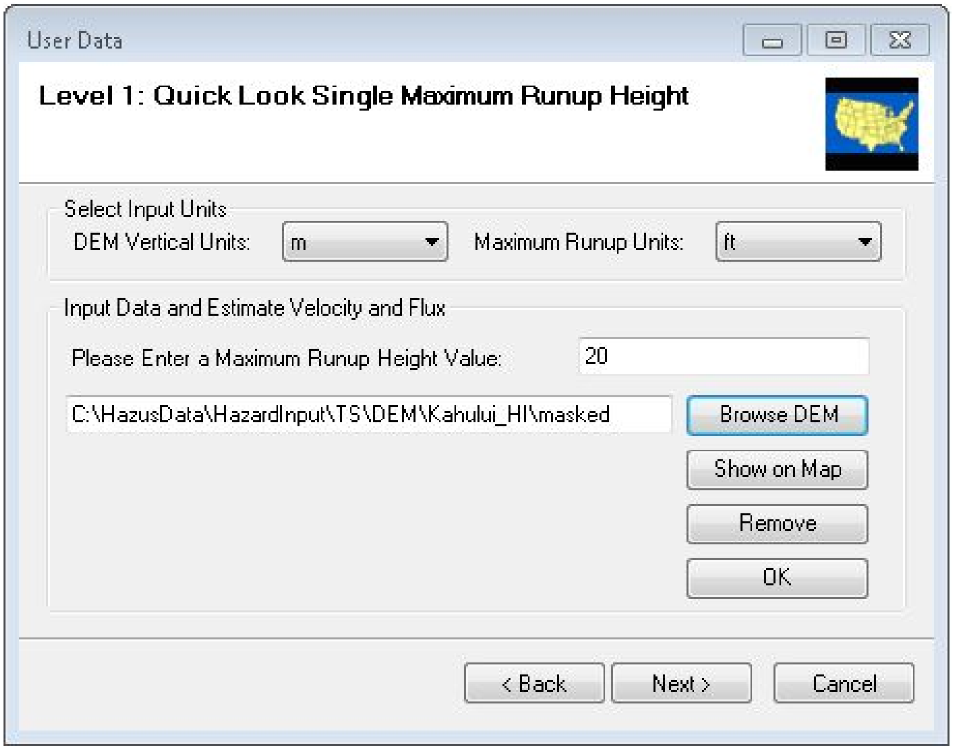
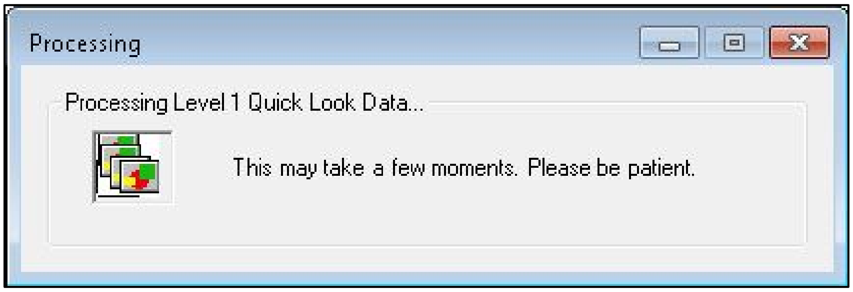


Figure 35: Processing Window



Enter the Tsunami Scenario Name (Figure 36), click **Next**. The model will now use the DEM and the entered Maximum Runup Height Value to create a Hazard Boundary (Figure 37) for the analysis. The boundaries include a Median Inundation Depth (ft) and a Median Momentum Flux (ft^3/sec^2) (**Figure 38**). The layers are added to the study region (**Figure 39**). Click **OK** in the next window to complete.

Figure 36: Tsunami Scenario Name

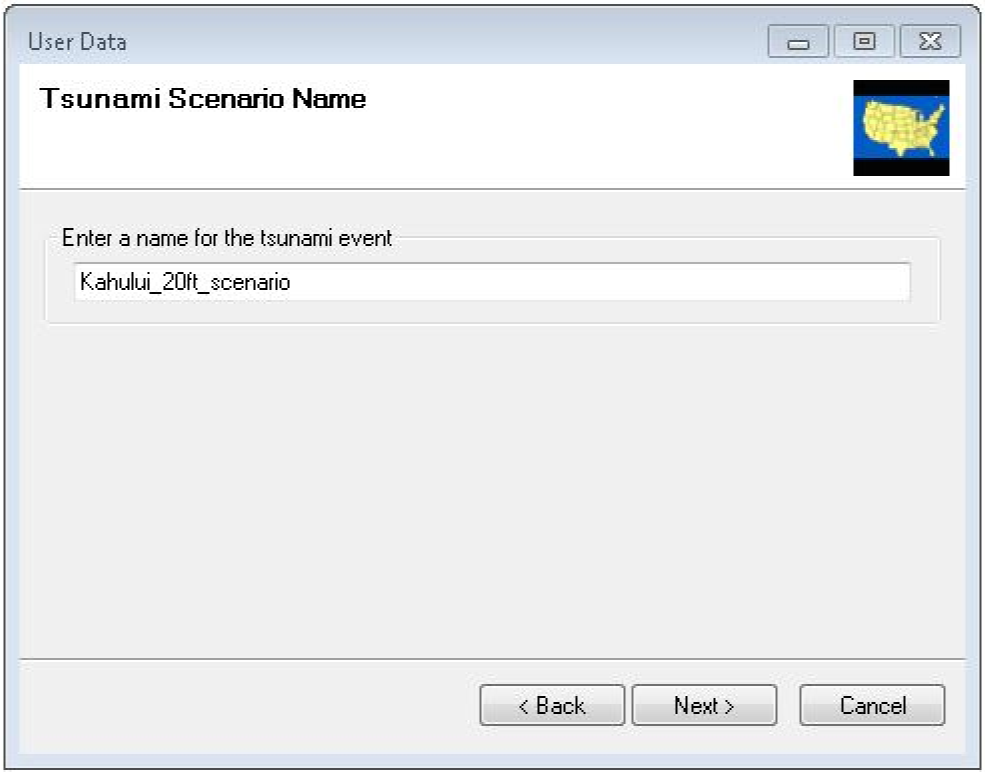


Figure 37: Hazard Boundary Creation

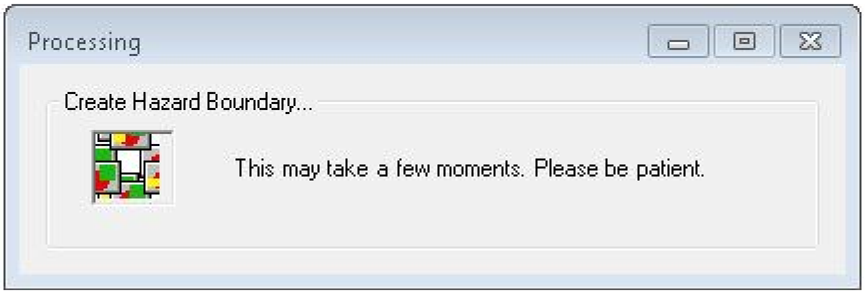


Figure 38: Hazard Layers

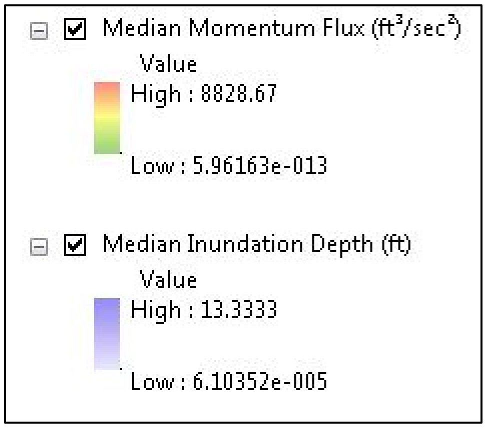
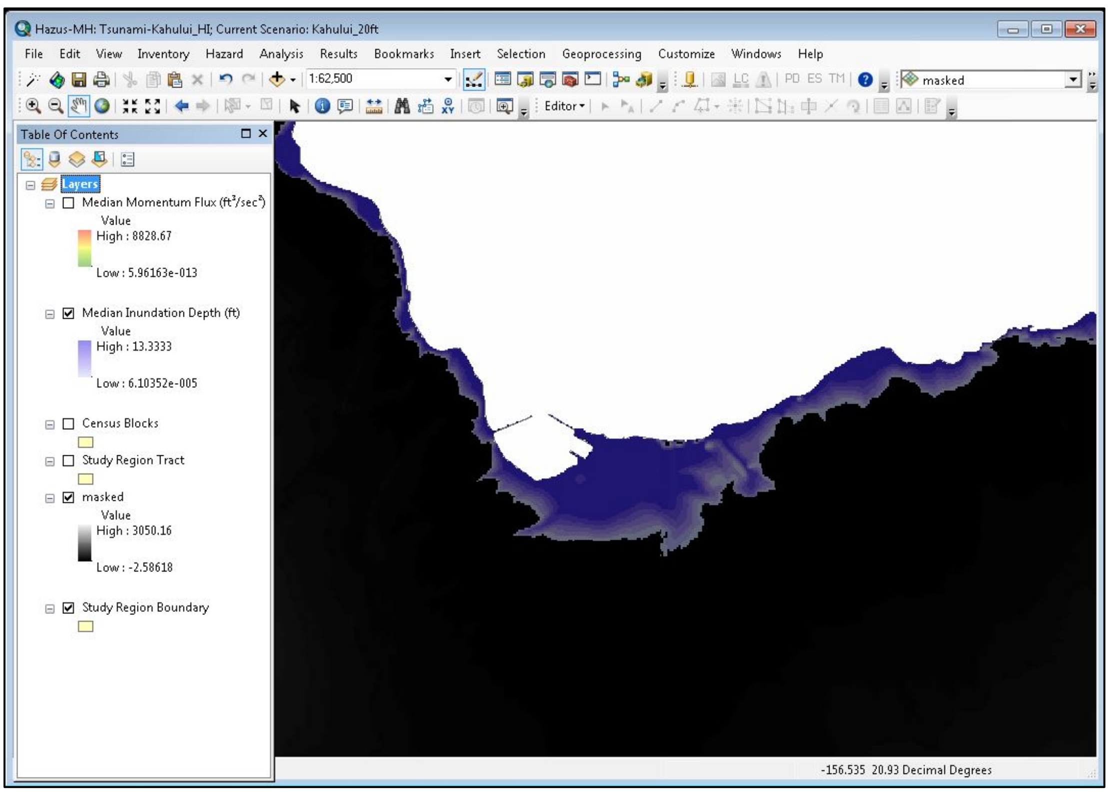


Figure 39: Median Inundation Depth (ft)



On the Analysis drop-down menu, select **Run** (**Figure 40**). Click **OK** on the Combined Analysis notice (**Figure 41**). The notice refers to the combined Earthquake and Tsunami Analysis for Near Source events. See Chapter 11 for more information.

Figure 40: Analysis Menu

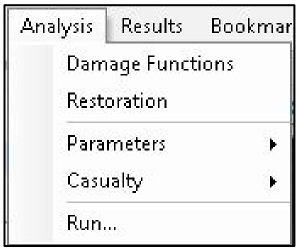
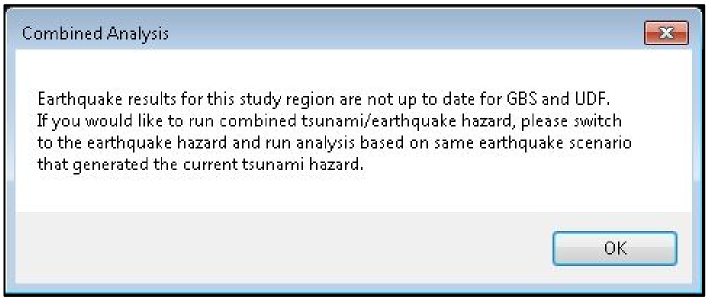


Figure 41: Combined Analysis Window



In the Analysis Option – Tsunami window, click Select All (**Figure 42**), then **OK**. A processing notification will appear (**Figure 43**). This may take a few moments.

Figure 42: Analysis Option – Tsunami Window

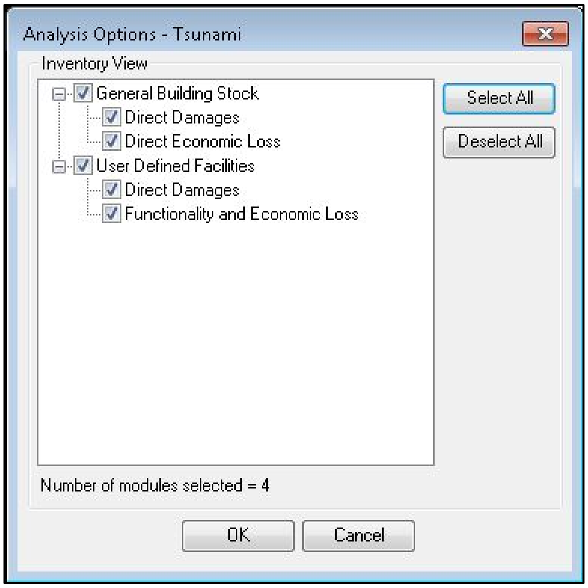
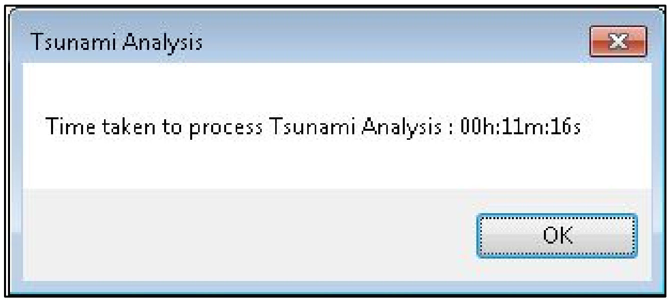


Figure 43: Processing Window

When the Analysis is complete, a notice will appear (**Figure 44**). Click **OK**. Results are viewable under the Results heading on the toolbar. (See Chapter 8 for more information)

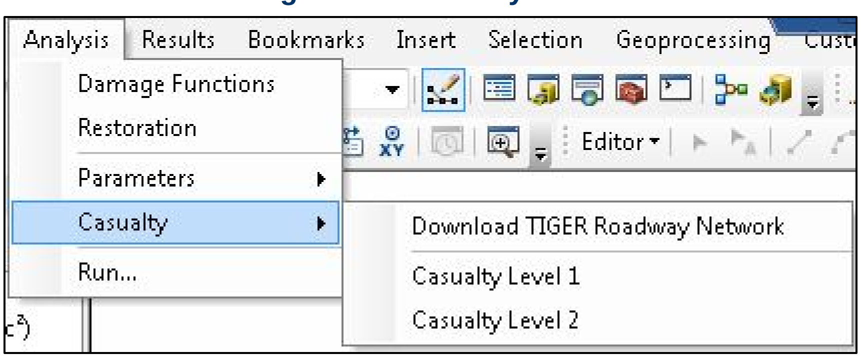
Figure 44: Analysis Completion Notice



4.2 Steps to Create and Run a Level 1 Casualty Analysis

Level 1 Casualty estimates can be calculated after the Tsunami GBS Analysis is complete. On the Analysis drop-down menu, choose Casualty (**Figure 45**). On the Casualty submenu, choose TIGER Roadway Network to download the road data. (Note: If a download error occurs, the road network can be obtained from the TIGER data website on https://www2.census.gov/geo/tiger/TIGER2016/ROADS/ based on County FIPS). The model will save the road network data to the C:\HazusData\HazardInput\TS\TIGER\ folder under the County FIPS code for the study region.

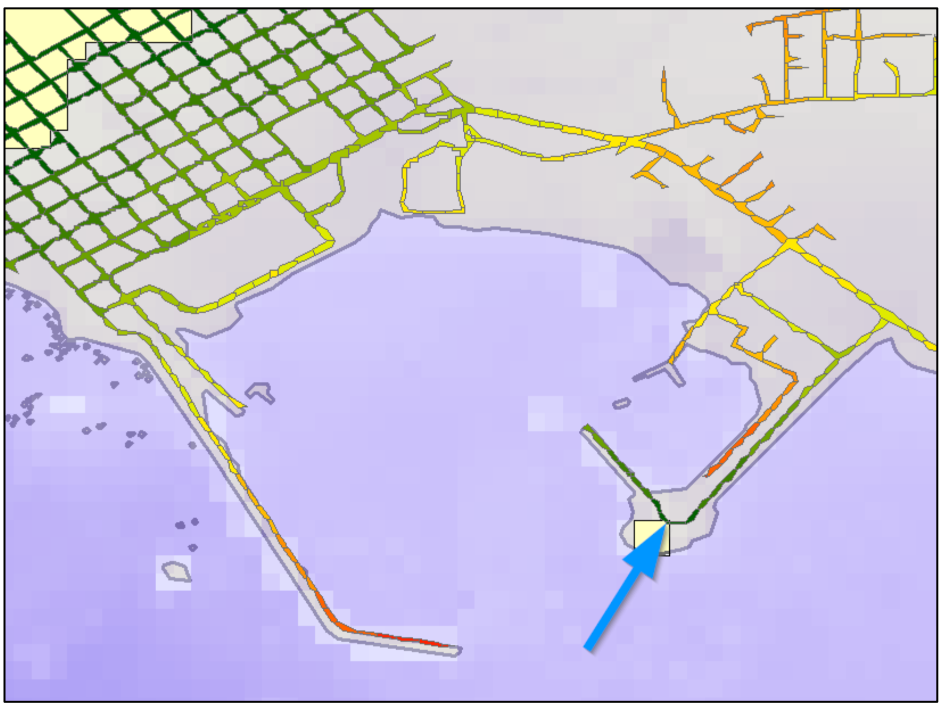
Figure 45: Casualty Menu



Select the Analysis drop-down menu, choose Casualty again, and then Casualty Level 1. In the Casualty Level 1 window **(Figure 47)**, load the DEM, the roads data, the Hazard Boundary and

Fatality Boundary data. The Hazard Boundary and Fatality Boundary are processed by the model, and can be located in the Regions folder under the study region folder **(Figure 48).** The Hazard Boundary is the inundation hazard boundary (depth > 0), and the Fatality Boundary is the portion of the inundation hazard where the flood depths are expected to be 2 meters or greater in depth (Fatality Rate = 99%). ***Users should review the boundaries to determine if slivers along the coast or other small pockets that intersect the road network might result in areas that would not be considered safe for evacuation, (where the slivers intersect roadways) and remove them. If the sliver does not intersect a roadway, the user does not have to remove it as it will not be identified by the model.*** **Figure 46** shows a point along the coast intersecting a road segment that would be identified as "Safe" if left within the Hazard Boundary. Road segments are represented as polygons in the figure, Note that the model did run with this sliver left in the Hazard Boundary, but produced erroneously low evacuation times for the area denoted by the arrow, which is shown in the figure for polygon segments for that portion of the roadway..

Figure 46: Hazard Boundary Error Checking



Once the input data is selected, enter the Casualty Time Parameters in the boxes below. The model will enter default values once there is a value for Arrival Time **(Figure 47)**. However, the user should review these and modify as needed. ***Note: Warning time cannot exceed arrival time; if values are entered that are inconsistent with this, Hazus will prompt the user to change them. In addition, for a near source event where the ground shaking provides the trigger for warning, a warning time value of 0 minutes may be entered.*** Click **Next**.

Figure 47: Casualty Level 1 Window

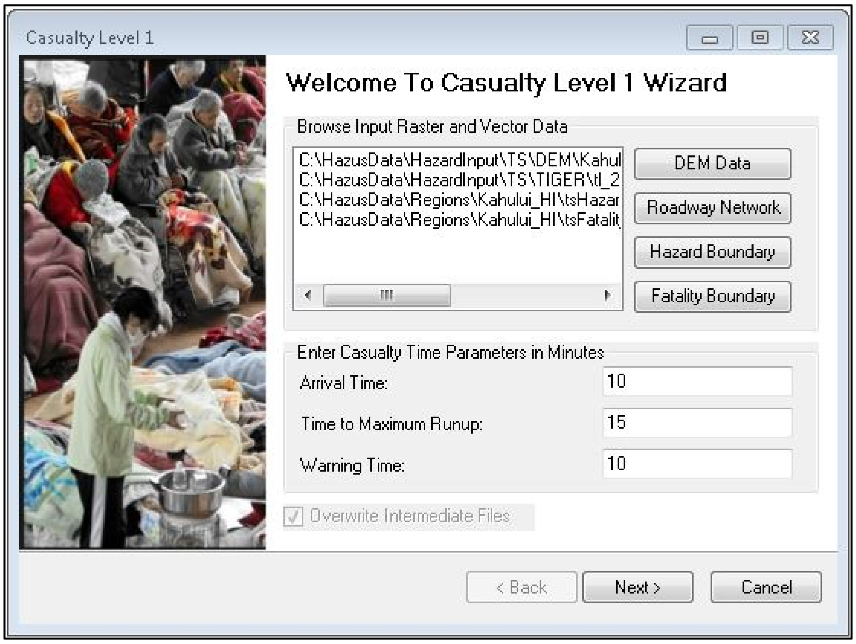
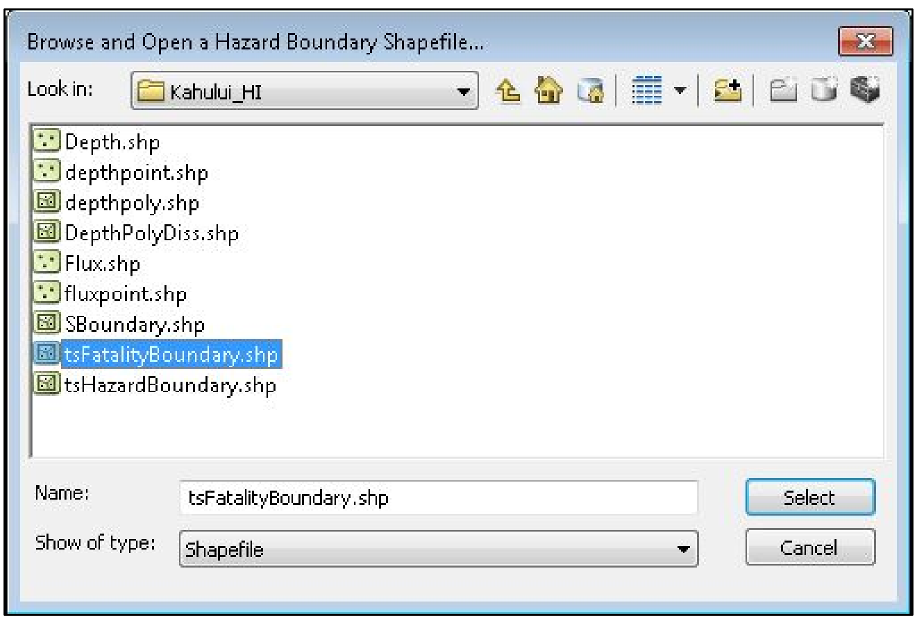


Figure 48: Study Region Folder



The next few steps are processed by the model. Beginning with the processing of the Level 1 Casualty Input. This step projects the data into the same projected coordinate system **(Figure 49).** Click **Next**. The model then preprocesses the DEM, Roads and Hazard Boundaries **(Figure 50).** The default output Cell Size is 10 meters. The Speed Conservation Value (SCV) default is 1, which assumes that road networks have no reduction in the capability to support evacuation.

SCV less than 1 reduces the capability of the road network to support evacuation. See Chapter 6 of the *Tsunami Model Technical Guidance* for more information. Click **Next**.

Figure 49: Process Level 1 Casualty Input

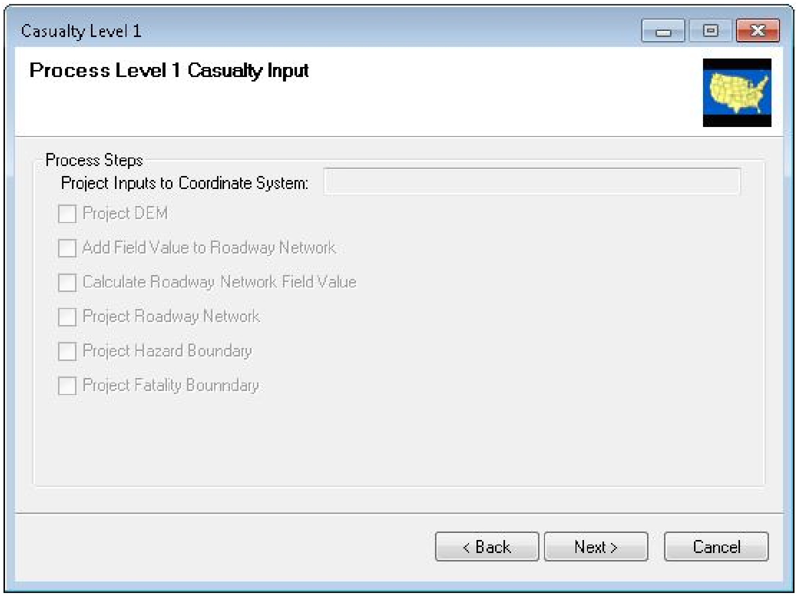
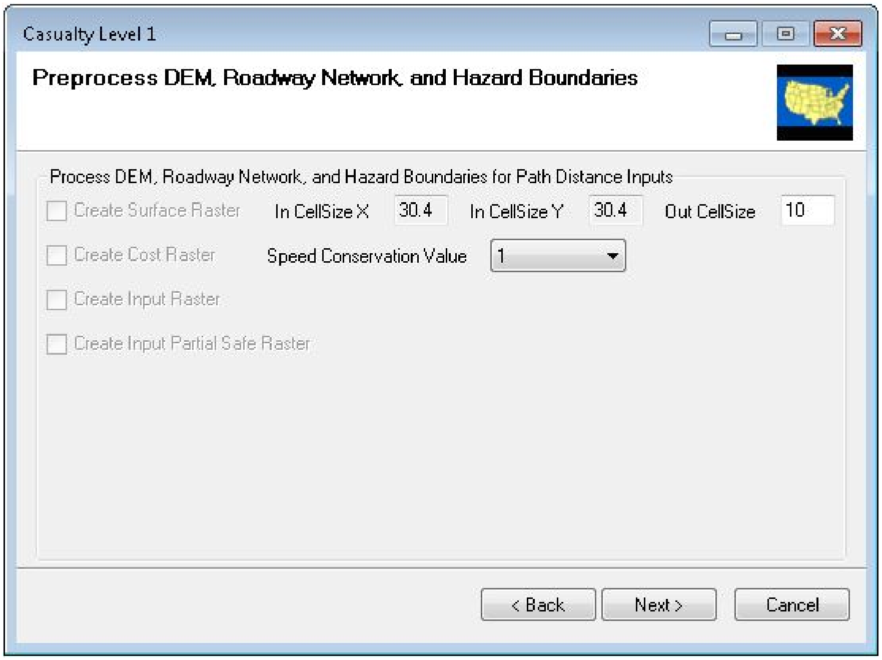
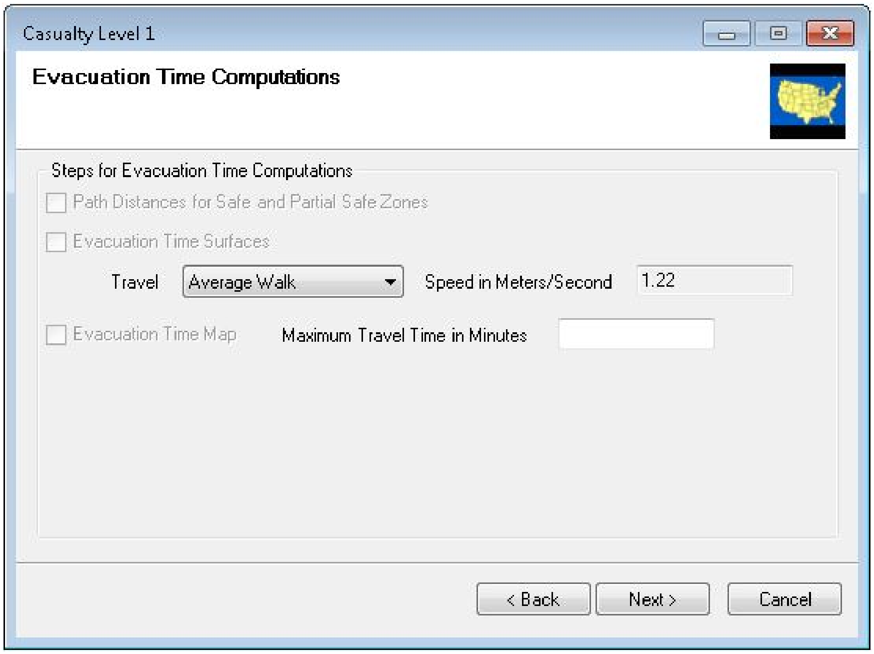


Figure 50: Preprocess Data



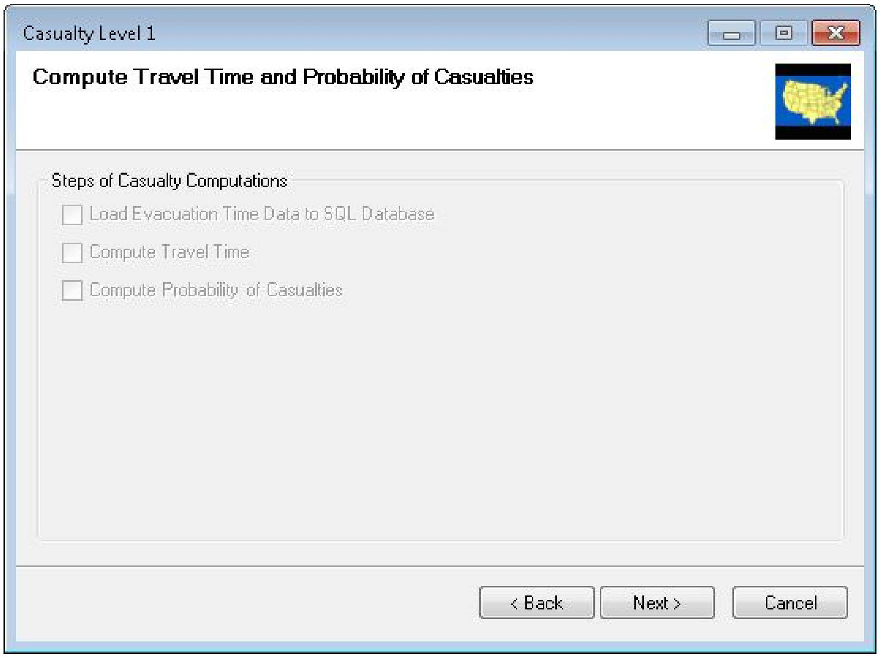
Next, the model calculates the Evacuation Time required at the selected Travel Speed **(Figure 51)**. The default speed is Average Walk. The Maximum Travel Time in Minutes, by default, is blank. Click **Next**.

Figure 51: Evacuation Time



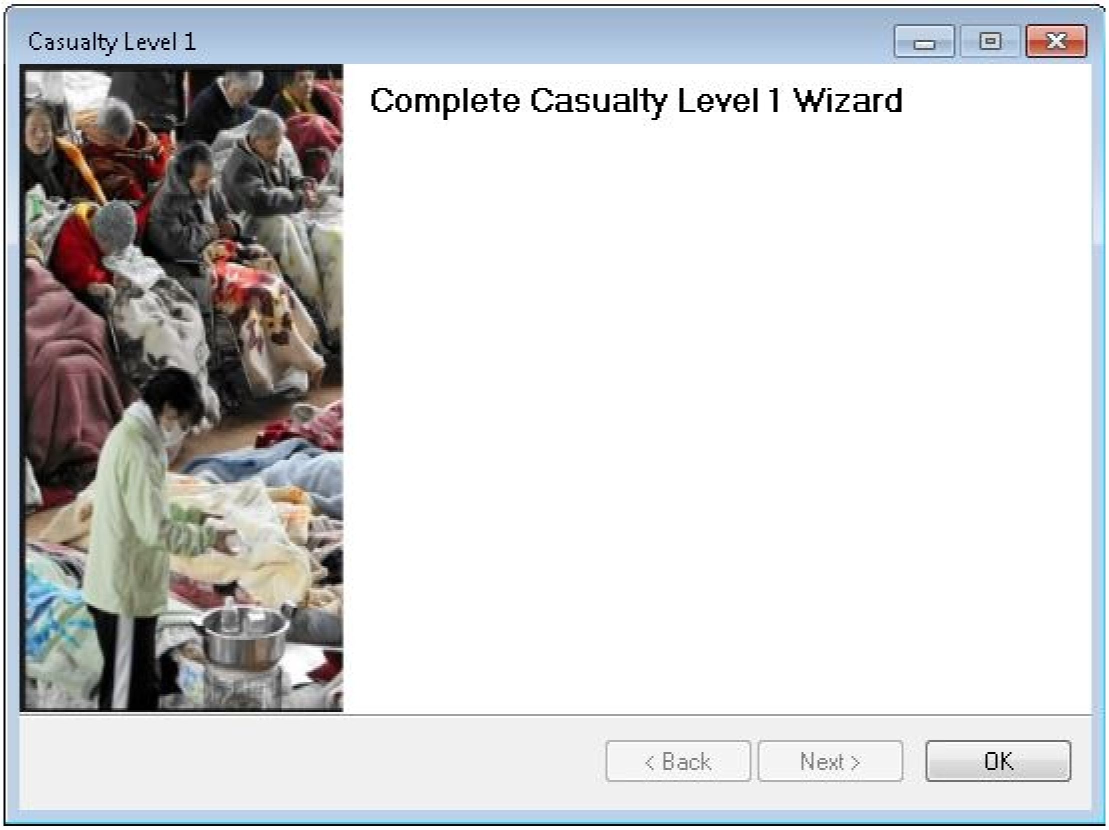
Next, the model computes travel time and the probability of casualties **(Figure 52).** Click **Next**.

Figure 52: Travel Time and Probability of Casualties



This completes the Casualty Level 1 Estimate **(Figure 53).** Click **OK**. The results and reports are accessible under the Results drop-down menu. See Chapter 8 for more information.

Figure 53: Complete Casualty Level 1 Wizard

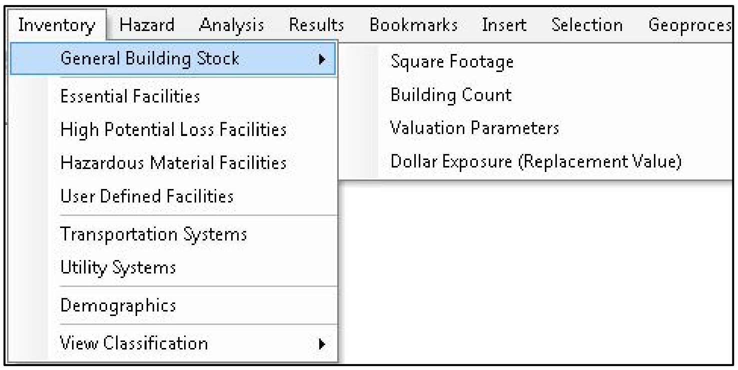


5.0 Tsunami Model: Inventory Menu

5.1 Inventory Menu

The Inventory menu (**Figure 54**) has a number of inventory types and submenus from which to choose. These options enable the user to estimate the amount of exposure or potential damage in the region. This section of the “User Guidance” document explains each selection and submenu to further the user’s understanding of these options.

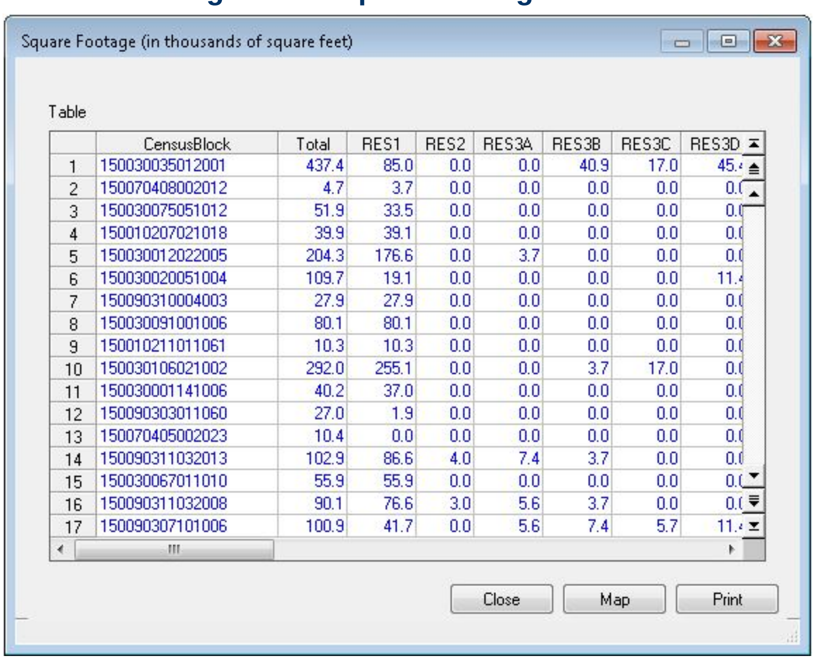
Figure 54: Hazus Inventory Menu



5.2 General Building Stock (GBS)

The first option within the Inventory menu is General Building Stock (GBS). The first submenu option allows the user to see the Square Footage distribution (in thousands of sq. ft.) by Specific Occupancy Type per census block (or tract) as seen in **Figure 55.**

Figure 55: Square Footage Table



Square Footage (in thousands of square feet)

Table

	CensusBlock	Total	RES1	RES2	RES3A	RES3B	RES3C	RES3D
1	150030035012001	437.4	85.0	0.0	0.0	40.9	17.0	45.4
2	150070408002012	4.7	3.7	0.0	0.0	0.0	0.0	0.0
3	150030075051012	51.9	33.5	0.0	0.0	0.0	0.0	0.0
4	150010207021018	39.9	39.1	0.0	0.0	0.0	0.0	0.0
5	150030012022005	204.3	176.6	0.0	3.7	0.0	0.0	0.0
6	150030020051004	109.7	19.1	0.0	0.0	0.0	0.0	11.4
7	150090310004003	27.9	27.9	0.0	0.0	0.0	0.0	0.0
8	150030091001006	80.1	80.1	0.0	0.0	0.0	0.0	0.0
9	150010211011061	10.3	10.3	0.0	0.0	0.0	0.0	0.0
10	150030106021002	292.0	255.1	0.0	0.0	3.7	17.0	0.0
11	150030001141006	40.2	37.0	0.0	0.0	0.0	0.0	0.0
12	150090303011060	27.0	1.9	0.0	0.0	0.0	0.0	0.0
13	150070405002023	10.4	0.0	0.0	0.0	0.0	0.0	0.0
14	150090311032013	102.9	86.6	4.0	7.4	3.7	0.0	0.0
15	150030067011010	55.9	55.9	0.0	0.0	0.0	0.0	0.0
16	150090311032008	90.1	76.6	3.0	5.6	3.7	0.0	0.0
17	150090307101006	100.9	41.7	0.0	5.6	7.4	5.7	11.4

Close Map Print

5.2.1 GBS Building Count

The Building Count inventory in the GBS submenu option (**Figure 56**) allows the user to review building count per census unit By Occupancy as well as By General Building Type for both Specific Occupancy and General Occupancy as seen in **Figure 57**.

Figure 56: General Building Stock Menu

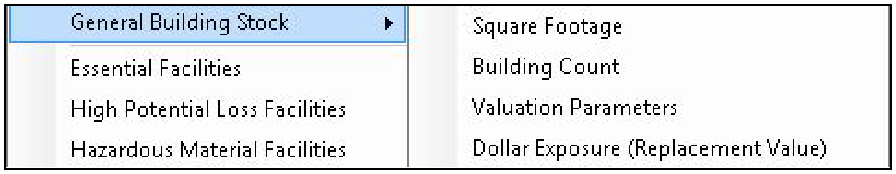
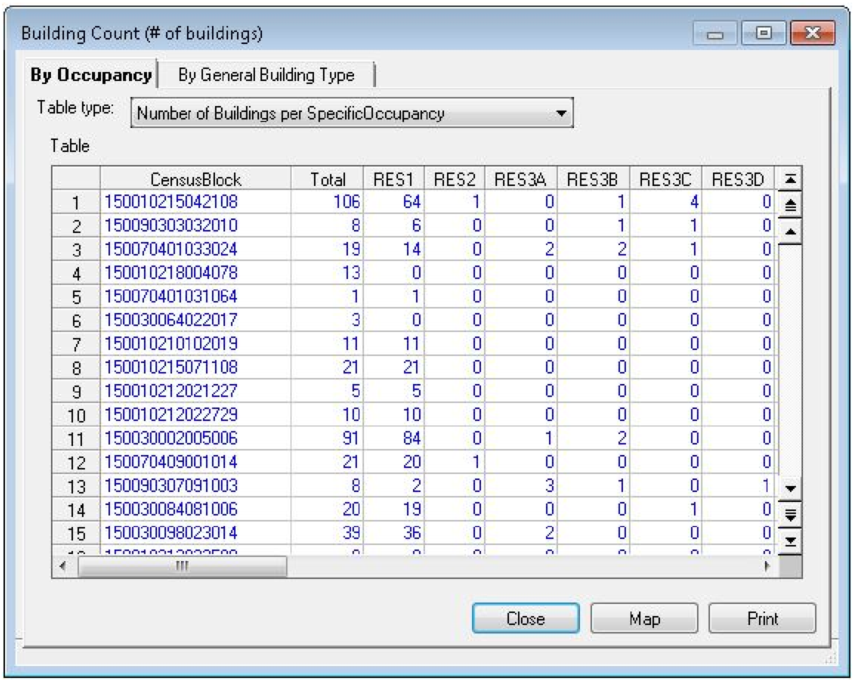


Figure 57: Building Count Table



	CensusBlock	Total	RES1	RES2	RES3A	RES3B	RES3C	RES3D
1	150010215042108	106	64	1	0	1	4	0
2	150090303032010	8	6	0	0	1	1	0
3	150070401033024	19	14	0	2	2	1	0
4	150010218004078	13	0	0	0	0	0	0
5	150070401031064	1	1	0	0	0	0	0
6	150030064022017	3	0	0	0	0	0	0
7	150010210102019	11	11	0	0	0	0	0
8	150010215071108	21	21	0	0	0	0	0
9	150010212021227	5	5	0	0	0	0	0
10	150010212022729	10	10	0	0	0	0	0
11	150030002005006	91	84	0	1	2	0	0
12	150070409001014	21	20	1	0	0	0	0
13	150090307091003	8	2	0	3	1	0	1
14	150030084081006	20	19	0	0	0	1	0
15	150030098023014	39	36	0	2	0	0	0

5.2.2 Valuation Parameters

The Valuation Parameters option (**Figure 58**) allows the user to review the estimated Replacement Cost per square foot for each building type (by Occupancy) (**Figure 59**).

Figure 58: General Building Stock Valuation Parameters Menu

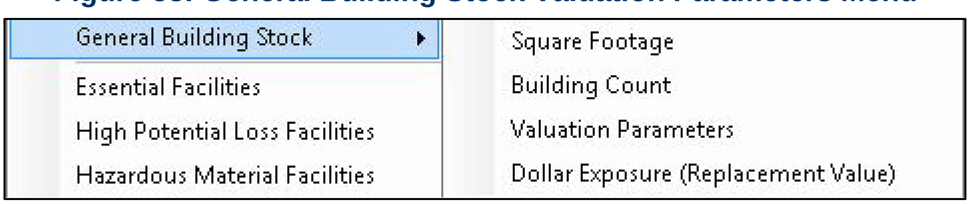
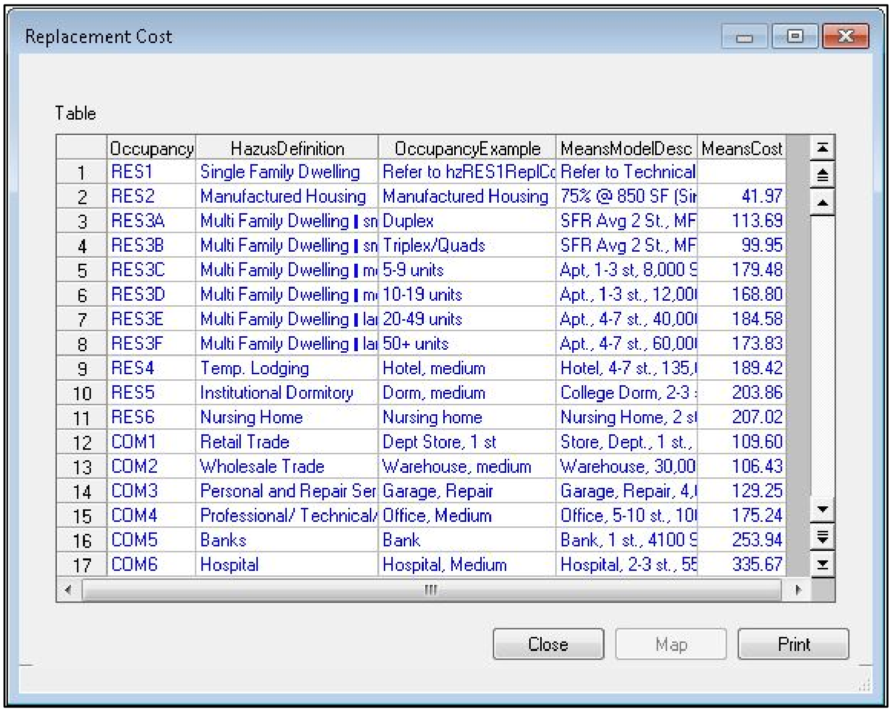


Figure 59: Replacement Cost Table



	Occupancy	HazusDefinition	OccupancyExample	MeansModelDesc	MeansCost
1	RES1	Single Family Dwelling	Refer to hzRES1ReplCc	Refer to Technical	
2	RES2	Manufactured Housing	Manufactured Housing	75% @ 850 SF (Sir	41.97
3	RES3A	Multi Family Dwelling ‖ sn	Duplex	SFR Avg 2 St., MF	113.69
4	RES3B	Multi Family Dwelling ‖ sn	Triplex/Quads	SFR Avg 2 St., MF	99.95
5	RES3C	Multi Family Dwelling ‖ m	5-9 units	Apt, 1-3 st, 8,000 S	179.48
6	RES3D	Multi Family Dwelling ‖ m	10-19 units	Apt., 1-3 st., 12,00	168.80
7	RES3E	Multi Family Dwelling ‖ la	20-49 units	Apt., 4-7 st., 40,00	184.58
8	RES3F	Multi Family Dwelling ‖ la	50+ units	Apt., 4-7 st., 60,00	173.83
9	RES4	Temp. Lodging	Hotel, medium	Hotel, 4-7 st., 135,(	189.42
10	RES5	Institutional Dormitory	Dorm, medium	College Dorm, 2-3 :	203.86
11	RES6	Nursing Home	Nursing home	Nursing Home, 2 st	207.02
12	COM1	Retail Trade	Dept Store, 1 st	Store, Dept., 1 st.,	109.60
13	COM2	Wholesale Trade	Warehouse, medium	Warehouse, 30,00	106.43
14	COM3	Personal and Repair Ser	Garage, Repair	Garage, Repair, 4,(	129.25
15	COM4	Professional/ Technical/	Office, Medium	Office, 5-10 st., 10	175.24
16	COM5	Banks	Bank	Bank, 1 st., 4100 S	253.94
17	COM6	Hospital	Hospital, Medium	Hospital, 2-3 st., 55	335.67

5.2.3 GBS Dollar Exposure

The Dollar Exposure (Replacement Value) inventory option (**Figure 60**) allows the user to review building exposure per census block or tract in thousands of dollars. The user can view Exposure by General Occupancy, Specific Occupancy, and General Building Type for Building Exposure, Content Exposure, and Total Exposure as seen in **Figure 61.**

Figure 60: General Building Stock Dollar Exposure Menu

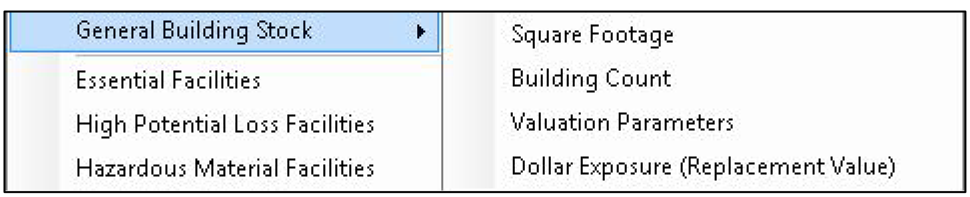
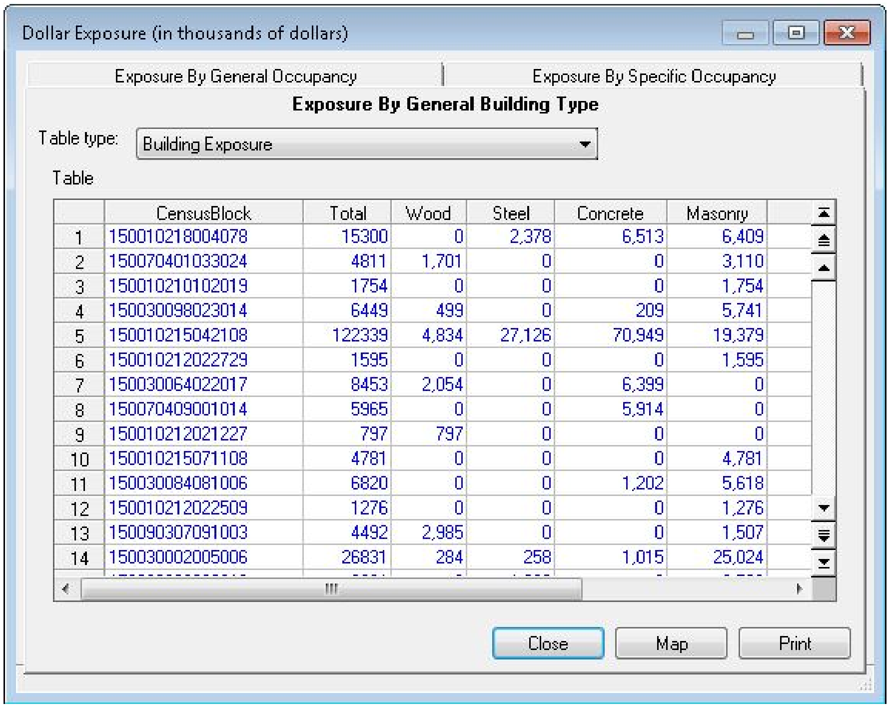


Figure 61: Dollar Exposure Table



5.3 Essential Facilities

5.3.1 Essential Facilities Inventory

The Essential Facilities inventory menu (Figure 62) allows the user to view the essential facilities found in the Hazus Program for the study region. These include Medical Care Facilities, Fire Stations, Police Stations, Emergency Response Centers, and Schools. Damage and loss are not computed for Essential Facilities in the present version of the Tsunami Model. Selecting this option will open the table seen in Figure 63.

Figure 62: Inventory Menu

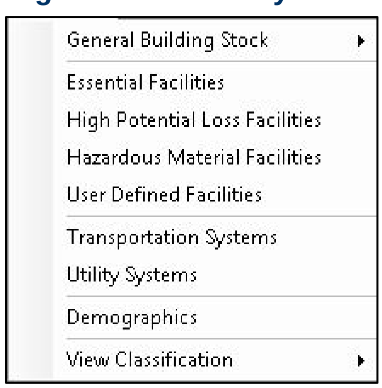
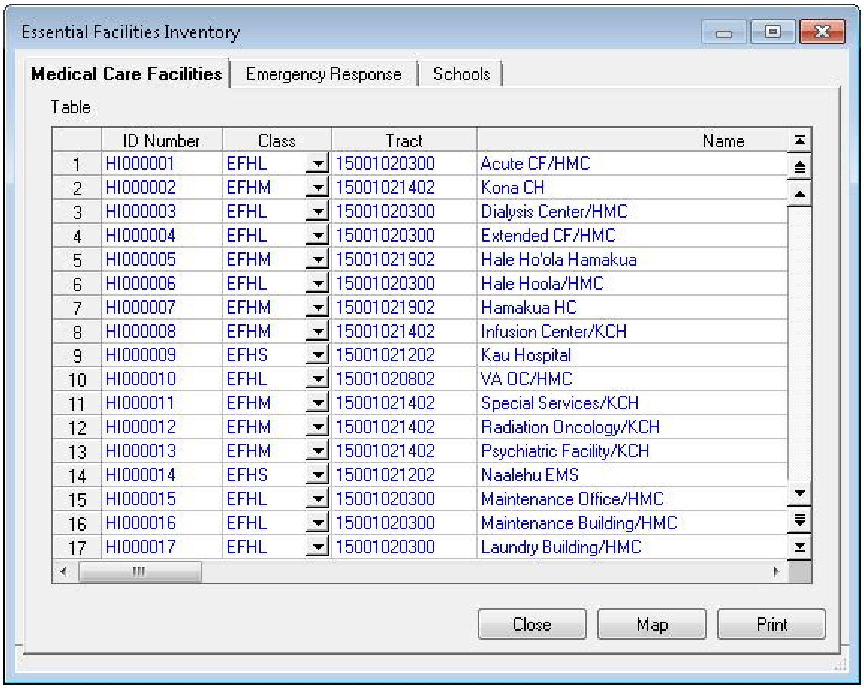


Figure 63: Essential Facilities Inventory Table



	ID Number	Class	Tract	Name
1	HI000001	EFHL	15001020300	Acute CF/HMC
2	HI000002	EFHM	15001021402	Kona CH
3	HI000003	EFHL	15001020300	Dialysis Center/HMC
4	HI000004	EFHL	15001020300	Extended CF/HMC
5	HI000005	EFHM	15001021902	Hale Ho'ola Hamakua
6	HI000006	EFHL	15001020300	Hale Hoola/HMC
7	HI000007	EFHM	15001021902	Hamakua HC
8	HI000008	EFHM	15001021402	Infusion Center/KCH
9	HI000009	EFHS	15001021202	Kau Hospital
10	HI000010	EFHL	15001020802	VA OC/HMC
11	HI000011	EFHM	15001021402	Special Services/KCH
12	HI000012	EFHM	15001021402	Radiation Oncology/KCH
13	HI000013	EFHM	15001021402	Psychiatric Facility/KCH
14	HI000014	EFHS	15001021202	Naalehu EMS
15	HI000015	EFHL	15001020300	Maintenance Office/HMC
16	HI000016	EFHL	15001020300	Maintenance Building/HMC
17	HI000017	EFHL	15001020300	Laundry Building/HMC

5.4 High Potential Loss Facilities

The High Potential Loss Facilities (HPLF) menu (**Figure 64**) allows the user to view and map the default database for the study region. Damage and loss are not computed for HPLFs in the present version of the Tsunami Model. Selecting the High Potential Loss Facilities option will open the table seen in **Figure 65**. These include Dams and Levees, Nuclear Power Facilities, and Military Installations.

Figure 64: Inventory Menu

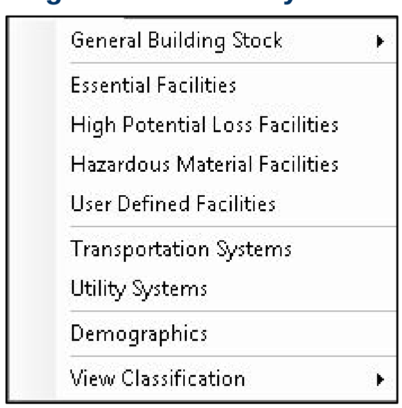
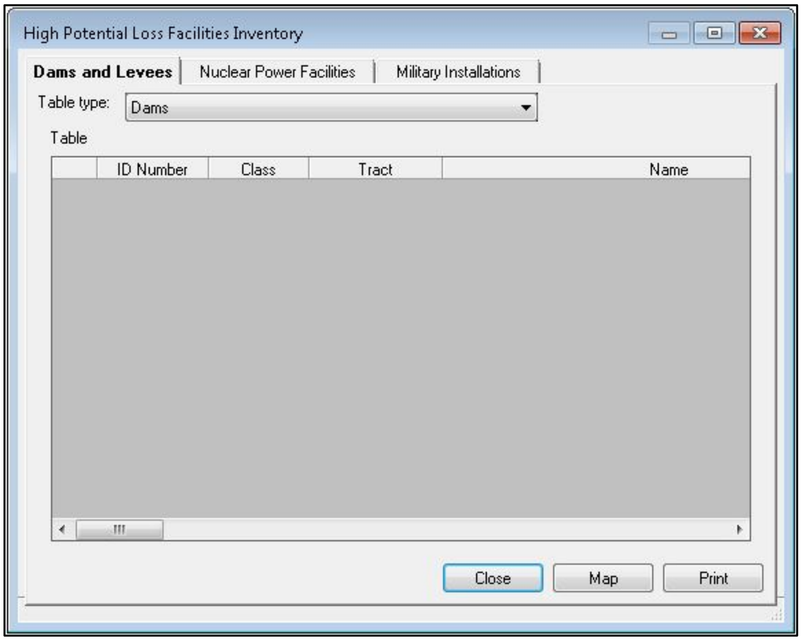


Figure 65: High Potential Loss Facilities Inventory



5.5 Hazardous Materials Facilities

The Hazardous Materials menu (**Figure 66**) allows the user to view and map the default database of the study region. Damage and loss are not computed for Hazardous Materials sites in the present version of the Tsunami Model. Selecting the Hazardous Materials Facilities option will open the table seen in Figure 67. Each row in the table represents a separate hazardous material at a site, so several rows may have the same latitude and longitude.

Figure 66: Inventory Menu

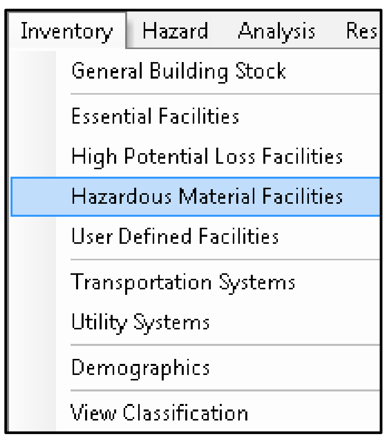
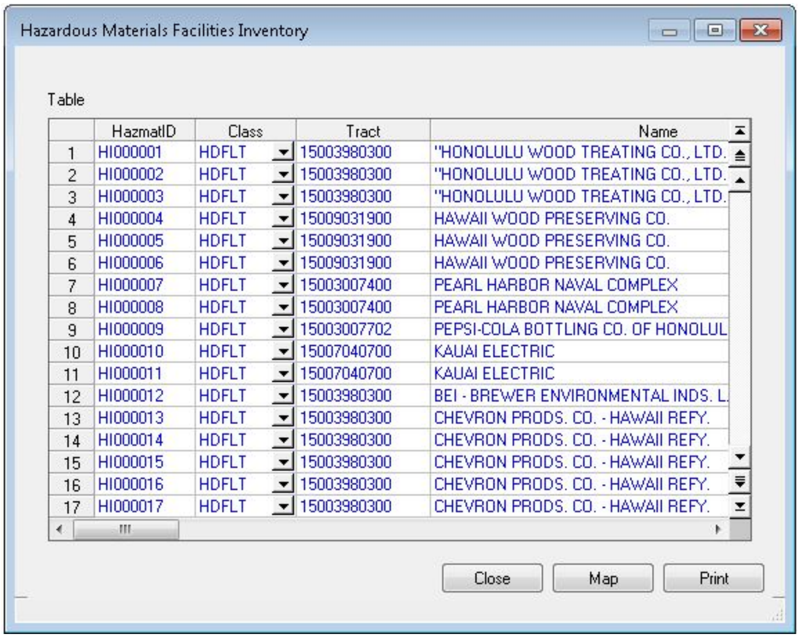


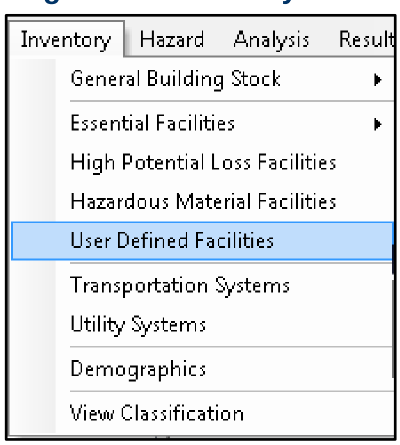
Figure 67: Hazardous Materials Facilities Inventory



5.6 User Defined Facilities[1]

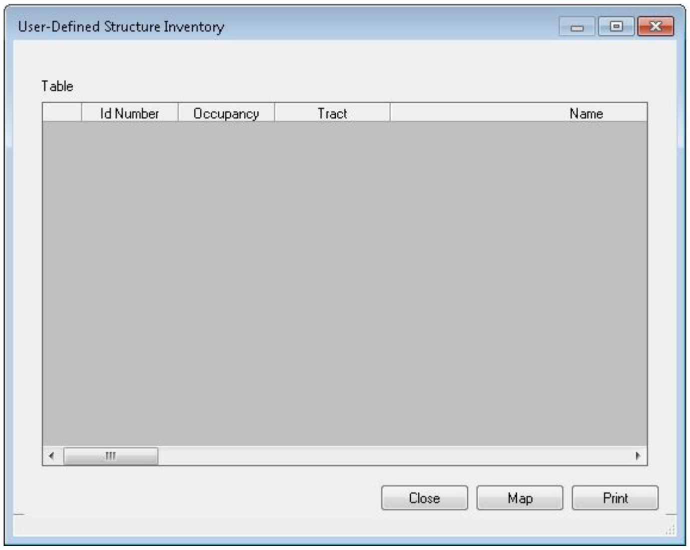
User-defined facilities are buildings at specific locations that the user adds to the inventory. Damage and loss is evaluated on a building-by-building basis for this class of structures. Selecting the User Defined Facilities option (**Figure 68**) will open the window seen in **Figure 69**.

Figure 68: Inventory Menu



[1] Hazus uses the terms "user-defined facilities" and "user-defined structures" interchangeably.

Figure 69: User Defined Facilities Inventory



Chapter 9 discusses Advanced Hazus Analysis: User Defined Inventory, which allows custom data to be imported into Hazus.

5.7 Transportation Systems

Transportation lifelines, including highways, railways, light rail, bus systems, ports, ferry systems, and airports, are broken into components such as bridges, stretches of roadway or track, terminals, and port warehouses. Damage and loss are not computed for Transportation Systems in the present version of the Tsunami Model. Selecting this option from the Inventory menu (**Figure 70**) will open the window seen in **Figure 71**.

Figure 70: Inventory Menu

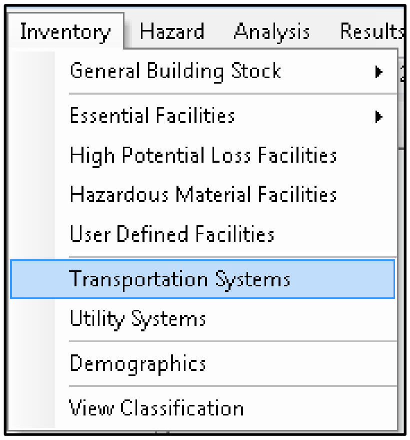
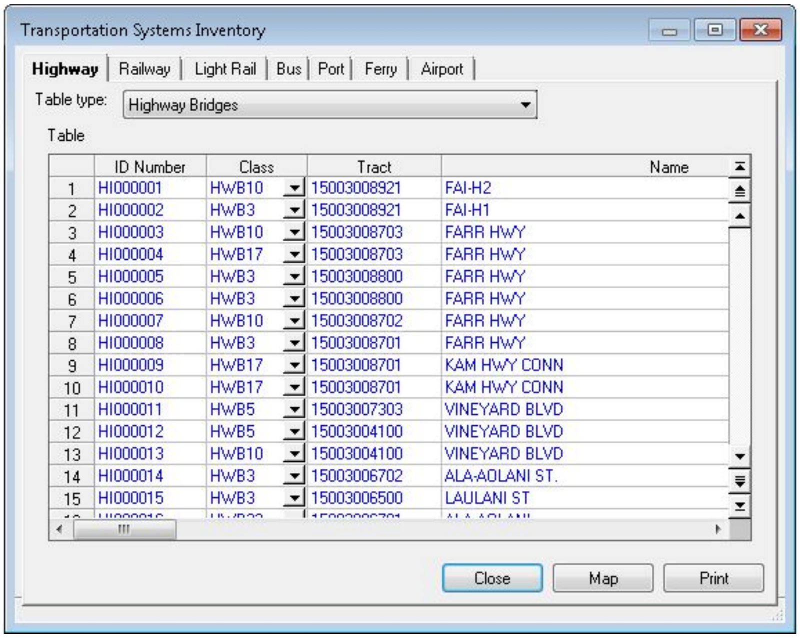


Figure 71: User Transportation Systems Inventory



5.8 Utility Systems

Utility lifelines, including potable water, electric power, waste water, communications, and liquid fuels (oil and gas), are treated in a manner similar to transportation lifelines. Examples of components are electrical substations, water treatment plants, tank farms, and pumping stations. Damage and loss are not computed for Utility Systems in the present version of the Tsunami Model. Selecting this option from the Inventory menu (Figure 72) will open the window seen in **Figure 73.**

Figure 72: Inventory Menu

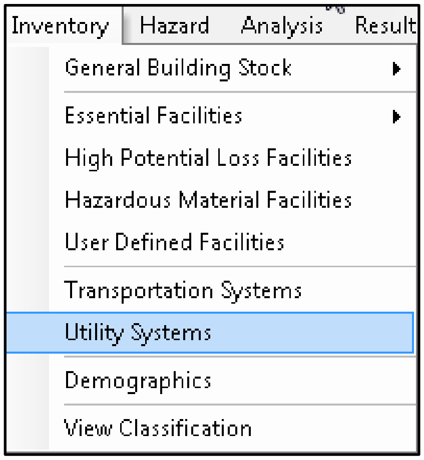
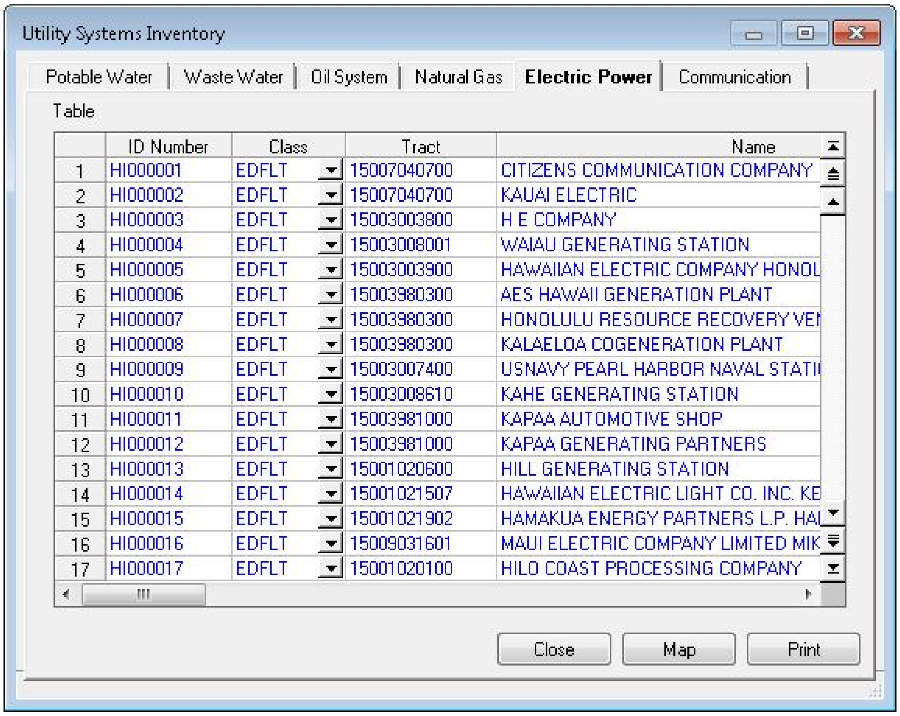


Figure 73: Utility Systems Inventory



5.9 Demographics

In Hazus, the population statistics are used in estimating several different losses such as casualties, displaced households, and shelter needs. Population location, as well as ethnicity, income level, age, and home ownership are needed to make these estimates. The 2010 Census data are included within Hazus. The user may be able to obtain updated information from the Census Bureau or from a regional planning agency. The present version of the tsunami model uses the demographic data and NSI location in calculating Evacuation Travel Time and Casualties. (See Chapter 6 of the *Hazus Tsunami Model Technical Guidance.*) Selecting this option from the Inventory menu (**Figure 74**) will open the window seen in **Figure 75.**

Figure 74: Inventory Menu

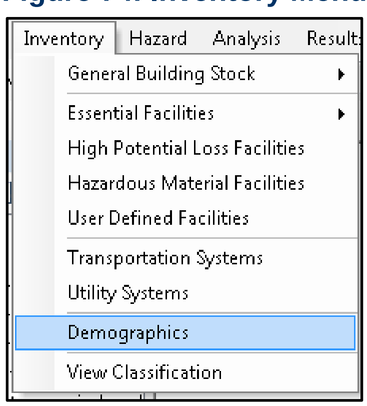
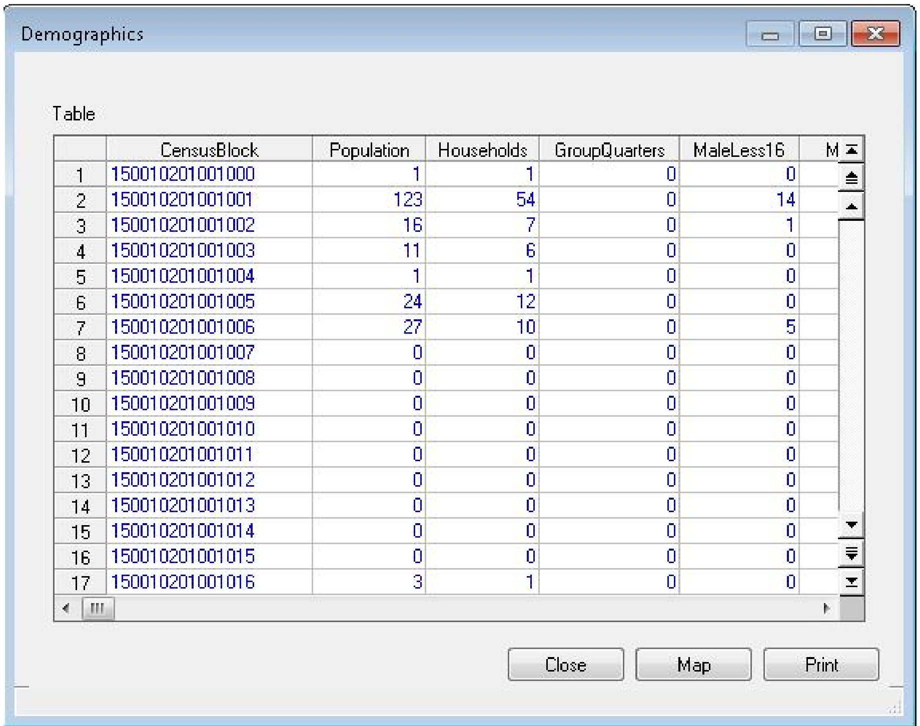


Figure 75: Demographics Inventory



	CensusBlock	Population	Households	GroupQuarters	MaleLess16	M
1	150010201001000	1	1	0	0	
2	150010201001001	123	54	0	14	
3	150010201001002	16	7	0	1	
4	150010201001003	11	6	0	0	
5	150010201001004	1	1	0	0	
6	150010201001005	24	12	0	0	
7	150010201001006	27	10	0	5	
8	150010201001007	0	0	0	0	
9	150010201001008	0	0	0	0	
10	150010201001009	0	0	0	0	
11	150010201001010	0	0	0	0	
12	150010201001011	0	0	0	0	
13	150010201001012	0	0	0	0	
14	150010201001013	0	0	0	0	
15	150010201001014	0	0	0	0	
16	150010201001015	0	0	0	0	
17	150010201001016	3	1	0	0	

5.10 View Classification

The View Classification option (**Figure 76**) allows the user to view definitions of the classification categories. Selecting this option will open the window seen in **Figure 77**.

Figure 76: View Classification Menu

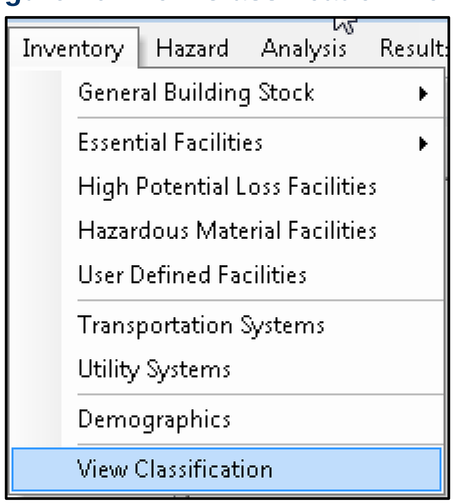
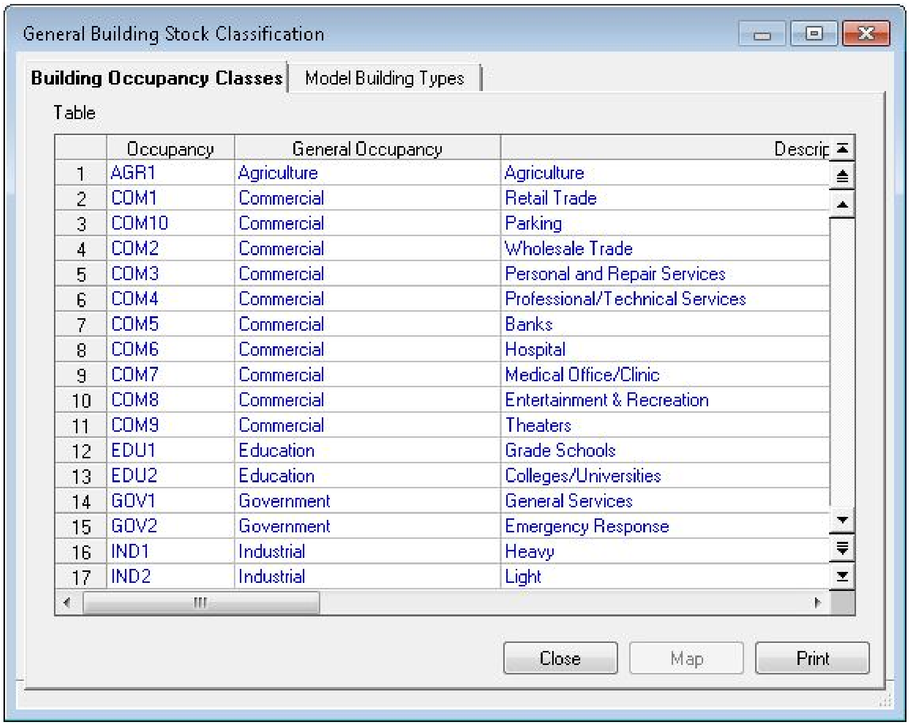


Figure 77: Inventory Classifications


General Building Stock Classification

Building Occupancy Classes | Model Building Types

Table

	Occupancy	General Occupancy	Descrip
1	AGR1	Agriculture	Agriculture
2	COM1	Commercial	Retail Trade
3	COM10	Commercial	Parking
4	COM2	Commercial	Wholesale Trade
5	COM3	Commercial	Personal and Repair Services
6	COM4	Commercial	Professional/Technical Services
7	COM5	Commercial	Banks
8	COM6	Commercial	Hospital
9	COM7	Commercial	Medical Office/Clinic
10	COM8	Commercial	Entertainment & Recreation
11	COM9	Commercial	Theaters
12	EDU1	Education	Grade Schools
13	EDU2	Education	Colleges/Universities
14	GOV1	Government	General Services
15	GOV2	Government	Emergency Response
16	IND1	Industrial	Heavy
17	IND2	Industrial	Light

Close Map Print

6.0 Tsunami Model: Hazard Menu

The Hazus Tsunami Model relies on varying levels of user input for the hazard, much like Hazus Flood Model, this chapter summarizes the Tsunami User Data options under the Hazard menu.

6.1 Tsunami Hazard Type

The Tsunami Hazard Type (**Figure 78**) submenu allows the user to select a Near Source (required for a Combined Earthquake + Tsunami Scenario) or Distant Source (Tsunami Scenario only) tsunamigenic event. It is accessible under the Tsunami Hazard Type menu (**Figure 79**). Select Tsunami Hazard Type in the menu. Choose source type. Click **OK**.

Figure 78: Hazard Menu

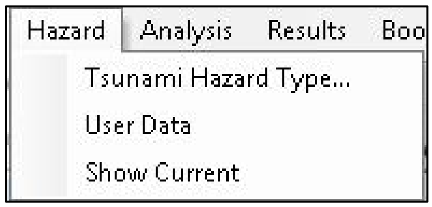
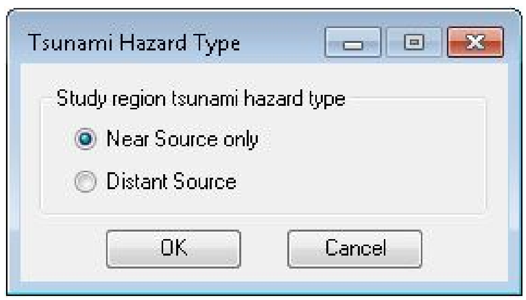


Figure 79: Tsunami Hazard Type Menu



6.2 Tsunami User Data Wizard

The Tsunami User Data Wizard, accessible under the Hazard Menu (**Figure 80**), allows the user to select a Hazard Type (**Figure 81**) based on the level of data available to the user. This section will provide a brief description of each. The first two (both with names beginning with "Level 1") are basic level tsunami model scenarios and the last two are advanced level tsunami model scenarios (**Table 1**).

Table 1: Hazus Tsunami Data Requirements

	Hazard Data Required	Input Data Files and Formats
Level 1	Runup Only - Mean Sea Level (MSL)	1. Maximum Runup height grid in raster format 2. DEM raster (download option for USGS provided similar to flood model)
Level 1	Quick Look - Single Maximum Runup	1. DEM raster and single maximum runup value (MSL)
Level 2	Depth Above Ground Level (AGL) and Velocity	Maximum Depth grid and Velocity grid in raster format ---OR--- Maximum Depth and Velocity NetCDF NOAA SIFT (.nc) files
Level 3	Depth AGL (ft) and Momentum Flux ($ft^3 sec^2$)	1. Median Depth grid in raster format 2. Median Momentum Flux grid in raster format

In the User Data Wizard, users have the flexibility to specify the units for the files they import, depending on Analysis Level. Level 3 assumes user-provided data are already in the required units. No system validation of units is performed by Hazus.

Sample data are available for all levels for the five U.S. states. See Chapter 10 for more information.

Figure 80: Hazard Scenario Menu

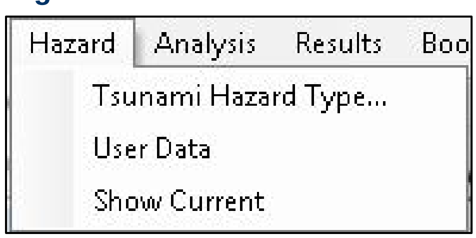
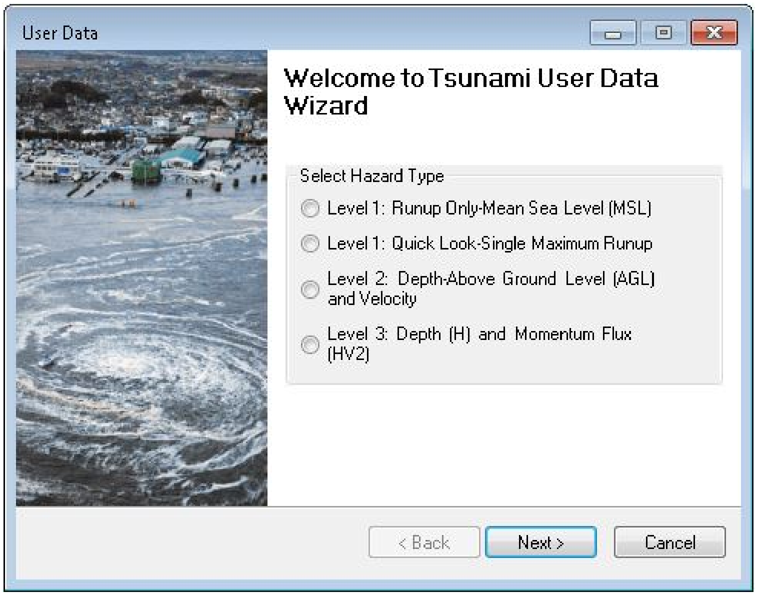


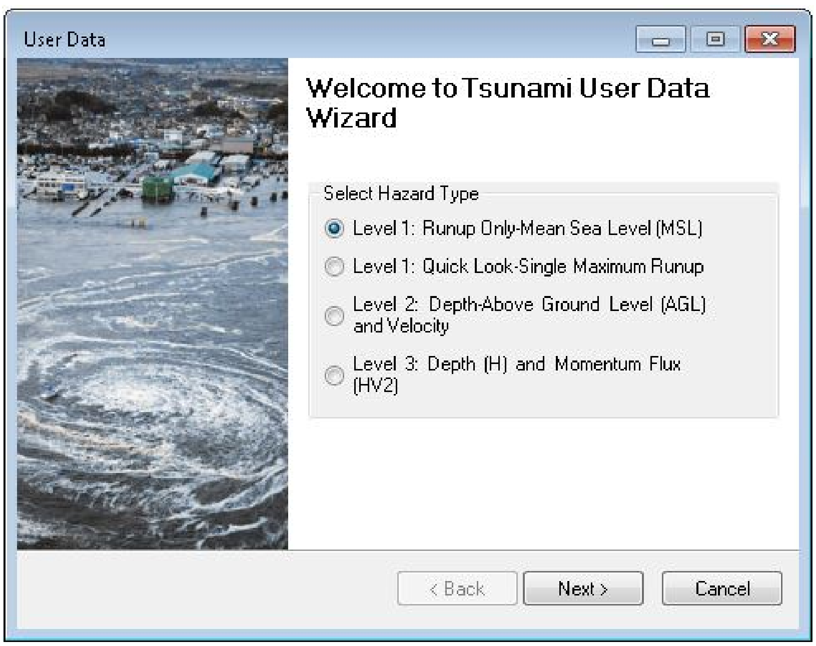
Figure 81: Tsunami User Data Wizard



6.2.1 Basic Level 1: Runup Only-Mean Sea Level (MSL)

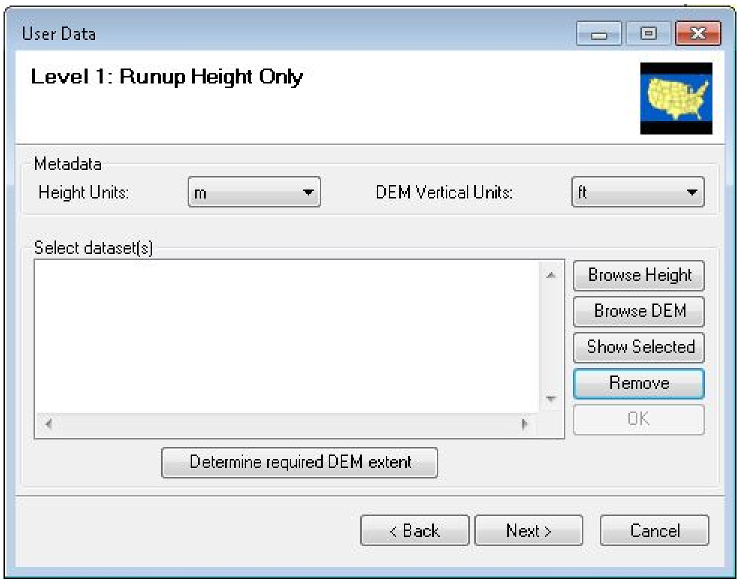
Select the first option, Level 1: Runup Only-Mean Sea Level (MSL) (**Figure 82**). Click **Next**.

Figure 82: Tsunami Wizard Level 1 Runup Only



The Level 1: Runup Height Only Scenario (**Figure 83**) requires a Maximum Runup height grid in raster format and a DEM. A download option for USGS DEMs is available (similar to the Flood Model). Click **Determine required DEM extent** to access the DEM download. The Metadata drop-down menus are used to identify the units for each dataset.

Figure 83: Level 1: Runup Height Only Scenario



The DEM Extent window will appear with a list of related NED Datasets (**Figure 84**). Click **Download and Unzip All** to download the data to the Hazard Input folder **(Figure 85).**

Figure 84: USGS DEM import tool

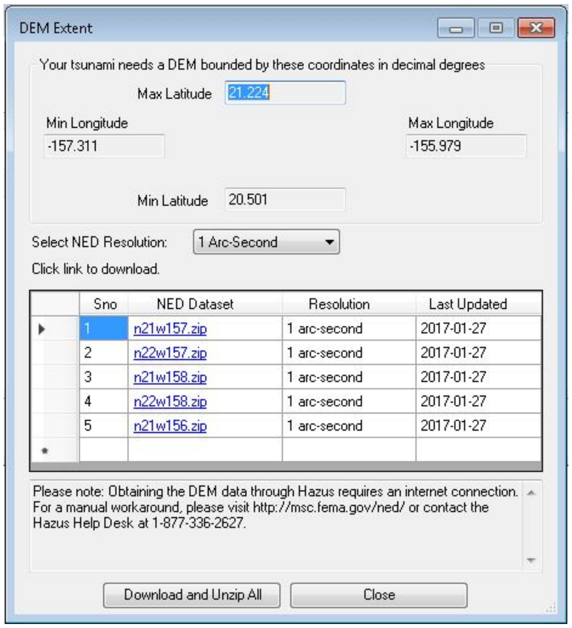
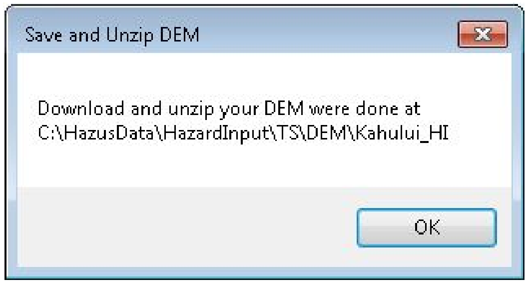


Figure 85: DEM Download Location

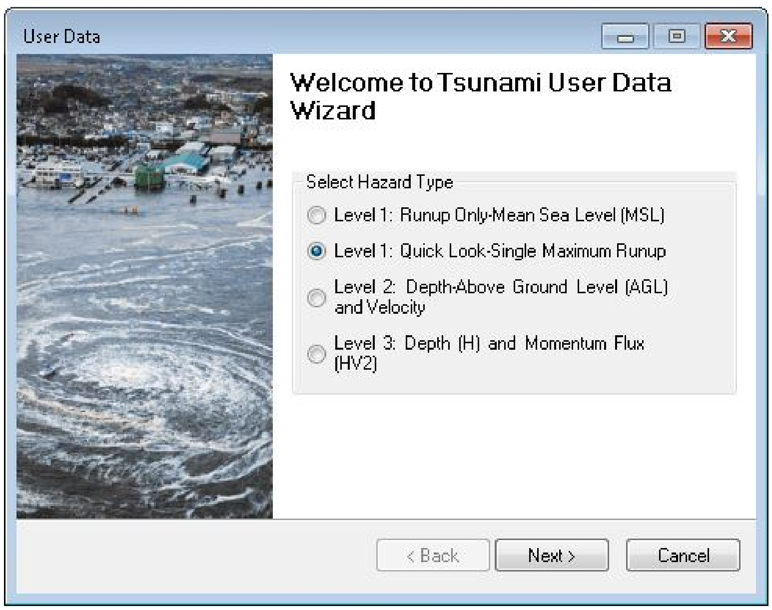


The Metadata drop-down menus are used to identify the units for each dataset. (Note: The USGS NED vertical units are always in meters.) The User Defined Tsunami Height Grid is added using the Browse Height button (**Figure 83**). The DEM is added using the Browse DEM button. The Show Selected button will map the imported user rasters. Click **OK** to create the velocity grid, and Hazard and Fatality Boundaries.

6.2.2 Basic Level 1: Quick Look-Single Maximum Runup

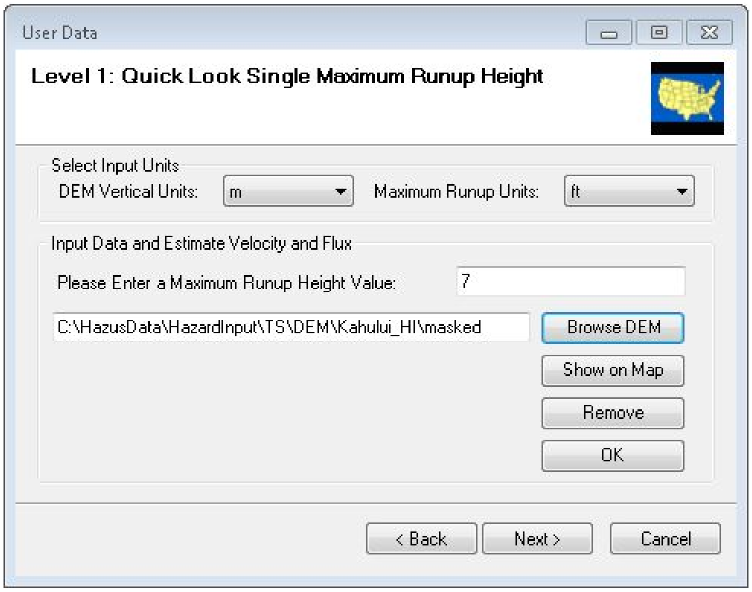
Select the second option, Level 1: Quick Look-Single Maximum Runup (**Figure 86**). Click **Next**.

Figure 86: Tsunami Wizard: Level 1 Quick Look



The Level 1: Quick Look-Single Maximum Runup (**Figure 87**) requires a DEM (download option available in the previous section), and a single maximum runup value. The Select Input Units drop-drown menus are used to identify the units of the DEM and the height value.

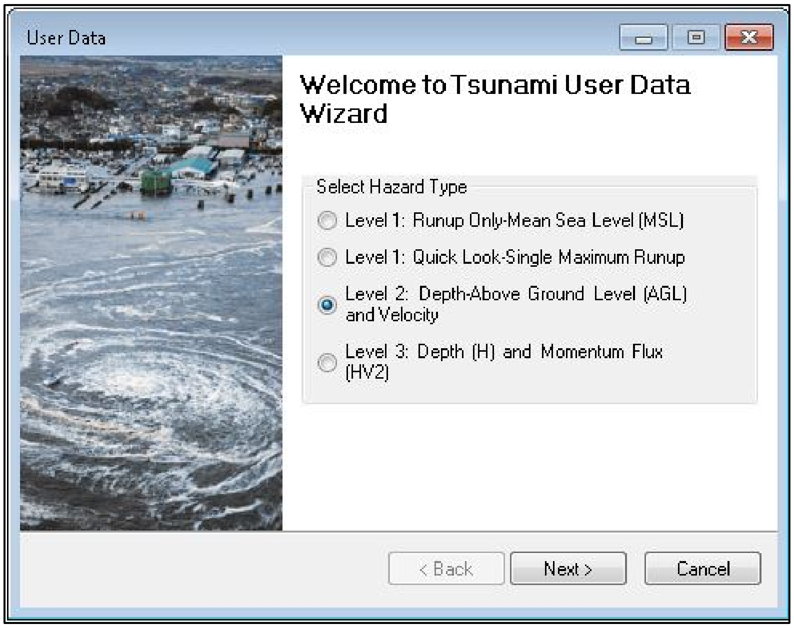
Figure 87: Level 1: Quick Look-Single Maximum Runup



6.2.3 Advanced Level 2: Depth-Above Ground Level (AGL) and Velocity

The next two options are Advanced Level options. The first is Level 2: Depth-Above Ground Level (AGL) and Velocity **(Figure 88)**.

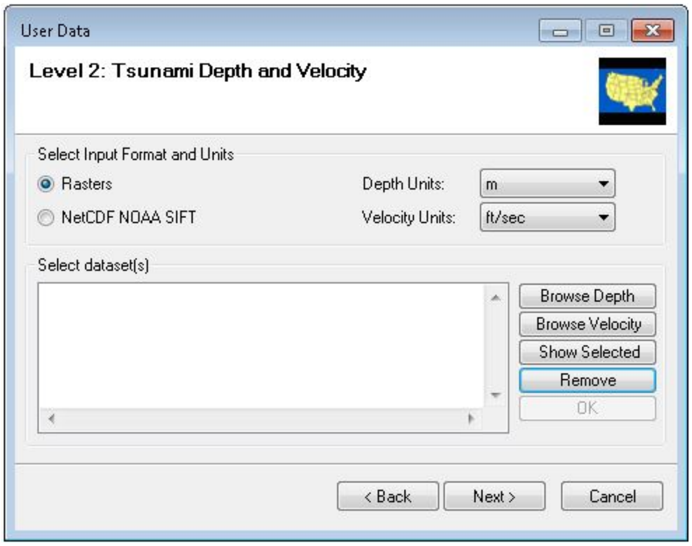
Figure 88: Tsunami Wizard Level 2



The Level 2: Depth-Above Ground Level (AGL) and Velocity **(Figure 89)** enables users to enter Maximum Depth grid and Velocity grid data in raster format, or Maximum Depth and Velocity

NetCDF NOAA SIFT (.nc) files. (Sample data are provided by NOAA. See Chapter 10 for more information.) The units are defined using the drop-down menus.

Figure 89: Level 2: Depth-Above Ground Level (AGL) and Velocity



6.2.4 Advanced Level 3: Depth (H) and Momentum Flux (HV2)

The last option is Level 3: Depth (H) and Momentum Flux (HV2) (**Figure 90**). This option requires a Median Depth grid in raster format and a Median Momentum Flux grid in raster format. Level 3 assumes user-provided data are already in required units (**Figure 91**).

Figure 90: Tsunami Wizard Level 3

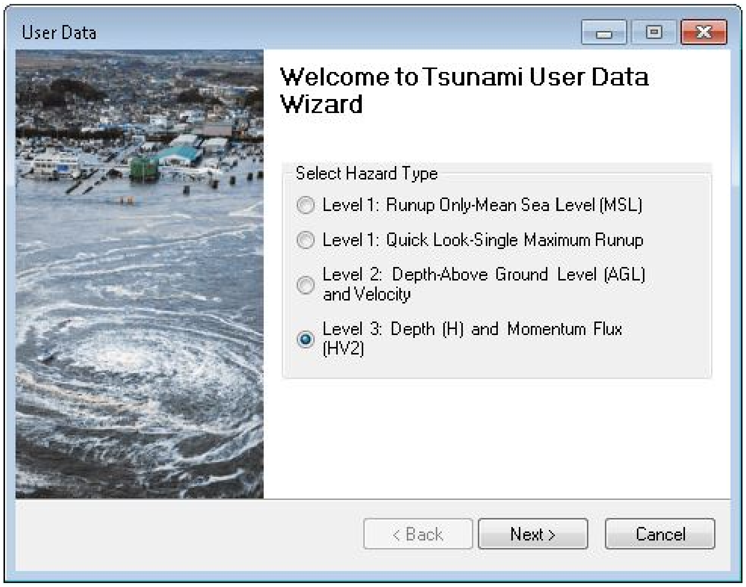
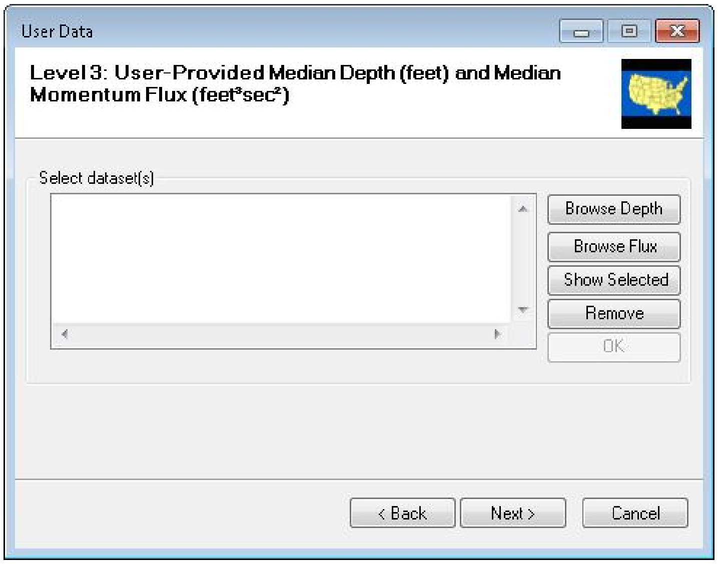


Figure 91: Level 3: Depth (H) and Momentum Flux (HV2)



7.0 Tsunami Model: Analysis Menu

There are three basic classes of analysis functions used in the Hazus Tsunami Model:

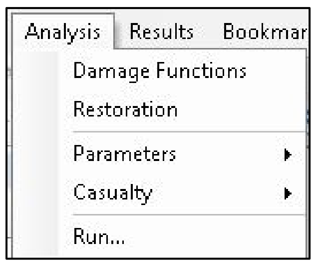
- Damage Functions
- Restoration
- Casualty

There are also two types of parameters in the tsunami model:

- Casualty
- Building economic

The menu in **Figure 92** shows each the Analysis selection. Functions are described in the following sections.

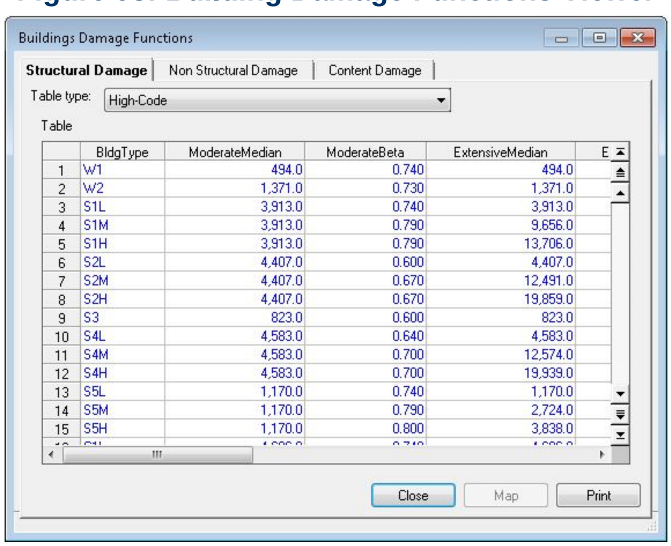
Figure 92: Analysis Menu



7.1 Damage Functions

The **Analysis | Damage Functions** option displays tables of the probabilities of damage states for building type as a function of tsunami inundation depth (for contents) and flux (for structural) (**Figure 93)**.

Figure 93: Building Damage Functions Viewer

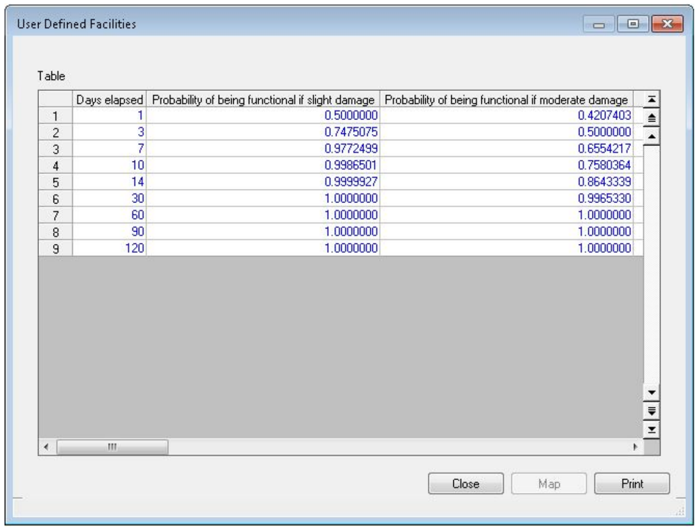


	BldgType	ModerateMedian	ModerateBeta	ExtensiveMedian	E
1	W1	494.0	0.740	494.0	
2	W2	1,371.0	0.730	1,371.0	
3	S1L	3,913.0	0.740	3,913.0	
4	S1M	3,913.0	0.790	9,656.0	
5	S1H	3,913.0	0.790	13,706.0	
6	S2L	4,407.0	0.600	4,407.0	
7	S2M	4,407.0	0.670	12,491.0	
8	S2H	4,407.0	0.670	19,859.0	
9	S3	823.0	0.600	823.0	
10	S4L	4,583.0	0.640	4,583.0	
11	S4M	4,583.0	0.700	12,574.0	
12	S4H	4,583.0	0.700	19,939.0	
13	S5L	1,170.0	0.740	1,170.0	
14	S5M	1,170.0	0.790	2,724.0	
15	S5H	1,170.0	0.800	3,838.0	

7.2 Restoration

The **Analysis | Restoration** option displays tables of the expected number of days to restore the function of each building type as a function of tsunami inundation depth and velocity (**Figure 94**).

Figure 94: Functionality

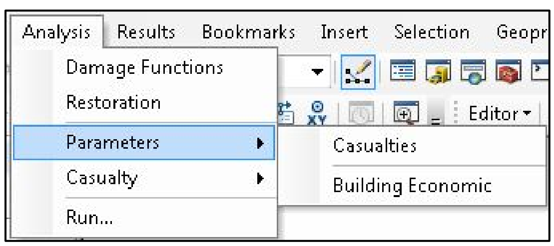


	Days elapsed	Probability of being functional if slight damage	Probability of being functional if moderate damage
1	1	0.5000000	0.4207403
2	3	0.7475075	0.5000000
3	7	0.9772499	0.6554217
4	10	0.9986501	0.7580364
5	14	0.9999927	0.8643339
6	30	1.0000000	0.9965330
7	60	1.0000000	1.0000000
8	90	1.0000000	1.0000000
9	120	1.0000000	1.0000000

7.3 Parameters

The **Analysis | Parameters** menu (**Figure 95**) allows the user to define Casualties and Building Economic parameters.

Figure 95: Analysis Parameters Menu

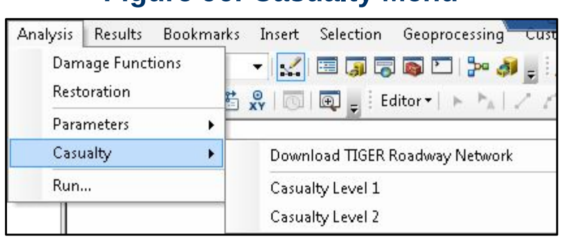


See Chapter 12 for detailed information on each parameter.

7.4 Casualties

The **Analysis | Casualty** menu (**Figure 96**) allows the user to download TIGER road data and set up Casualty Level scenarios.

Figure 96: Casualty Menu

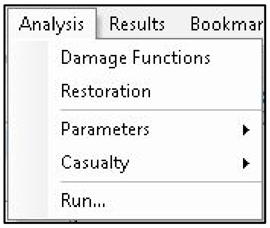


Hazus Tsunami Model makes use of a USGS methodology (see Chapter 6 of *Hazus Tsunami Model Technical Guidance*) for estimating pedestrian evacuation times, arrival, warning times, and community preparedness levels to estimate potential loss of life and injuries. Prior to running the Casualty model, the user must first run the Tsunami GBS Analysis. Hazus will prompt the user to do this if it is not already done. View Chapter 12.0 for detailed information.

7.5 Run

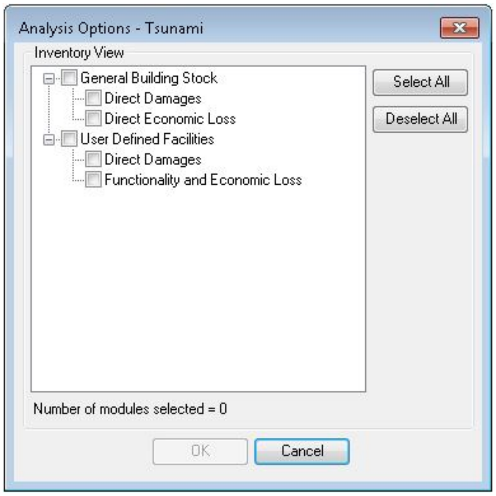
When the study region inventory, hazard, and analysis parameters have been specified, the user is ready to run an analysis. Select the **Analysis | Run** menu (**Figure 97**) option to display the Analysis Options window shown in **Figure 98**.

Figure 97: Analysis Run Menu



The Analysis Options window **(Figure 98)** allows the user to select inventory items. Once satisfied with inventories, click **OK** to Run the analysis.

Figure 98: Analysis Options

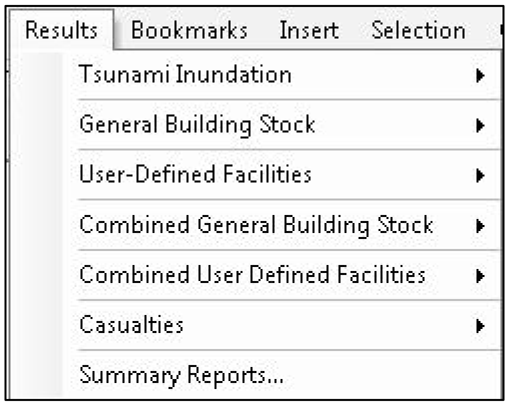


After the analysis is completed, the user can access the results under the Results menu outlined in Chapter 8.

8.0 Tsunami Model: Results Menu

The output from the analysis is available in the form of result tables, maps, and reports produced by the Hazus Tsunami Model. The items discussed are accessed via the Results menu (**Figure 99**) after running a Tsunami GBS Scenario and Casualty Analysis. This section will describe the outputs associated with each menu selection including: Tsunami Inundation, General Building Stock, User Defined Facilities, Combined General Building Stock, Combined User Defined Facilities, Casualties, and Summary Reports.

Figure 99: Results Menu



8.1 Model Outputs

Hazus provides the user with a series of outputs for each model. The outputs can be in a numerical or graphical form. **Table 2** summarizes the outputs that can be obtained from an analysis using the Hazus Tsunami Model.

Table 2: Hazus Tsunami Model Output

Maps of Tsunami Inundation	**User Defined Facilities**
Median Inundation Depth (ft)	Damage probabilities by occupancy
Median Momentum Flux (ft^3/sec^2)	Damage probabilities by building type
Inundation/Hazard Boundary (depth $\geq$ 0)	Cost of building repair or replacement
Fatality Boundary (depth $\geq$ 2m)	Loss of content
General Building Stock	Business inventory loss
Damage probabilities by occupancy	Loss of rental income
Damage probabilities by building type	Relocation costs
Cost of building repair or replacement	Business income loss
Loss of contents	Employee wage loss
Business inventory loss	**Casualties**
Loss of rental income	Evacuation Travel Time (Under 65, 65 and Over)
Relocation costs	Day and Night Population Exposure
Business income loss	Day and Night Probability of Casualties
Employee wage loss	Casualties Based on Community Preparedness Levels

Examples of pre-event applications of the outputs are as follows:

- Development of mitigation strategies that outline policies and programs for reducing tsunami losses and disruptions indicated in the initial loss estimation study. Strategies can involve upgrading existing buildings, the adoption of new building codes, and relocating essential facilities to areas outside the tsunami inundation area.
- Preliminary investigation of the ideal location of vertical evacuation refuges so as to minimize the casualties from future tsunami events.
- Anticipation of the nature and scope of response and recovery efforts including: identifying safe zones for evacuations, locations of essential facilities, and areas where fatalities may occur.
- Development and implementation of community preparedness outreach programs to increase community readiness especially targeted in areas where longer pedestrian evacuation times occur and populations may be concentrated.

Post-event applications of the outputs would include:

- Projection of immediate economic impact assessments for state and federal resource allocation and support for actions including the declaration of a state and/or federal disaster by calculating direct economic impact on public and private resources, local governments, and the functionality of the area.
- Activation of immediate emergency recovery efforts including provision of emergency housing shelters.
- Application of long-term reconstruction plans including the identification of long-term reconstruction goals, the institution of appropriate wide-range economic development plans for the entire area, allocation of permanent housing needs, and the application of land-use planning principles and practices.
- Application of lessons learned to improve community response and preparedness

Once inventory data have been collected and imported, making modifications and running new analyses are simple tasks. The ease with which reports and maps can be generated makes the software a useful tool for a variety of applications.

8.2 Tsunami Inundation

Tsunami Inundation results **(**Figure 100**)** include the median tsunami Depth, median Momentum Flux, and Inundation Boundary for the scenario. The structural, non-structural, and content tsunami damage functions are based on the median rather than maximum hazard values. See the *Hazus Tsunami Model Technical Guidance* document for details of the methodology. The tsunami depth is mapped in feet **(Figure 101)**. The tsunami momentum flux is mapped in ft^3/sec^2 **(Figure 102)**. Each map shows similar patterns with the highest depth and flux values are along the coastline, with progressively lower values going inland from the coast until the values go to zero at the limit of the tsunami inundation. The tsunami hazard boundary is the extent of the tsunami inundation and is mapped as shown in **Figure 103**. The layer can be exported as a shapefile or geodatabase feature class.

Figure 100: Results Tsunami Inundation Menu

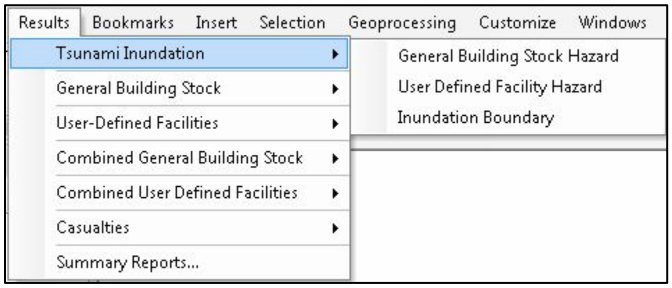


Figure 101: Tsunami Depth Results Example

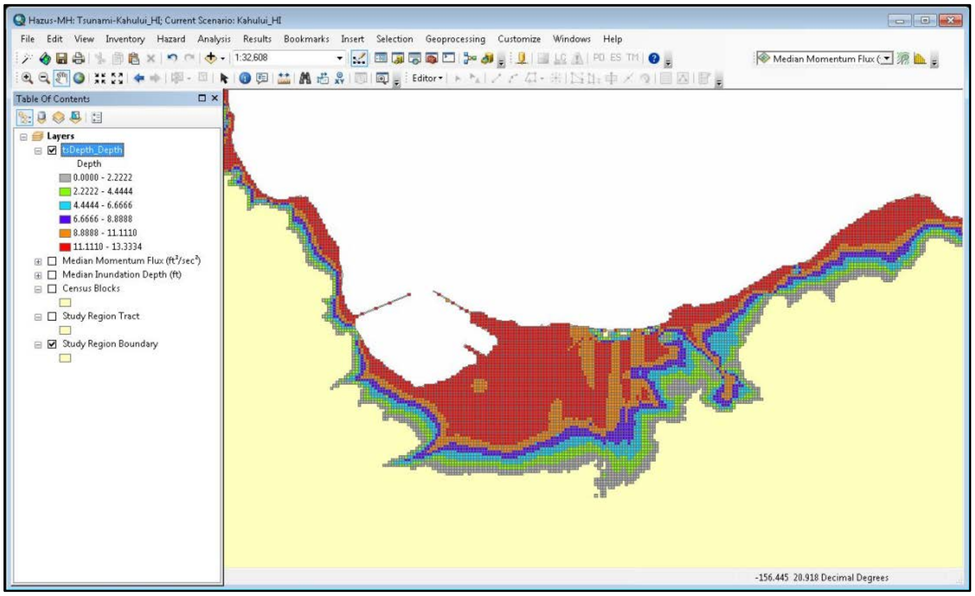


Figure 102: Tsunami Momentum Flux Results Example

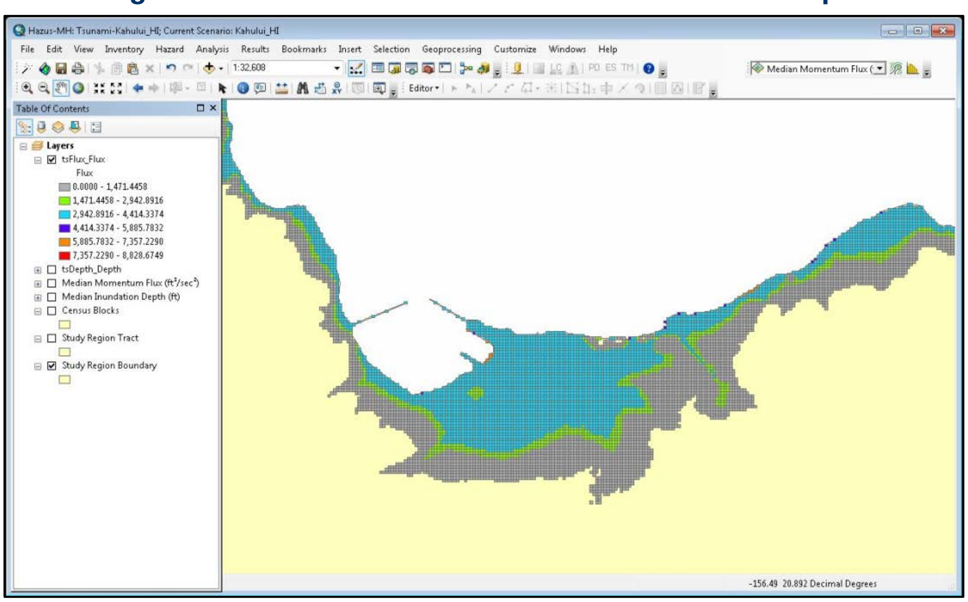
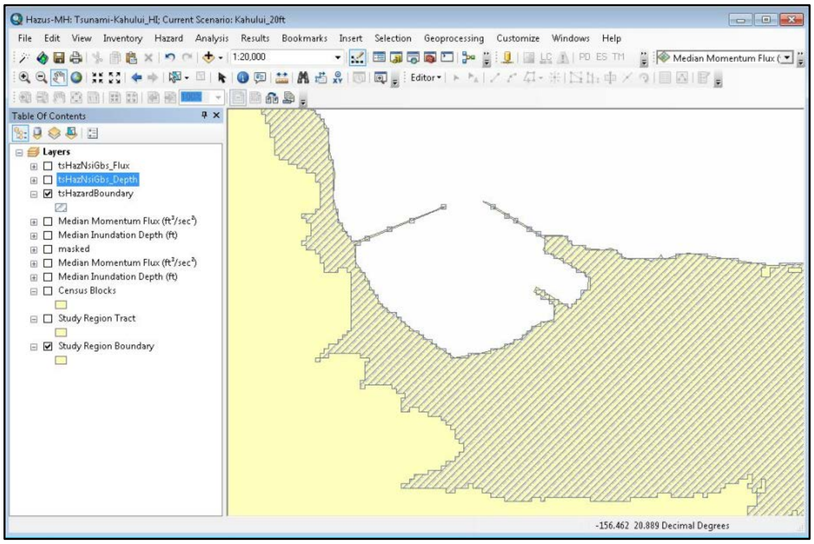


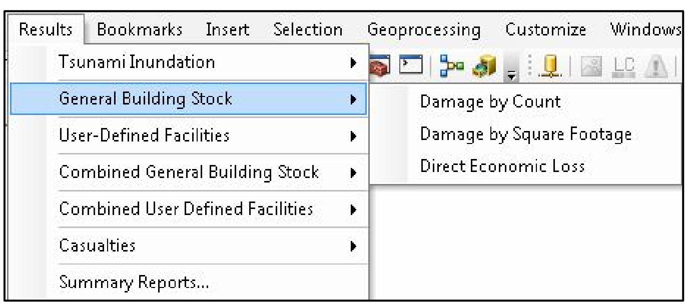
Figure 103: Tsunami Inundation Boundary Results Example



8.3 General Building Stock (GBS) Results

The **Results | General Building Stock** menu **(Figure 104)** allows the user to view and map the general inventory damage results either by occupancy or building type. ***Note: the values for damage are building counts aggregated by damage state probabilities. This may lead to "counts" of damaged buildings with decimals, giving the appearance that fractions of buildings were counted. This provides more accurate aggregated damage counts since no fractions are discarded.***

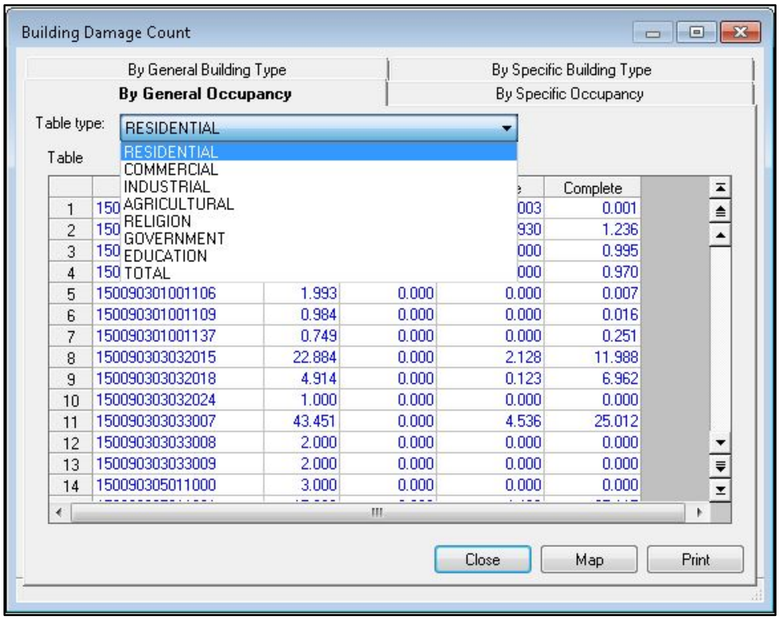
Figure 104: General Building Stock Menu



8.3.1 GBS Damage Count by Occupancy Class

Figure 105 shows the GBS Damage Count by occupancy class results table, allowing the user to view and map the general inventory damage results either by general or specific occupancy class. The values in the table represent the expected number of buildings in each damage state.

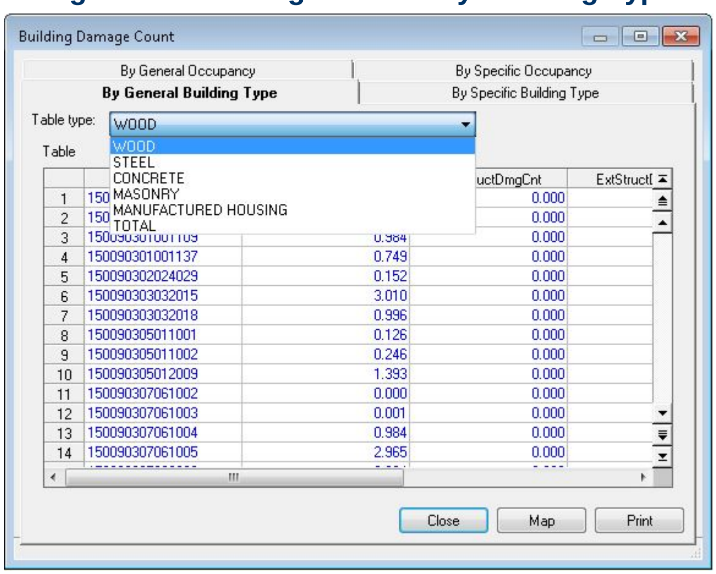
Figure 105: Damage Count by Occupancy Class



8.3.2 GBS Damage Count by Building Type

Figure 106 shows GBS Damage by Building Type, which allows the user to view results by the General Building Type and Specific Building Type. The values in the table represent the expected number of buildings in each damage state.

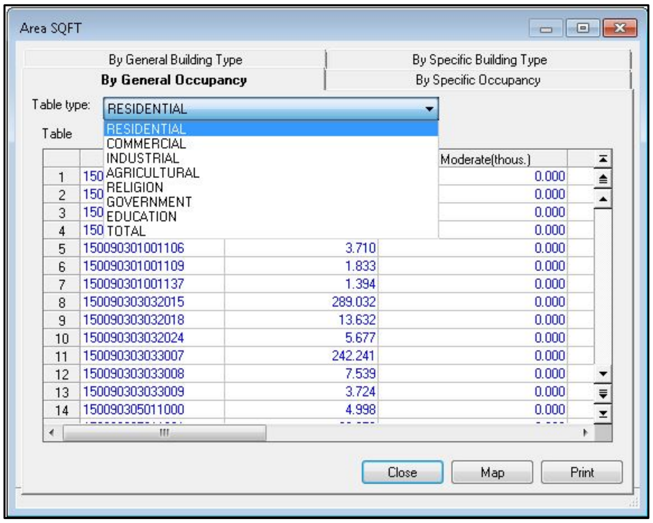
Figure 106: Damage Counts by Building Type



8.3.3 GBS Building Stock Damage by (Square Footage) by Occupancy

Figure 107 shows the GBS Damage by square footage by occupancy class results table, which allows the user to view and map the general inventory damage results either by general or specific occupancy class. The values in the table represent the expected damage by square footage (in thousands) by occupancy class.

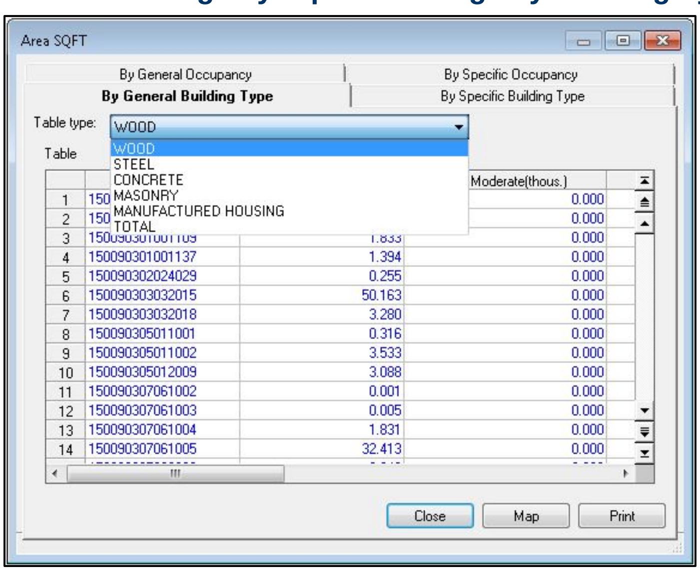
Figure 107: Damage by Square Footage by Occupancy Class



8.3.4 GBS Damage by Square Footage by Building Type

Figure 108 shows the GBS Damage by square footage by Building Type results table, which allows the user to view and map the general inventory damage results either by general or specific building type. The values in the table represent the expected damage by square footage (in thousands) by Building Type.

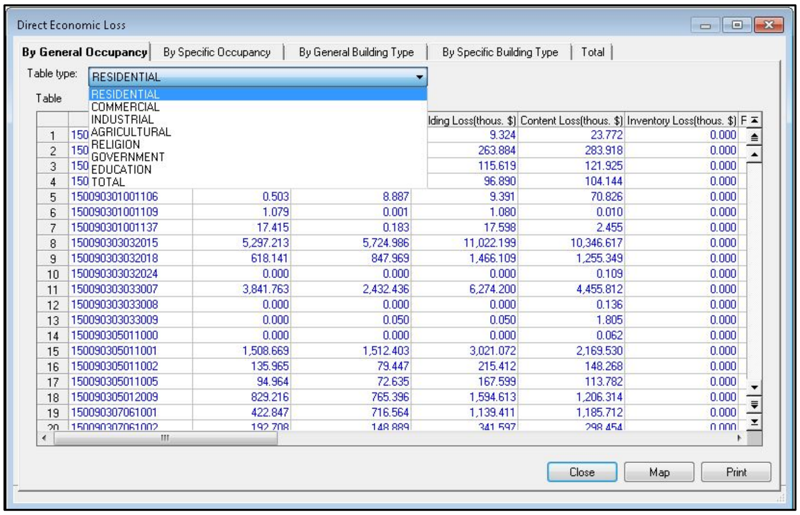
Figure 108: Damage by Square Footage by Building Type



8.3.5 GBS Direct Economic Loss by Occupancy

Figure 109 shows GBS Direct Economic Loss by Occupancy. The user can select and view direct economic loss values by different general and specific occupancy classes, in thousands of dollars (US).

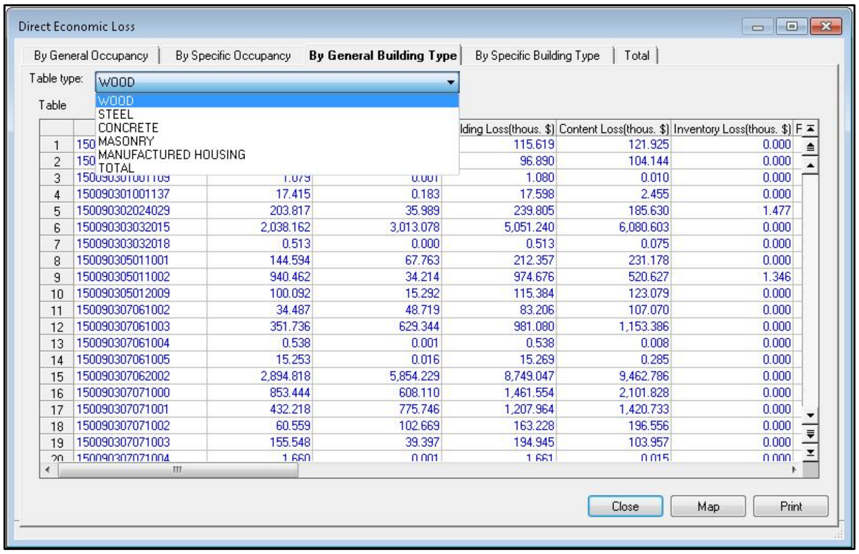
Figure 109: Direct Economic Loss by Occupancy



8.3.6 GBS Direct Economic Loss by Building Type

Figure 110 shows GBS Direct Economic Loss by Building Type. The user can select and view direct economic loss values by different general and specific building types, in thousands of dollars (US).

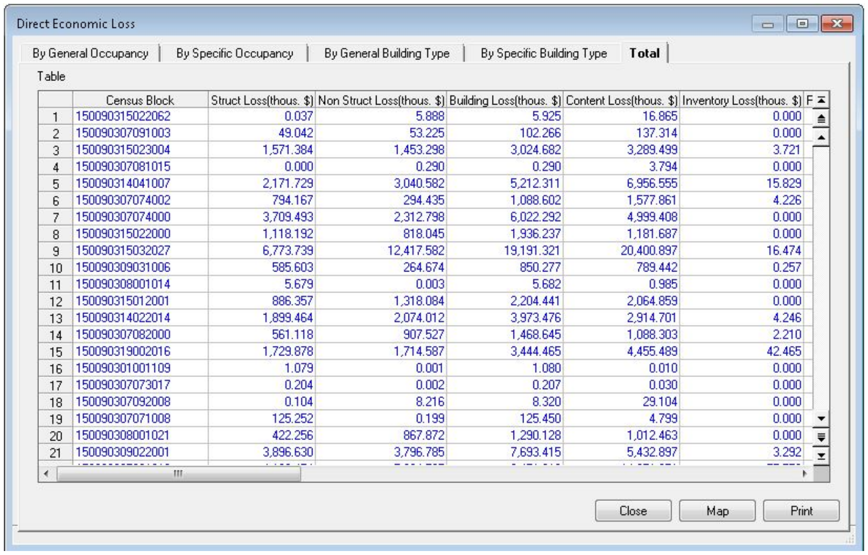
Figure 110: Direct Economic Loss by Building Type



8.3.7 GBS Total Direct Economic Loss

Figure 111 shows Total Direct Economic Loss for the scenario, in thousands of dollars (US).

Figure 111: Total Building Economic Loss

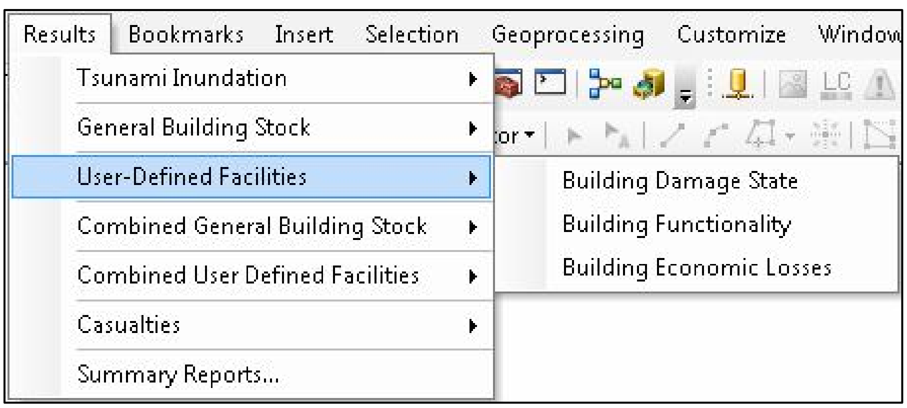


	Census Block	Struct Loss(thous. $)	Non Struct Loss(thous. $)	Building Loss(thous. $)	Content Loss(thous. $)	Inventory Loss(thous. $)
1	150090315022062	0.037	5.888	5.925	16.865	0.000
2	150090307091003	49.042	53.225	102.266	137.314	0.000
3	150090315023004	1,571.384	1,453.298	3,024.682	3,289.499	3.721
4	150090307081015	0.000	0.290	0.290	3.794	0.000
5	150090314041007	2,171.729	3,040.582	5,212.311	6,956.555	15.829
6	150090307074002	794.167	294.435	1,088.602	1,577.861	4.226
7	150090307074000	3,709.493	2,312.798	6,022.292	4,999.408	0.000
8	150090315022000	1,118.192	818.045	1,936.237	1,181.687	0.000
9	150090315032027	6,773.739	12,417.582	19,191.321	20,400.897	16.474
10	150090309031006	585.603	264.674	850.277	789.442	0.257
11	150090308001014	5.679	0.003	5.682	0.985	0.000
12	150090315012001	886.357	1,318.084	2,204.441	2,064.859	0.000
13	150090314022014	1,899.464	2,074.012	3,973.476	2,914.701	4.246
14	150090307082000	561.118	907.527	1,468.645	1,088.303	2.210
15	150090319002016	1,729.878	1,714.587	3,444.465	4,455.489	42.465
16	150090301001109	1.079	0.001	1.080	0.010	0.000
17	150090307073017	0.204	0.002	0.207	0.030	0.000
18	150090307092008	0.104	8.216	8.320	29.104	0.000
19	150090307071008	125.252	0.199	125.450	4.799	0.000
20	150090308001021	422.256	867.872	1,290.128	1,012.463	0.000
21	150090309022001	3,896.630	3,796.785	7,693.415	5,432.897	3.292

8.4 User Defined Facilities

The User-Defined Facilities (Figure 112) submenu allows the user to view and map the damage results for individual, user-specified facilities. Results are available for Building Damage State (structure, non-structural, and content), Building Functionality (probability that the structure is functional), and Building Economic Losses.

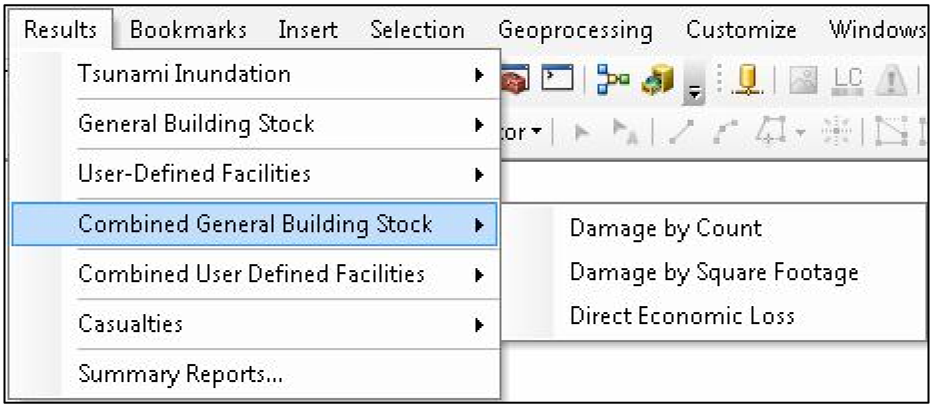
Figure 112: User Defined Facilities Menu



8.5 Combined General Building Stock

The Combined General Building Stock (Figure 113) submenu allows the user to view and map combined earthquake and tsunami losses computed in the Hazus Tsunami Model incorporating results computed by the Earthquake Model. Results are available for Damage by Count, Damage by Square Footage, and Direct Economic Losses. Details on how to run a combined analysis are outlined in Chapter 11.

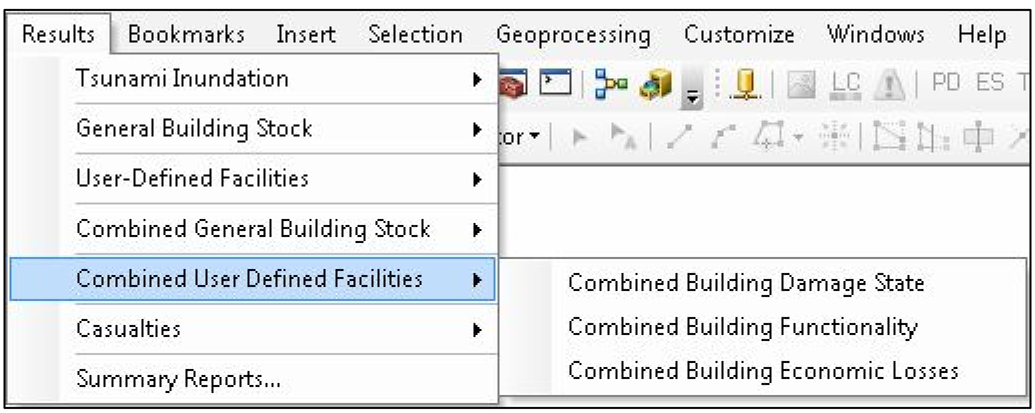
Figure 113: Combined General Building Stock Menu



8.6 Combined User Defined Facilities

The Combined User Defined Facilities (Figure 114) submenu allows the user to view and map combined earthquake and tsunami losses computed in the Hazus Tsunami Model incorporating results computed by the Earthquake Model. Results are available for Combined Building Damage State, Combined Building Functionality, and Combined Building Economic Losses. Details on how to run a combined analysis are outlined in Chapter 11.

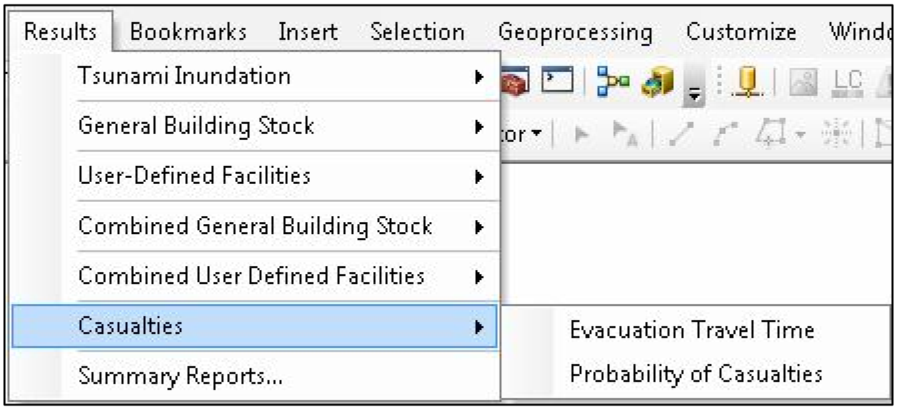
Figure 114: Combined User Defined Facilities



8.7 Casualties

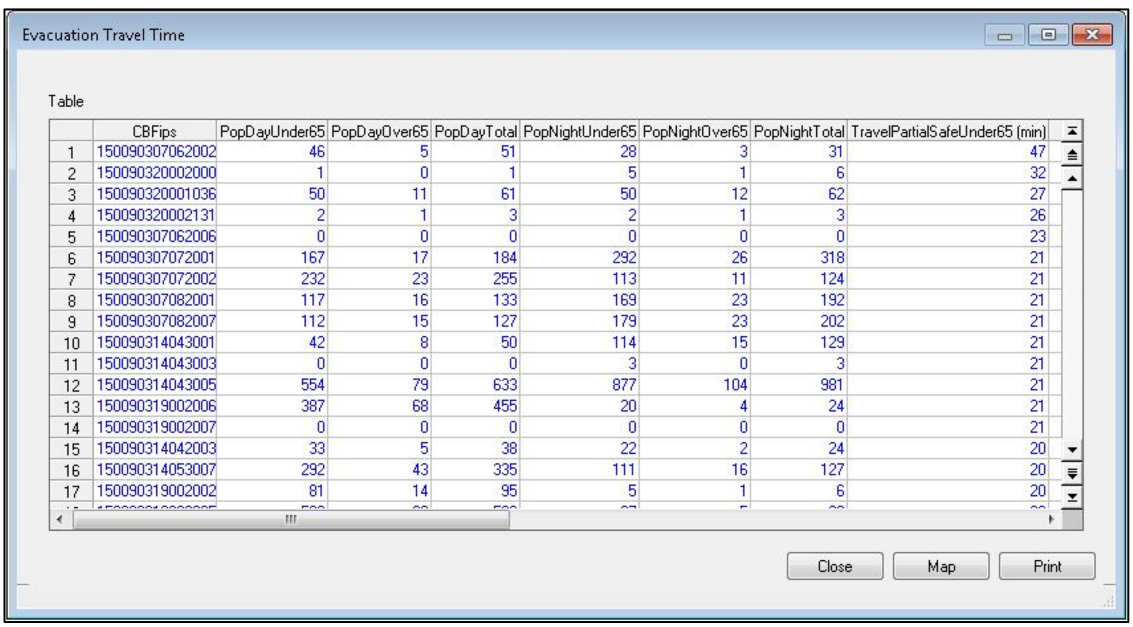
The Casualties (Figure 115) submenu allows the user to view and map results for Evacuation Travel Time and Probability of Casualties.

Figure 115: Casualty Menu



The Evacuation Travel Time (**Figure 116**) estimates the total population evacuated for Population Under 65, Population Over 65, and Total Population for Day (population at school, at work, and in commercial buildings); and Night (population at home). Estimates are also calculated in minutes for Travel to Partial Safety (water depth is $\leq$ 2 meters), and Travel to Safety (out of inundation zone) for Population Under 65 and Population Over 65 and Total Population.

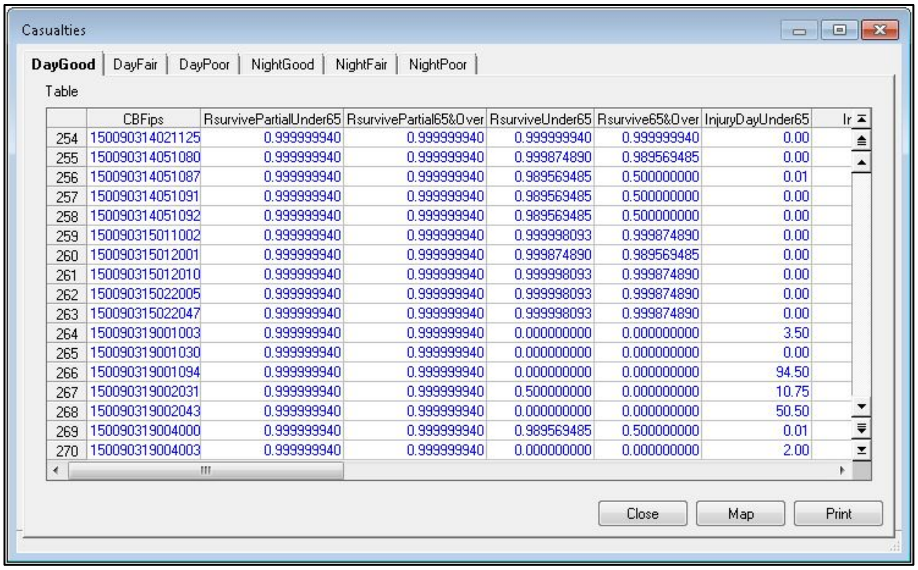
Figure 116: Evacuation Travel Time



	CBFips	PopDayUnder65	PopDayOver65	PopDayTotal	PopNightUnder65	PopNightOver65	PopNightTotal	TravelPartialSafeUnder65 (min)
1	150090307062002	46	5	51	28	3	31	47
2	150090320002000	1	0	1	5	1	6	32
3	150090320001036	50	11	61	50	12	62	27
4	150090320002131	2	1	3	2	1	3	26
5	150090307062006	0	0	0	0	0	0	23
6	150090307072001	167	17	184	292	26	318	21
7	150090307072002	232	23	255	113	11	124	21
8	150090307082001	117	16	133	169	23	192	21
9	150090307082007	112	15	127	179	23	202	21
10	150090314043001	42	8	50	114	15	129	21
11	150090314043003	0	0	0	3	0	3	21
12	150090314043005	554	79	633	877	104	981	21
13	150090319002006	387	68	455	20	4	24	21
14	150090319002007	0	0	0	0	0	0	21
15	150090314042003	33	5	38	22	2	24	20
16	150090314053007	292	43	335	111	16	127	20
17	150090319002002	81	14	95	5	1	6	20

The Probability of Casualties results (**Figure 117**) estimate the percentage of the Population Under 65 and Over 65 to survive by reaching Partial Safety (water depth $\leq$ 2 meters) or Total Safety (water depth < 0 meters). These results also provide an estimate of Injuries for population Under 65, Over 65, and total number of injuries, as well as fatalities for population Under 65, over 65 and total fatalities. The estimates are provided for both Day (population at school, at work, and in commercial buildings); and Night (population at home), by the estimated level of preparedness of the community: Good, Fair, or Poor. (See Chapter 12 for more information.)

Figure 117: Probability of Casualties



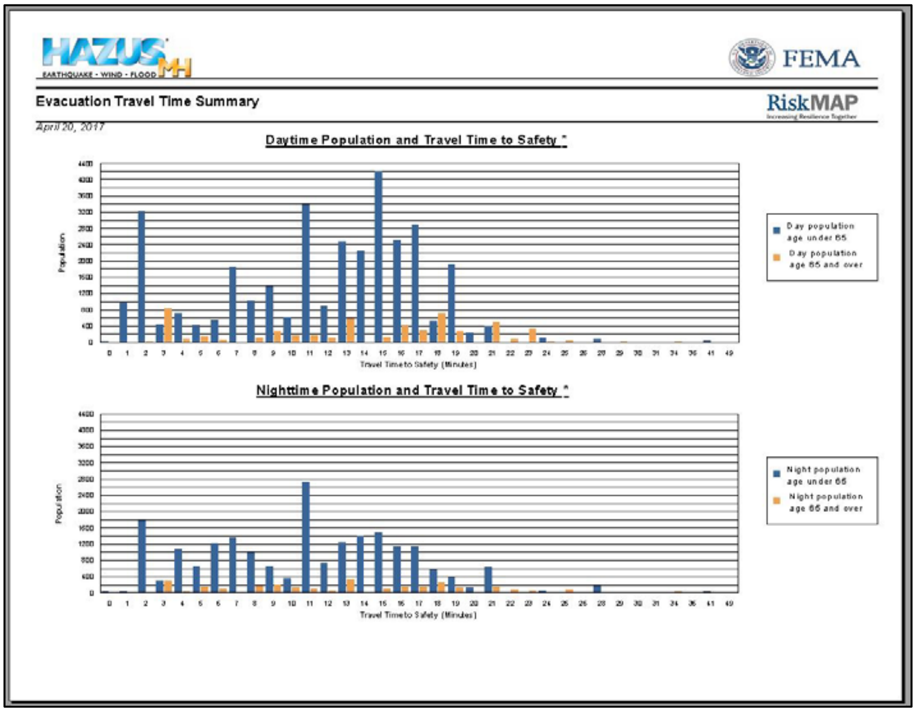
	CBFips	RsurvivePartialUnder65	RsurvivePartial65&Over	RsurviveUnder65	Rsurvive65&Over	InjuryDayUnder65	Ir
254	150090314021125	0.999999940	0.999999940	0.999999940	0.999999940	0.00	
255	150090314051080	0.999999940	0.999999940	0.999874890	0.989569485	0.00	
256	150090314051087	0.999999940	0.999999940	0.989569485	0.500000000	0.01	
257	150090314051091	0.999999940	0.999999940	0.989569485	0.500000000	0.00	
258	150090314051092	0.999999940	0.999999940	0.989569485	0.500000000	0.00	
259	150090315011002	0.999999940	0.999999940	0.999998093	0.999874890	0.00	
260	150090315012001	0.999999940	0.999999940	0.999874890	0.989569485	0.00	
261	150090315012010	0.999999940	0.999999940	0.999998093	0.999874890	0.00	
262	150090315022005	0.999999940	0.999999940	0.999998093	0.999874890	0.00	
263	150090315022047	0.999999940	0.999999940	0.999998093	0.999874890	0.00	
264	150090319001003	0.999999940	0.999999940	0.000000000	0.000000000	3.50	
265	150090319001030	0.999999940	0.999999940	0.000000000	0.000000000	0.00	
266	150090319001094	0.999999940	0.999999940	0.000000000	0.000000000	94.50	
267	150090319002031	0.999999940	0.999999940	0.500000000	0.000000000	10.75	
268	150090319002043	0.999999940	0.999999940	0.000000000	0.000000000	50.50	
269	150090319004000	0.999999940	0.999999940	0.989569485	0.500000000	0.01	
270	150090319004003	0.999999940	0.999999940	0.000000000	0.000000000	2.00	

8.8 Summary Reports

Various summary reports are available for viewing and printing through the Summary Reports menu (Figure 118). After selecting a report click the **View** button and a sample report is shown **(**Figure 119**)**, where the bars are shown as pairs where the day population under 65 is shown on the left (and is usually the greater value) and 65 and over is shown on the right.. The Combined Reports are only available if a combined earthquake and tsunami scenario has been completed. (See Chapter 11 for more information.)

Figure 118: Summary Reports Menu

Figure 119: Summary Reports Output Example



9.0 Advanced Hazus Analysis: User Defined Inventory Data

The Hazus default data inventory provides datasets that can be used for immediate assessment, but in certain areas (particularly for tsunamis) there may be the need to use a custom data set that is more relevant to the study region being analyzed. User Defined Facilities (UDF), accessible via the option **Inventory | User-defined Facilities**, enables user specific datasets to be analyzed through the Hazus methodologies providing more accurate results.

Within Hazus, the UDF table is empty and it is the responsibility of the user to populate the table with data specific to the area being analyzed using the Hazus Comprehensive Data Management System (CDMS). The assumption is that the user will obtain custom data from another source, such as parcel data, organize it into the format seen in **Table 3,** and add it to the UDF tables (hzUserDefinedFlty, eqUserDefinedFlty, and flUserDefinedFlty) in the State Database in Hazus, using the enhanced CDMS UDF interface. The design of Tsunami UDF utilizes attributes that are already part of the earthquake- and flood-specific UDF tables. Fields in italics in **Table 3** are required for the Tsunami Loss Analysis.

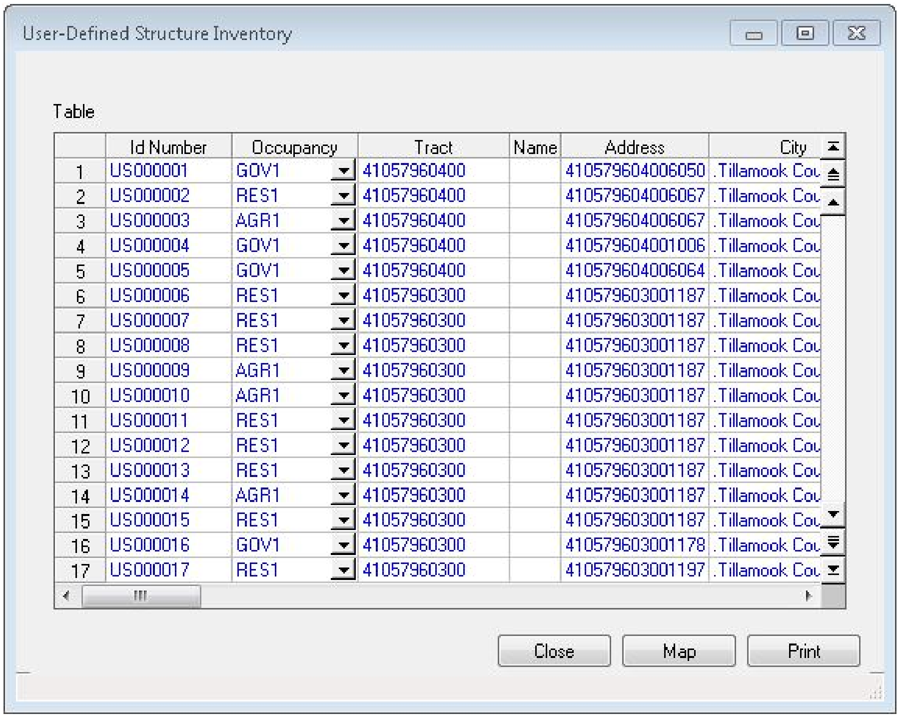
Table 3: UDF Database Tables

hzUserDefinedFlty	eqUserDefinedFlty	flUserDefinedFlty
[UserDefinedFltyId]	*[eqBldgType]*	*[FirstFloorHt]*
[Occupancy]	*[DesignLevel]*	[foundationtype]
[Tract]	[eqUdsClass]	
[Name]		
[Address]		
[City]		
[Statea]		
[Zipcode]		
[Contact]		
[PhoneNumber]		

hzUserDefinedFlty	eqUserDefinedFlty	flUserDefinedFlty
[YearBuilt]		
[Cost]		
[BackupPower]		
[NumStories]		
[Area]		
[ContentCost]		
[ShelterCapacity]		
[Latitude]		
[Longitude]		
[Comment]		
[Shape]		

On aggregation, the data will be added to a new tsunami UDF table (tsUserDefinedFlty) as seen in **Figure 120**.

Figure 120: User Defined Facility Inventory



The intent is to begin to prioritize facilities requiring further study, as well as to prioritize mitigation strategies for the impacted communities. It would be potentially misleading to estimate damage and losses of these structures without a detailed engineering analysis performed with the agreement of the facility owner. The general approach is to call attention to these facilities, include their locations in the inventory, and indicate a potential for loss in the final report.

9.1 UDF Required Attributes

The minimum attributes required for analysis of UDF are presented in **Table 4**. If any of the attributes are not imported (i.e., mapped), then Hazus will populate with default values using the CDMS tool. While it is possible to edit those values later through the Hazus interface, it is not practical to edit for larger datasets; therefore, it is more time-efficient to have the correct values in the imported file.

Table 4: UDF Required Attributes

Attribute	Description	Why is it needed?
Record Identifier (ID)	A unique identifier for each record. Hazus will create its own primary key (it does not prompt the user for one since there is no guarantee it is unique). Map this identifier to any column that is not used: COMMENT is a good candidate.	Hazus will output all results keyed by the ID it generates on import. If a join to the original data is needed, this attribute will be the only way to link the results to the original data.

Attribute	Description	Why is it needed?
Occupancy	Occupancy type per the Hazus classification. Map it to OCCUPANCY	Analyses are based on the occupancy and/or building type
Building Type	Building type per the Hazus classification. Map it to BLDGTYPE	As above
Design Level	Seismic Design Level. Map to DesignLevel. CDMS default is PC.	To assess lateral strength of structure – for building damage
First floor height	Top of Finished Floor Relative to Adjacent Grade (ft). Map to FirstFloorHt. CDMS default is 1, which represents slab on grade.	To assess content damage
Building replacement cost	Cost ($) to replace the building in case of damage. Used by economic loss model. Map it to COST. CDMS will estimate based on RS Means table.	To assess building economic loss
Content replacement cost	As above (in Building replacement cost) relating to building content. Map to Content Cost. CDMS will estimate based on % of building replacement.	To assess content economic loss
Location	The location of the structure/facility can be supplied as latitude/longitude (in that case, Hazus will create the geospatial points), or directly when the table imported is a feature class.	Hazus needs location of structure to calculate the hazard. Hazus uses the location at import time to filter the points that do not fall within the study region (i.e., discarding any point that falls outside the study region).

9.2 UDF Inventory

User Defined Inventory can require significant dedicated work to prepare. The extent of preparation and data compilation work involved depends on the condition and completeness of existing information, required data conversions, and the contributions of subject expertise. The greatest impact from enhanced inputs are produced both by editing the basic inventory and updating the model parameters. Strategic planning is required to estimate and execute the level of effort required to produce the useful analysis outputs.

The most detailed type of analysis incorporates the results from completed loss studies. For example, it is possible to include the output of loss estimates performed using locally developed assessments. Reviews and updates to the vulnerability ratings for each model building type will also produce more accurate analysis results.

It is advisable to run a baseline analysis for comparison with results after introduction of user-supplied data. Sensitivity of the loss estimation methodology under local conditions is measured best by review of outputs after inclusion of each enhanced inventory. Good record-keeping and inventory of documentation are essential.

Issues that can occur are that data collected will have to be adjusted so that the inventory is classified according to the systems defined in the methodology, including replacement values, locations as points rather than polygons. In addition, a school may have two building wing additions that were constructed over the forty-year lifetime of the structure. Each era of construction used improved materials, but the best materials were used to construct the smallest addition. The individual responsible for assigning the building type of the school according to the Hazus methodology will need to define and document the criteria applied to classify the structure. The easiest approach is to break the facility into different entries, i.e., two separate records. Refer to the *Hazus Tsunami Model Technical Guidance* document for more information.

10.0 Advanced Hazus Analysis: User Defined Hazard Data

10.1 User Defined Tsunami Grids

Since Hazus Tsunami utilizes authoritative hazard datasets from external providers rather than creating hazard data, sample data from NOAA Pacific Marine Environmental Laboratory (PMEL) are provided so that users can review and understand input requirements for all three levels of analysis.

Sample data **(Table 5)** are prepared for each level of analysis based on data provided for five of the PMEL forecast inundation model communities: http://nctr.pmel.noaa.gov/sim.html.

Table 5: NOAA PMEL Sample Data

Community	County	Scenario	Level 1	Level 2	Level 3
Homer, AK	Kenai	M 9.2 1964 Alaska	hom_dem_ft hom_maxR_ft	hom_maxdg_ft hom_maxv_ftsec	hom_dg_ft_median hom_flux_ft3sec2_median
Crescent City, CA	Del Norte	M 9.0 Cascadia	crc_dem_ft crc_maxR_ft	crc_maxdg_ft crc_maxv_ftsec	crc_dg_ft_median crc_flux_ft3sec2_median
Kahului, HI	Maui	M 9.0 Cascadia	kah_dem_ft kah_maxR_ft	kah_maxdg_ft kah_maxv_ftsec	kah_dg_ft_median kah_flux_ft3sec2_median
Garibaldi, OR	Tilla-mook	M 9.0 Cascadia	gar_dem_ft gar_maxR_ft	gar_maxdg_ft gar_maxv_ftsec	gar_dg_ft_median gar_flux_ft3sec2_median
Westport, WA	Grays Harbor	M 9.0 Cascadia	wes_dem_ft wes_maxR_ft	wes_maxdg_ft wes_maxv_ftsec	wes_dg_ft_median wes_flux_ft3sec2_median

In the table above:

- Level 1: DEMs include post-earthquake ground deformation (feet) for near-source scenarios; Max runup (maxR, feet) relative to Mean Sea Level (MSL)
- Level 2: Depth grids are maximum depths (maxdg) in feet above ground level; maximum velocity (maxv) in feet/sec.
- Level 3: Depth grids are median depths in feet above ground level; momentum flux is median values in $ft^3 sec^2$.

The hazard data (runup and velocity) were developed using NOAA's SIFT (Short-term Inundation Forecasting for Tsunamis) system: http://nctr.pmel.noaa.gov/tsunami-forecast.html.

For additional information, including access to SIFT products see: http://nctr.pmel.noaa.gov.

In addition, each State and Territory supported by the tsunami model has also developed or are actively working on the development of tsunami hazard data. Many of these datasets are available online or can be obtained through state contacts. A summary of some of the state efforts is available at: http://nctr.pmel.noaa.gov/hazard_assessment.html. Note that each state provides hazard data in different GIS formats and units. Although the Hazus GUI helps provide the ability to convert units, the input needs to be in either ArcGRID or NetCDF NOAA SIFT output format.

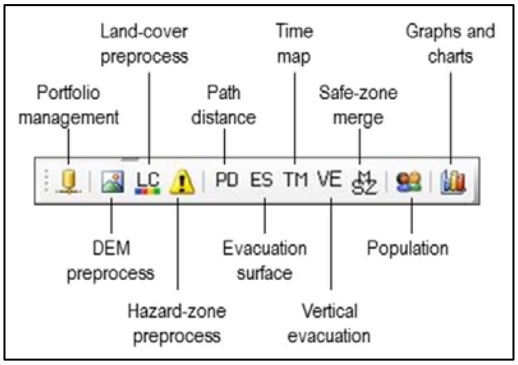
The National Tsunami Hazard Mitigation Program (NTHMP) provides a comprehensive list of state agency partners: http://nws.weather.gov/nthmp/statesandterritories.html as well as official NTHMP Coordinating Members: http://nws.weather.gov/nthmp/documents/OfficialDesignees.pdf.

10.2 User Defined Casualty Data

The Level 2 Casualty Analysis leverages the output from the USGS Pedestrian Evacuation Analyst (PED) ArcGIS tool **(Figure 121)**, which assesses evacuation times to high ground.

The tool can be found at: http://geography.wr.usgs.gov/science/vulnerability/tools.html.

Figure 121: USGS Pedestrian Evacuation Analyst ArcGIS tool



Input data required for the Hazus Level 2 Casualty Analysis include:

- Travel Time to Safe Zone (depth = 0)
- Travel Time to Partially Safe Zone (depth < 2 meters)

10.3 Advanced: Post-Earthquake DEM

In the case of a tsunami analysis involving a Near Source earthquake, it is recommended that the DEM used in the scenario be based on deformed (post-earthquake) topography. This will allow for more accurate inundation modeling by factoring in any ground deformation caused by the earthquake. Also if the ground surface elevations relative to sea-level have decreased, the inundation and losses could be more extensive. See the *Tsunami Model Technical Guidance* document for more information.

11.0 Advanced Hazus Analysis: Combined Earthquake and Tsunami Scenario with Level 2 Casualty Analysis

In order to run a combined earthquake and tsunami analysis, the user needs to build a multi-hazard (earthquake and tsunami) study region that includes a shoreline (i.e., must be a coastal region) following the workflow outlined in **Table 6**.

Table 6: Combined Earthquake and Tsunami Scenario - User Workflow

Build Multi-Hazard Study Region: Earthquake Model	Build Multi-Hazard Study Region Tsunami Model
• Define/Select Earthquake Scenario (using same scenario source that creates the Tsunami hazard) • Run Analysis • Display Earthquake-Only Losses	• Select Tsunami Scenario • Define Tsunami Type as Near Source • Define Scenario – Level 2 or 3 • Run Tsunami Analysis • Define Casualty Level 2 • Display Combined Earthquake and Tsunami Losses

11.1 Analysis

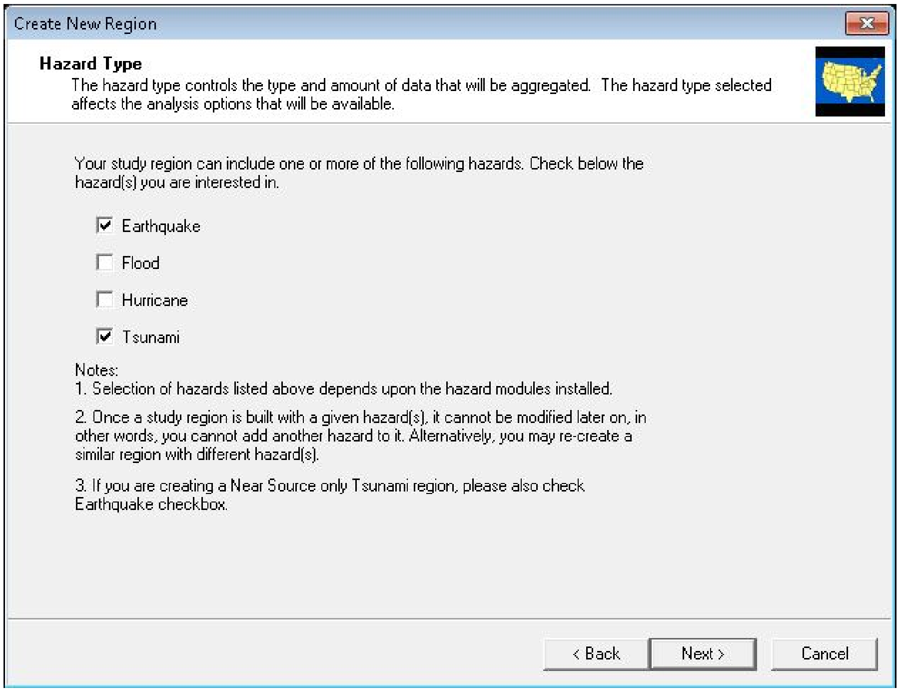
The combined earthquake and tsunami scenarios are available for Near Source tsunami hazards, where the earthquake ground shaking impacts the study region. For the following regions:

- Alaska
- Oregon
- Washington
- California
- Hawaii
- Puerto Rico

Sample data for all levels of analysis have been provided for a selected community for each of the five U.S. states: http://nctr.pmel.noaa.gov/sim.html. See chapter 10 for more information. The following example uses the data for Garibaldi, Oregon (in Tillamook County) for a Level 2 Analysis based on a Magnitude 9.0 Cascadia Subduction Zone earthquake.

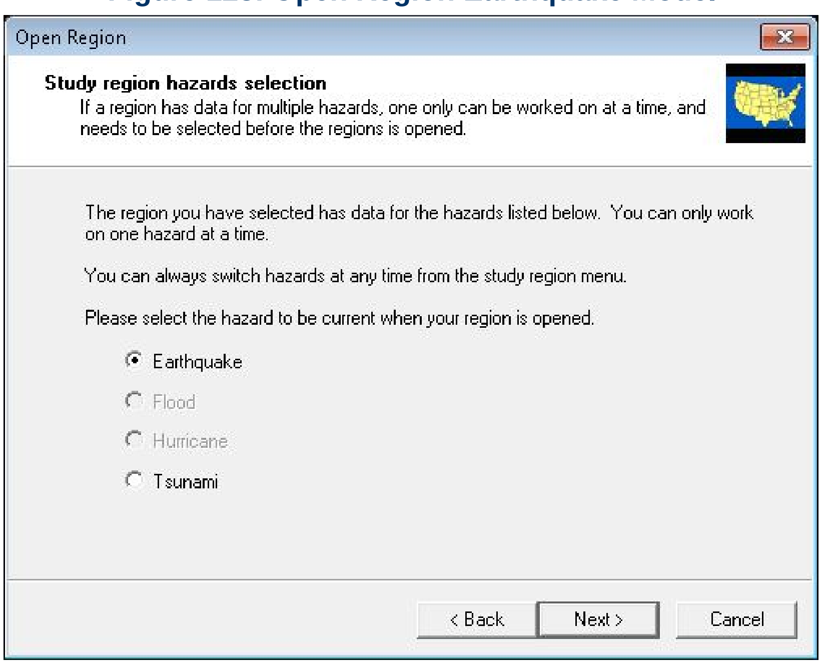
To run a combined analysis, the study region must be created for both earthquake and tsunami hazard analysis. Start with Create a New Region Wizard (**Figure 122**). Select both Earthquake and Tsunami and click **Next**.

Figure 122: Create New Region Multi-hazard



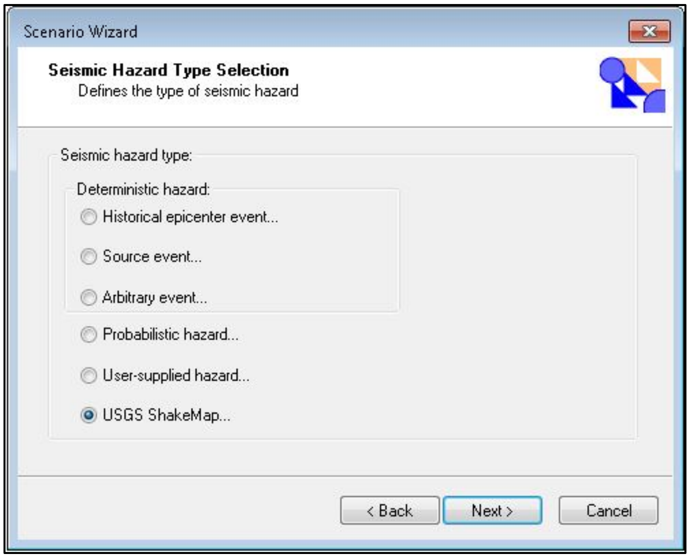
Specify the study region for Tillamook, Oregon, and finish the Create New Region wizard. Open a region and select the new multi-hazard region (created above). When prompted, select the Earthquake Model to run first as shown in **Figure 123**.

Figure 123: Open Region Earthquake Model



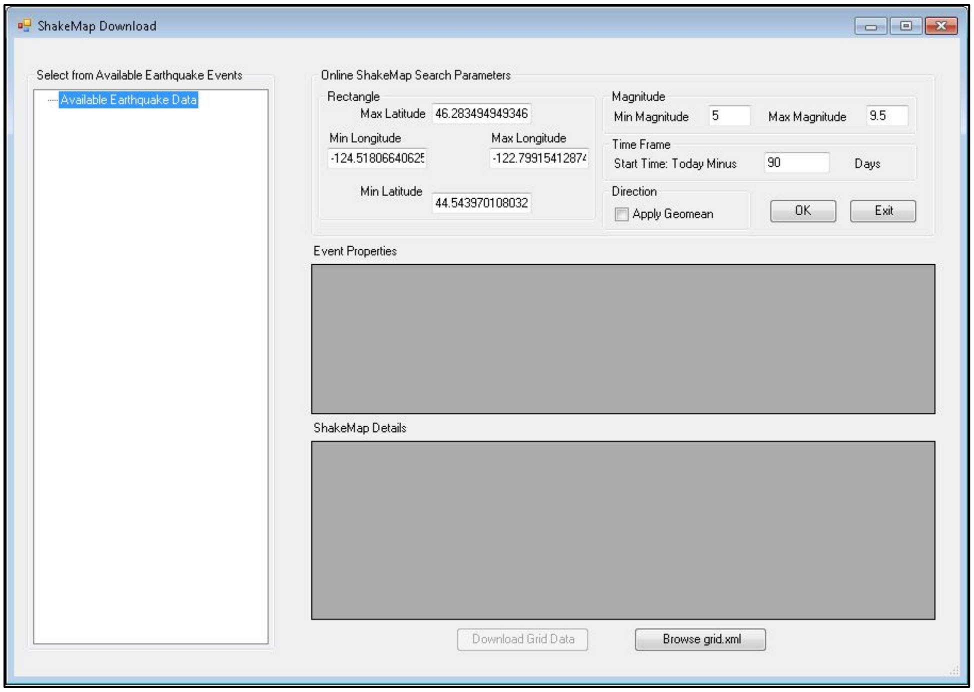
In the Seismic Hazard Type menu, choose to run a scenario using USGS ShakeMap as the Seismic Hazard Type (**Figure 124**).

Figure 124: Scenario Wizard – Seismic Hazard Type Selection



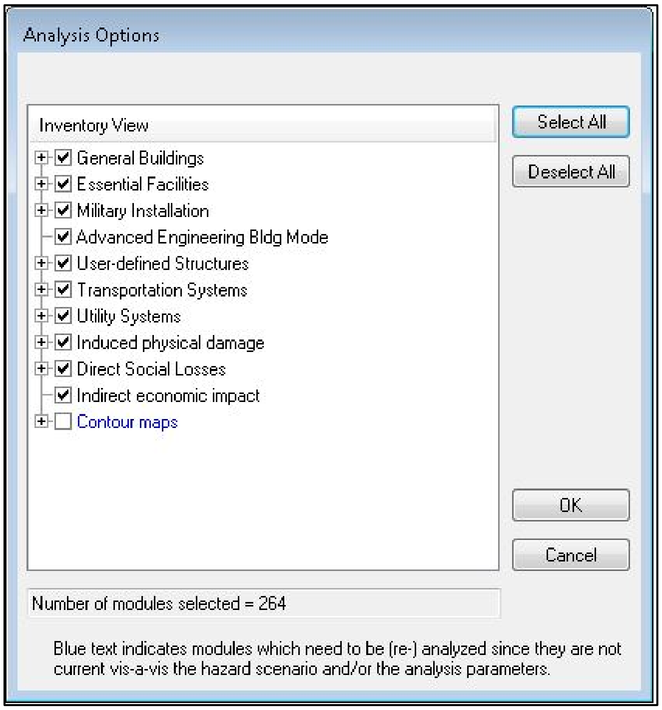
Use the ShakeMap Download window **(Figure 125)** to search for available USGS ShakeMaps or use the **Browse grid.xml** button to search for previously downloaded ShakeMap. (See *Hazus Earthquake Model User Guidance* for instructions on downloading USGS ShakeMaps.)

Figure 125: ShakeMap Download



Complete the scenario setup and run the Analysis **(Figure 126)**.

Figure 126: Run Earthquake Analysis



When the run is complete, choose **Switch Hazard** under File on the Toolbar. Select Tsunami (**Figure 127**) to switch to the Tsunami Model.

Figure 127: Select Hazard Model

In the Hazus Tsunami Model, select Tsunami Hazard Type **(Figure 128)** from the Hazard menu. Choose Near Source only **(Figure 129)**. Click **OK**.

Figure 128: Hazard Menu

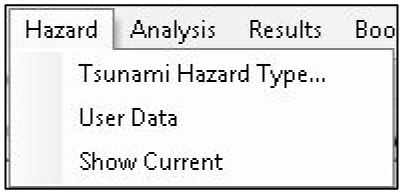
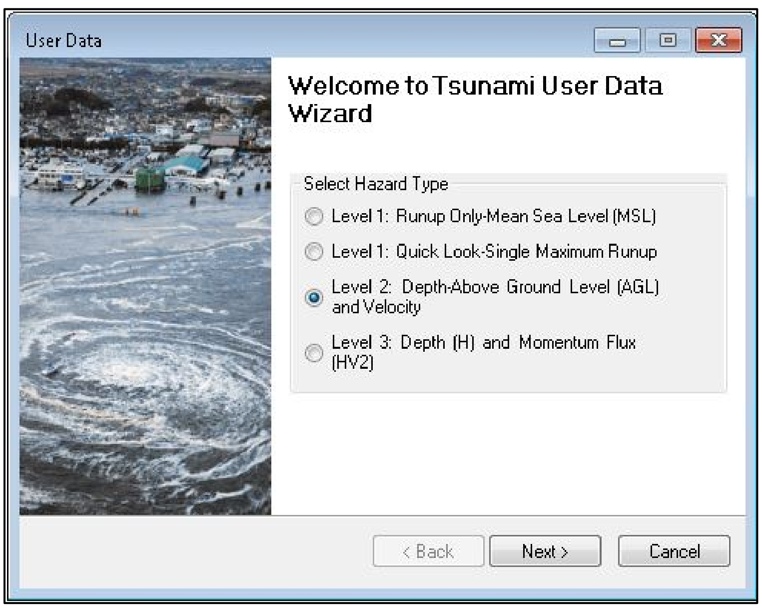


Figure 129: Tsunami Hazard Type

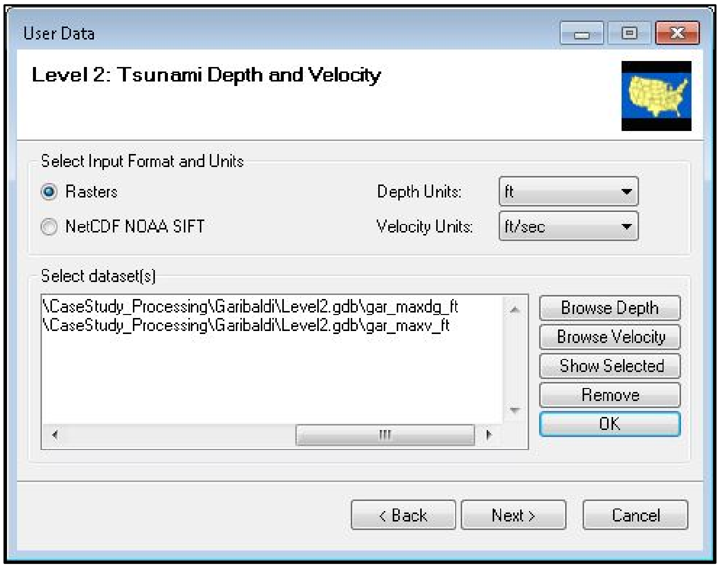
From the Hazard menu, select User Data. Then, choose Level 2: Depth-Above Ground Level (AGL) and Velocity **(Figure 130)**.

Figure 130: User Data Menu



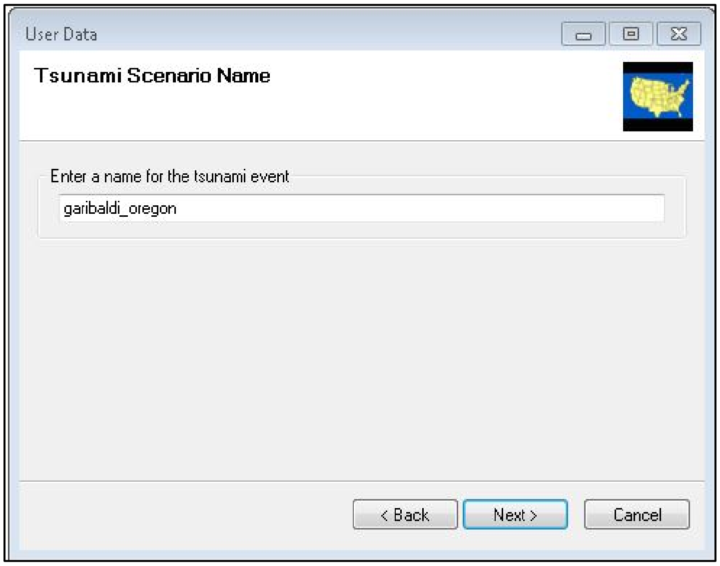
As seen in **Figure 131**, under Select Input Format, choose Rasters and set the units to depth = ft and velocity = ft/sec. Use the **Browse Depth** and **Browse Velocity** buttons to load the sample data for Garibaldi, Oregon. Click **OK** to load the data into the analysis. Then click **Next**.

Figure 131: Level 2: Tsunami Depth and Velocity



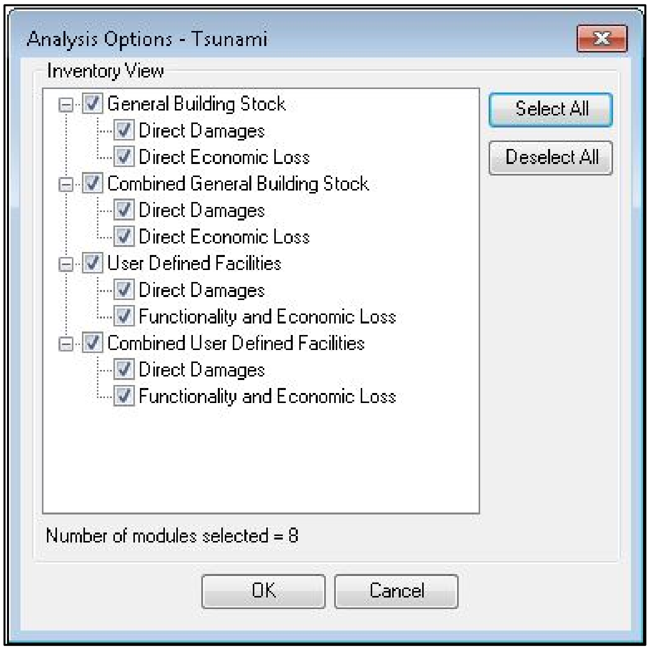
Enter the scenario name and click **Next (Figure 132)**. Click **OK** to continue.

Figure 132: Tsunami Scenario Name



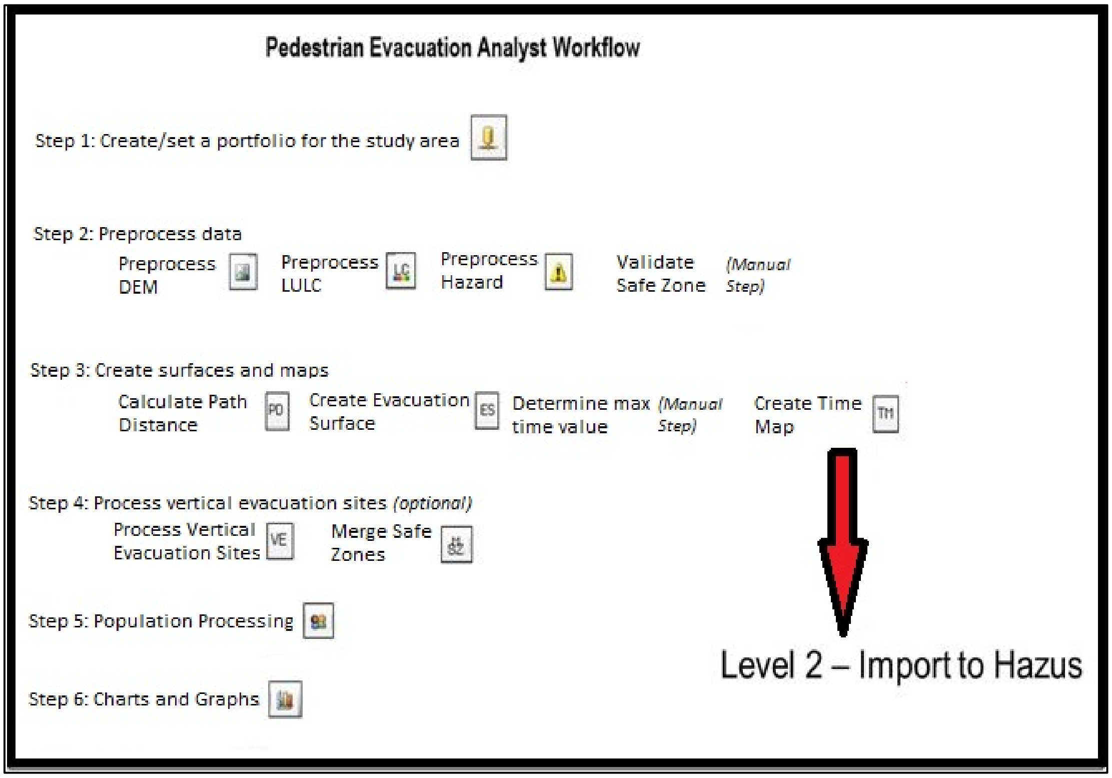
In the Analysis menu, choose **Run**. In the Analysis Option–Tsunami window (**Figure 133**), click Select All. Note that the study region for Tillamook, Oregon, has a user defined facility (UDF) database included in Hazus.

Figure 133: Analysis Option - Tsunami



The next step requires output data from the USGS Pedestrian Evacuation Model. The USGS model includes the capability for more detailed analysis using land-use layers, and safe-zone validation, as well as the ability to incorporate vertical evacuation. The Level 2 Hazus input is the Travel Time Map output to Safety and Partial Safety of the USGS model as shown in **Figure 134**.

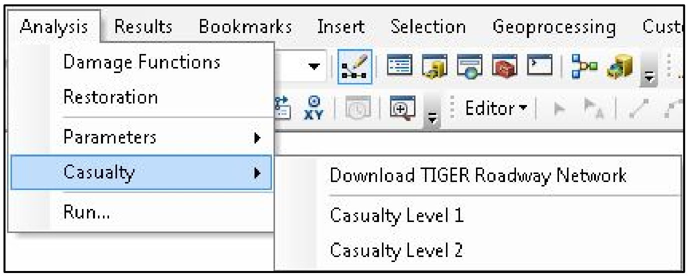
Figure 134: Pedestrian Evacuation Analyst Workflow Example



11.2 Casualty – Level 2 Analysis

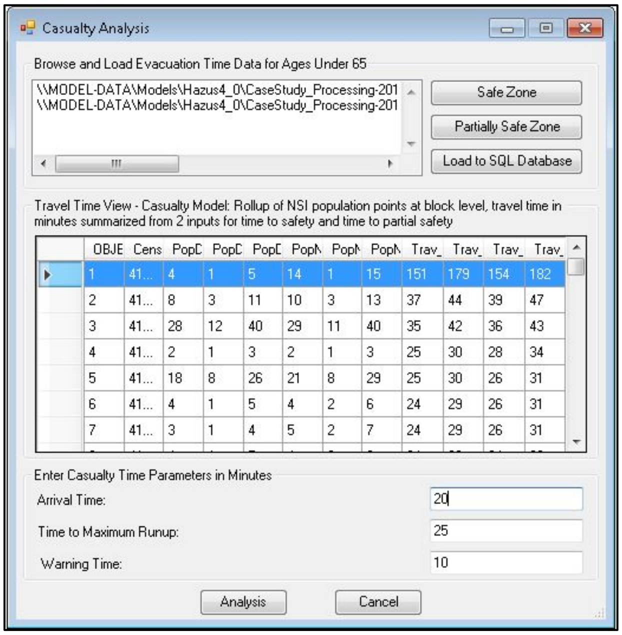
In the Analysis menu, in the Casualty submenu choose Casualty Level 2.

Figure 135: Casualty Menu



In the Casualty Analysis window **(Figure 136)**, load the Safe Zone data and the Partially Safe Zone data from the USGS Pedestrian Evacuation Analyst Tool. Click on **Load to SQL Database** to add to Hazus. Enter an Arrival Time of 20 minutes. The rest will fill in with default values of a Time to Maximum Runup of 25 minutes and a Warning Time of 10 minutes. Click on Analysis.

Figure 136: Casualty Analysis – Level 2



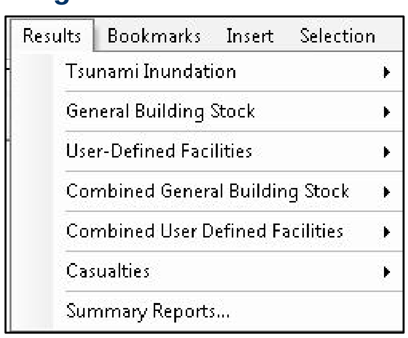
The output will be available to view as tables, map layers, and reports. The next section will focus on the combined reports (earthquake and tsunami). See Chapter 8 for additional information regarding the result reporting options.

11.3 Reports

Tsunami losses that occur with near-source earthquakes occur typically in narrow coastal zones. In Hazus, the smaller Tsunami region losses are incorporated into the larger Earthquake study region losses. The results of a combined earthquake and tsunami analysis can be viewed only in the Tsunami Model.

The output can be viewed in the form of results tables, maps, and reports. The tables and map layers are accessible from the Results menu **(Figure 137)** on the toolbar for Combined GBS, Combined User Defined Facilities, and Casualties. See Chapter 8 for additional information.

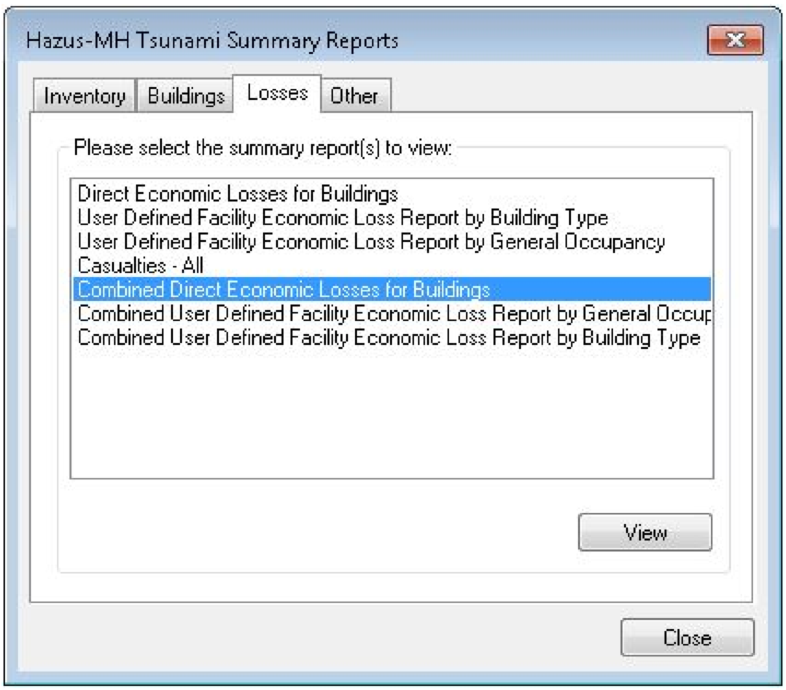
Figure 137: Results Menu



This section will review the reports, which are located under Summary Reports (**Figure 138**) on the Results menu. The Combined Analysis reports are available under the following tabs in the Summary Report window:

- Losses
  - Combined Direct Economic Losses for Building
  - Combined User Defined Facility Economic Loss Report by General Occupancy
  - Combined User Defined Facility Economic Loss Report by Building Type
- Other
  - Combined Earthquake and Tsunami Global Risk Report

Figure 138: Summary Reports



11.3.1 Combined Direct Economic Losses for Buildings

The Combined Direct Economic Losses for Buildings displays the combined losses (in thousands of dollars US) for:

- Capital Stock Losses
  - Structural Damage
  - Non-structural Damage
  - Contents Damage
  - Inventory Loss
- Income Losses

- Relocation Losses
- Capital Related Losses
- Wage Losses
- Rental Income Loss

- Total Loss

Figure 139: Combined Direct Economic Losses for Buildings

HAZUS MH
EARTHQUAKE • WIND • FLOOD

FEMA

RiskMAP
Increasing Resilience Together

Combined Direct Economic Losses for Buildings

May 19, 2017

All values are in thousands of dollars

	Capital Stock Losses					Income Losses				
	Cost Structural Damage	Cost Non-struct. Damage	Cost Contents Damage	Inventory Loss	Loss Ratio %	Relocation Loss	Capital Related	Wages Losses	Rental Income Loss	Total Loss
Oregon										
Tillamook	211,242	782,996	506,108	5,882	27.65	126,768	60,463	105,972	55,332	1,854,763
Total	**211,242**	**782,996**	**506,108**	**5,882**		**126,768**	**60,463**	**105,972**	**55,332**	**1,854,763**
Region Total	**211,242**	**782,996**	**506,108**	**5,882**	**27.65**	**126,768**	**60,463**	**105,972**	**55,332**	**1,854,763**

Totals only reflect data for those census tracts/blocks included in the user's study region and will reflect the entire county/state only if all of the census blocks for that county/states were selected at the time of study region creation.

Study Region : oregon
Scenario : garibaldi_tsn_comb

Page : 1 of 1

Tsunami Hazard Report

11.3.2 Combined User-Defined Facility Economic Loss Report by General Occupancy

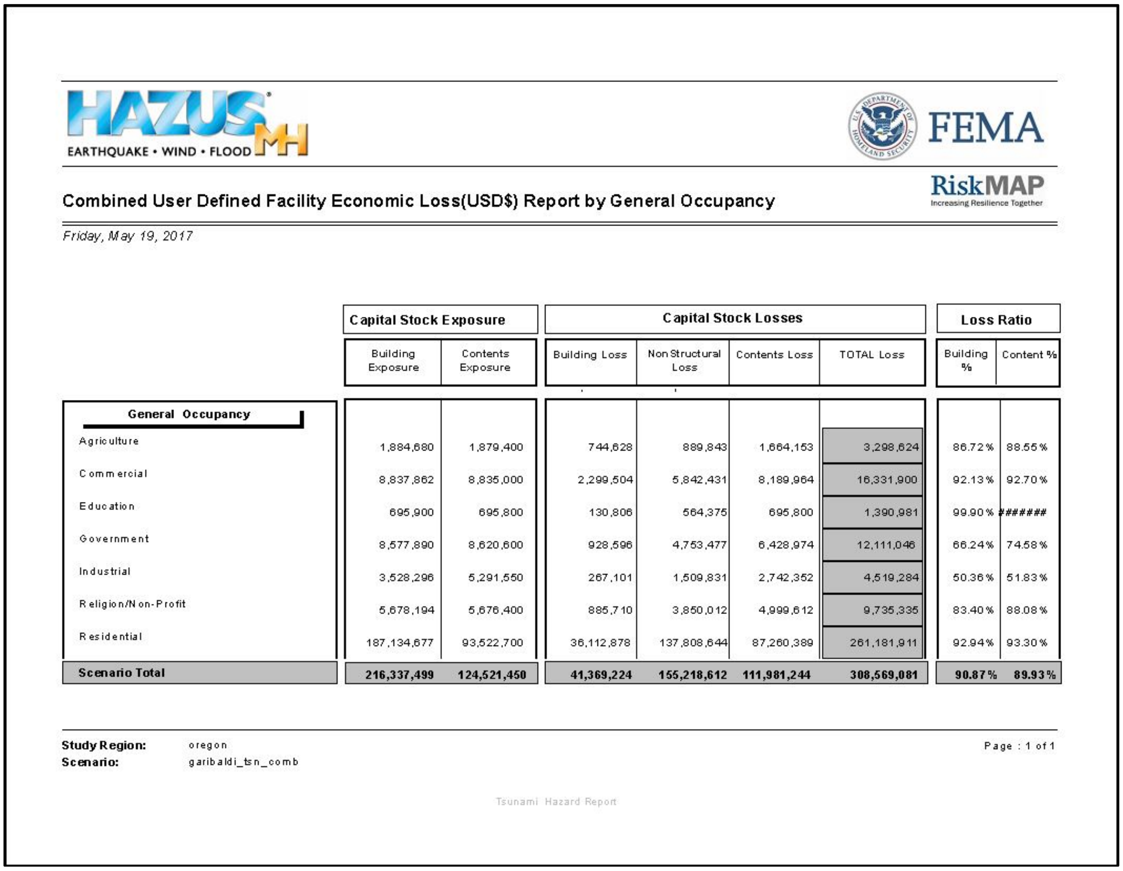
The Combined User-Defined Facility Economic Loss Report by General Occupancy (**Figure 140**) displays the combined exposure and losses by general occupancy for:

- Capital Stock Exposure
  - Building Exposure
  - Content Exposure
- Capital Stock Losses
  - Building Loss
  - Non-Structural Loss

- Content Loss
- Total Loss

- Loss Ratio
  - Building %
  - Content %

Figure 140: Combined User-Defined Economic Loss Report by General Occupancy



Combined User Defined Facility Economic Loss(USD$) Report by General Occupancy

Friday, May 19, 2017

General Occupancy	Capital Stock Exposure		Capital Stock Losses				Loss Ratio	
	Building Exposure	Contents Exposure	Building Loss	Non Structural Loss	Contents Loss	TOTAL Loss	Building %	Content %
Agriculture	1,884,680	1,879,400	744,628	889,843	1,664,153	3,298,624	86.72%	88.55%
Commercial	8,837,862	8,835,000	2,299,504	5,842,431	8,189,964	16,331,900	92.13%	92.70%
Education	695,900	695,800	130,806	564,375	695,800	1,390,981	99.90%	#######
Government	8,577,890	8,620,600	928,596	4,753,477	6,428,974	12,111,046	66.24%	74.58%
Industrial	3,528,296	5,291,550	267,101	1,509,831	2,742,352	4,519,284	50.36%	51.83%
Religion/Non-Profit	5,678,194	5,676,400	885,710	3,850,012	4,999,612	9,735,335	83.40%	88.08%
Residential	187,134,677	93,522,700	36,112,878	137,808,644	87,260,389	261,181,911	92.94%	93.30%
Scenario Total	**216,337,499**	**124,521,450**	**41,369,224**	**155,218,612**	**111,981,244**	**308,569,081**	**90.87%**	**89.93%**

Study Region: oregon
Scenario: garibaldi_tsn_comb

Page : 1 of 1

Tsunami Hazard Report

11.3.3 Combined Earthquake and Tsunami Global Report

The Combined Global Report (**Figure 141**) provides a 25-page report with text, tables, and graphics displaying earthquake and tsunami losses for the scenario. The sections unique to earthquake or tsunami are labeled to show that the losses refer to the specific hazard only:

Combined earthquake and tsunami losses include:

- Combined Building Damage
- Combined Building Losses

Earthquake specific losses include:

- Earthquake Scenario Parameters
- Essential Facilities Damage from Earthquake
- Transportation and Utility Lifeline Damage from Earthquake
- Debris Generation from Earthquake
- Shelter Requirements from Earthquake
- Casualties from Earthquake
- Transportation and Utility Lifeline Losses from Earthquake

Tsunami specific losses include:

- Tsunami Scenario Parameters
- Tsunami Evacuation (Travel Time)
- Casualties from Tsunami

Figure 141: Combined Global Report

Combined Building Damage

Combined Earthquake and Tsunami Building Damage

Hazus estimates that about 26,961 buildings will be at least moderately damaged. This is over 80.00 % of the buildings in the region. There are an estimated 9,467 buildings that will be damaged beyond repair. The definition of the 'damage states' is provided in Volume 1: Chapter 5 of the Hazus technical manual. Table 3 below summarizes the expected damage by general building type.

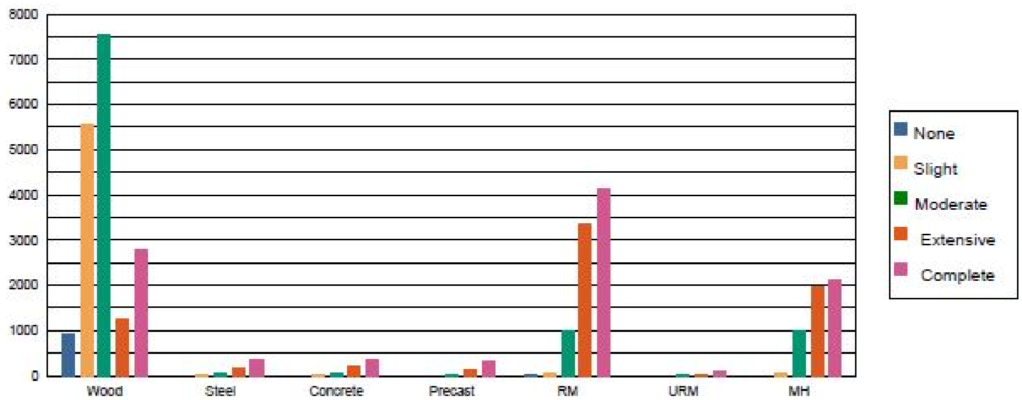


Table 3: Expected Building Damage by Building Type (All Design Levels)

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Wood	929	97.54	5563	97.23	7,551	77.73	1,258	17.74	2,787	27.44
Steel	0	0.05	3	0.05	40	0.41	162	2.29	375	3.70
Concrete	1	0.06	5	0.09	69	0.71	205	2.89	373	3.68
Precast	0	0.02	2	0.03	31	0.32	135	1.90	306	3.01
RM	20	2.07	77	1.35	1,001	10.30	3,329	46.95	4,119	40.56
URM	0	0.00	1	0.01	11	0.11	37	0.53	93	0.92
MH	3	0.26	70	1.23	1,012	10.42	1,965	27.71	2,103	20.70
Total	952		5,721		9,714		7,091		10,156	

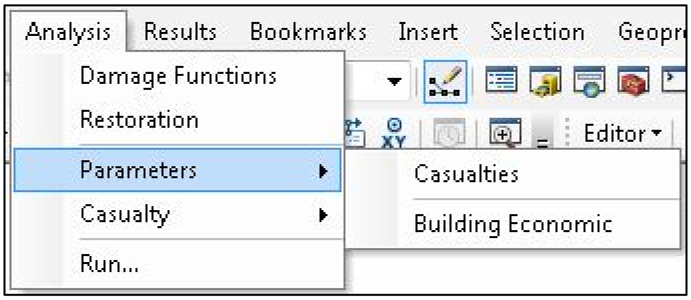
*Note:
RM Reinforced Masonry
URM Unreinforced Masonry
MH Manufactured Housing

Combined Earthquake and Tsunami Global Risk Report — Page 9 of 26

12.0 Advanced Hazus Analysis: Modifying Analysis Factors

As previously discussed, the Analysis | Parameters menu (**Figure 142**) allows the user to define casualty and building economic loss parameters.

Figure 142: Analysis Parameters Menu



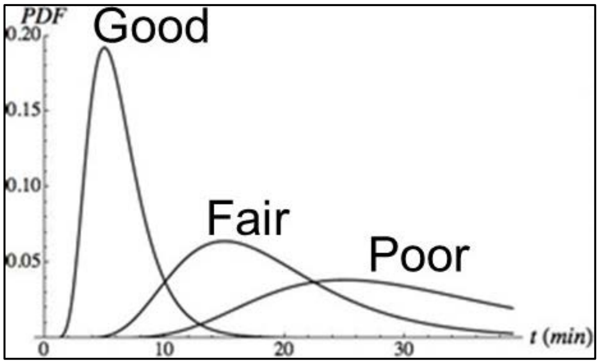
12.1 Casualty Parameters

The Casualties window allows the user to view and edit the parameters that effect the casualty analysis. These include:

- Community Preparedness Level
- Walking Speed
- Walking Speed Reduction

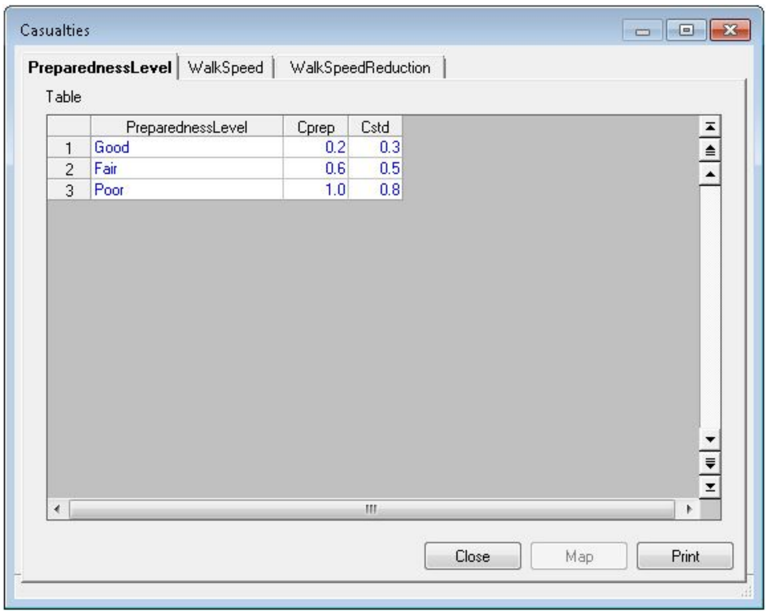
The Community Preparedness Level parameters (**Figure 143**) are based on FEMA's methodology, concerning the time required between the warning and the evacuation of the community. The classifications of Good, Fair, or Poor are based on tsunami hazard preparedness level. This can be determined based, for example, on the condition of shore-protection structures, emergency loud speakers, preparation of evacuation routes and signs, a community's risk management level, and/or the education level for tsunami awareness. A community rated "good," for example, could be one that is designated "Tsunami Ready" by the National Weather Service (http://www.tsunamiready.noaa.gov/). See the *Tsunami Model Technical Guidance* for more information.

Figure 143: Community preparation times following warning based on Community Preparedness Levels



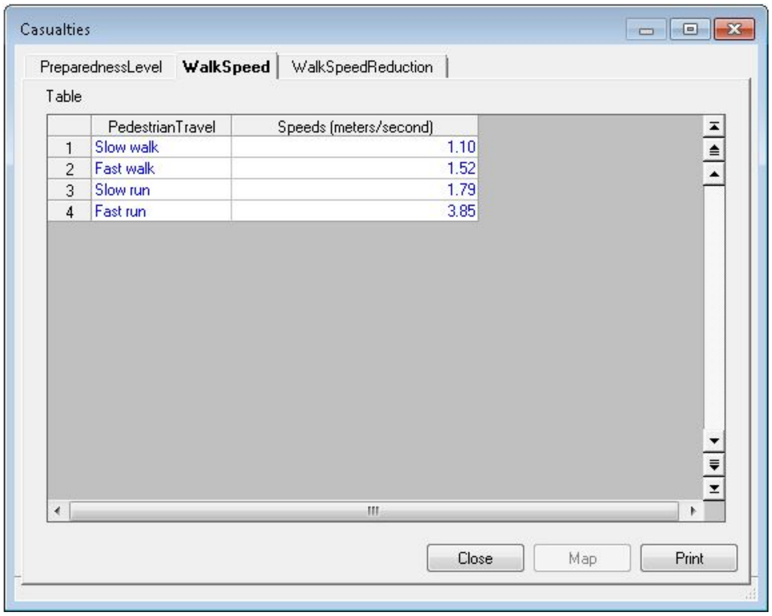
In **Figure 144**, C_{prep} refers to the amount of preparation time needed after the initial warning is given (including the natural cue = ground shaking). The Community Preparedness Level (Good, Fair, or Poor) grading defaults are 0.2, 0.6 and 1.0 respectively. C_{prep} is used as a multiplier to the time available (e.g., travel time – warning time) and represents the median where half the community has begun evacuating and half have not. Using 0.2 for a well-prepared community implies that the community median will need 1/5th the time available to react to the warning compared with a community with Poor grading. The model also considers Community Preparedness Level standard deviation values with defaults of 0.3, 0.5 and 0.8 representing the shape of the curves shown in **Figure 145**.

Figure 144: Casualty Preparedness Level Parameters



The average Walking Speeds are based on the USGS Pedestrian Evacuation Analyst Tool for populations under 65 **(Figure 145)**.

Figure 145: Casualty Walking Speed Parameters



A Walking Speed Reduction parameter is included to account for the difference in evacuation walking speed for population over 65 years old **(Figure 146)**. These can be used to reduce walking speeds for either category to represent local or post-earthquake conditions.

Figure 146: Walking Speed Reduction Parameters

12.2 Building Economic Parameters

Economic losses are based on a summation of the damage state probabilities and repair cost ratio. This methodology closely follows the earthquake methodology, except that the "Slight" category is not used for Tsunami. Estimates of damage to the built environment are converted to dollar loss in this model. Direct economic losses begin with the cost of repair and replacement of damaged or destroyed buildings. However, building damage will result in a number of consequential losses that, in Hazus, are defined as direct.

Losses that are directly derived from building damage:

- Cost of repair and replacement of damaged and destroyed buildings
- Costs of damage to building contents
- Losses of building inventory (contents related to business activities)

Losses that are related to the length of time the facility is non-operational (or the immediate economic consequences of damage):

- Relocation expenses (for businesses and institutions)
- Capital-related income losses (a measure of the loss of productivity, services or sales)
- Wage losses (consistent with income loss)
- Rental income losses (to building owners)

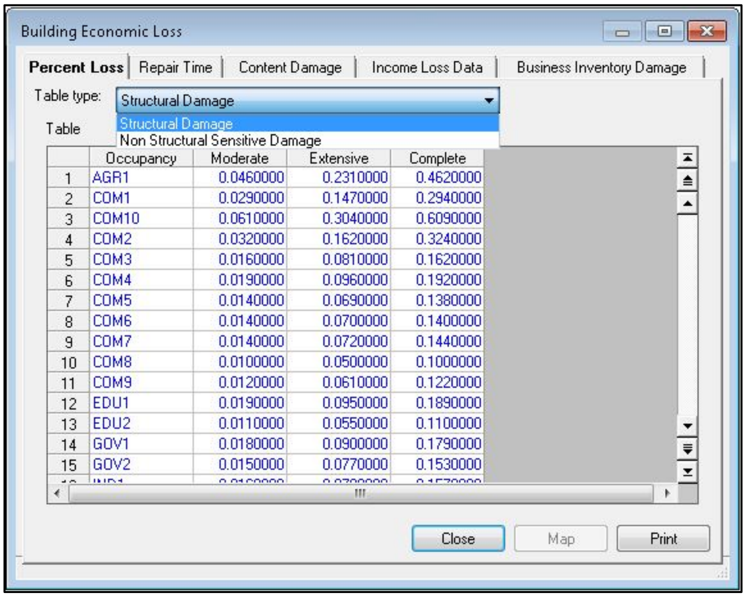
The default economic data can be viewed and modified from within the Building Economic Loss Parameters window.

12.2.1 Percent Loss

The replacement costs (damage state = complete) were derived from Means Square Foot Costs, for Residential, Commercial, Industrial, and Institutional Buildings. The Means publication is a nationally accepted reference on building construction costs, which is published annually. This publication provides cost information for a number of low-rise residential model buildings, and for 70 other residential, commercial, institutional and industrial buildings. These are presented in a format that shows typical costs for each model building, showing variations by size of building, type of building structure, and building enclosure. One of these variation is chosen as “typical” for this typical model, and a breakdown is provided that shows the cost and percentages of each building system or component. A description of how to estimate costs from the Means publication is found in the *Hazus Tsunami Model Technical Guidance*. Since Means is published annually, fluctuations in typical building cost can be tracked and the user can insert the most up-to-date Means typical building cost into the default database. This procedure is outlined in the *Tsunami Model Technical Guidance*.

In Hazus, selected Means models have been chosen from the 70 plus models that represent the 33 occupancy types. The wide range of costs shown, even for a single model, emphasize the importance of understanding that the dollar values shown should only be used to represent costs of large aggregations of building types. If costs for single buildings or small groups (such as a college campus) are desired for more detailed loss analysis, local building-specific cost estimates should be used. Since a building has both structural and non-structural repair costs, those are provided for each occupancy type by damage state (**Figure 147**).

Figure 147: Percent Loss Parameters



	Occupancy	Moderate	Extensive	Complete
1	AGR1	0.0460000	0.2310000	0.4620000
2	COM1	0.0290000	0.1470000	0.2940000
3	COM10	0.0610000	0.3040000	0.6090000
4	COM2	0.0320000	0.1620000	0.3240000
5	COM3	0.0160000	0.0810000	0.1620000
6	COM4	0.0190000	0.0960000	0.1920000
7	COM5	0.0140000	0.0690000	0.1380000
8	COM6	0.0140000	0.0700000	0.1400000
9	COM7	0.0140000	0.0720000	0.1440000
10	COM8	0.0100000	0.0500000	0.1000000
11	COM9	0.0120000	0.0610000	0.1220000
12	EDU1	0.0190000	0.0950000	0.1890000
13	EDU2	0.0110000	0.0550000	0.1100000
14	GOV1	0.0180000	0.0900000	0.1790000
15	GOV2	0.0150000	0.0770000	0.1530000

12.2.2 Repair Time

The time to repair a damaged building can be divided into two parts: construction and clean-up time, and time to obtain financing, permits and complete a design. For the lower damage states, the construction time will be close to the real repair time. At the higher damage levels, a number of additional tasks must be undertaken that typically will considerably increase that actual repair time. These tasks, which may vary considerably in scope and time between individual projects, include:

- Decision-making (related to businesses of institutional constraints, plans, financial status, etc.)
- Negotiation with FEMA (for public facilities), Small Business Administration, etc.
- Negotiation with insurance company, if insured
- Obtaining financing
- Contract negotiation with design firm(s)
- Detailed inspections and recommendations
- Preparation of contract documents
- Obtaining building and other permits
- Bidding/negotiating construction contract
- Start-up and occupancy activities after construction completion

Default building repair and clean-up times are provided within Hazus. These default values are broken into two parts: construction time and extended time. The construction time is the time to do the actual construction or repair. The extended time includes construction plus all of the additional delays described above. The discussion of these values is found in the *Hazus Tsunami Model Technical Guidance*. Default values can be viewed and modified using the window shown in **Figure 148**.

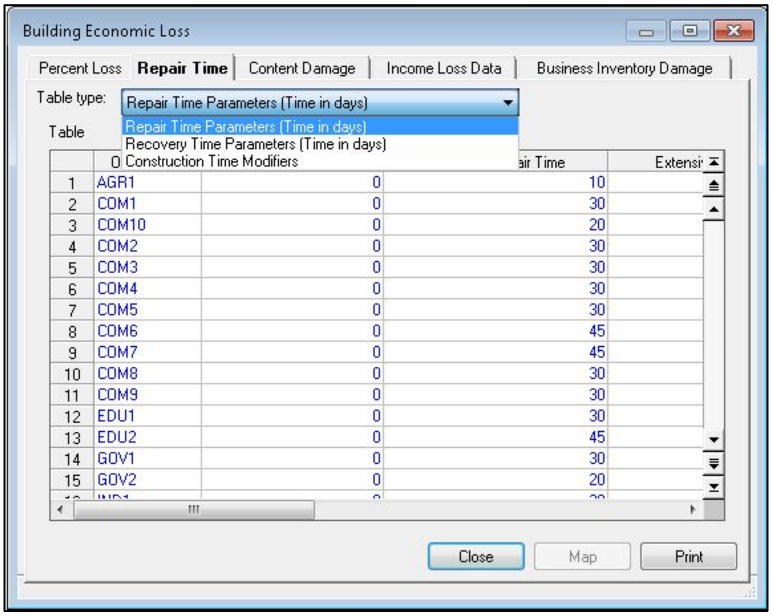
Repair times are presented as a function of both amount of damage and occupancy class. Clearly there can be a great deal of variability in repair times, but these represent estimates of the median times for actual cleanup and repair. This window is accessed from the Analysis Parameters – Building Economic menu. To modify these values, right click inside the menu and choose **Start Editing**. Enter new values and then right click and choose **Stop Editing**. A prompt will request that changes be confirmed.

Default values of the extended building cleanup and repair times that account for delays in decision-making, financing, inspection, etc. are viewed by clicking on the desired table. Default extended estimates also can be modified.

Application of the interruption multipliers to the extended building cleanup and repair times results in average values for business or service interruption. For low levels of damage the time loss is assumed to be short, with cleanup by staff, and work can resume while slight repairs are being done. For most commercial and industrial businesses that suffer moderate or extensive damage, the default business interruption time is short on the assumption that businesses will find alternate ways of continuing their activities. Churches will generally find temporary accommodation quickly, and government offices will also resume operating almost at once. It is assumed that hospitals and medical offices can continue operating, perhaps with temporary rearrangement and departmental relocation, after sustaining moderate damage. However, with extensive damage their loss of function time is assumed to be equal to the total time for repair. This applies to residential, entertainment, theater, parking, and religious facilities whose revenue or continued service is dependent on the existence and continued operation of the facility.

The median value of repair time applies to a large inventory of facilities. At moderate damage, some marginal businesses may close, while others will open after a day's cleanup. Even with extensive damage some businesses will accelerate repair, while a number of others will close or be demolished. For example, one might reasonably assume that an unreinforced masonry (URM) building that suffers moderate damage is more likely to be demolished than a newer building that suffers moderate or even extensive damage. If the URM building is a historic structure, its likelihood of survival and repair will probably increase. There will also be a small number of extreme cases: the slightly damaged building that becomes derelict, or the extensively damaged building that continues to function for years with temporary shoring, until an expensive repair is financed and executed.

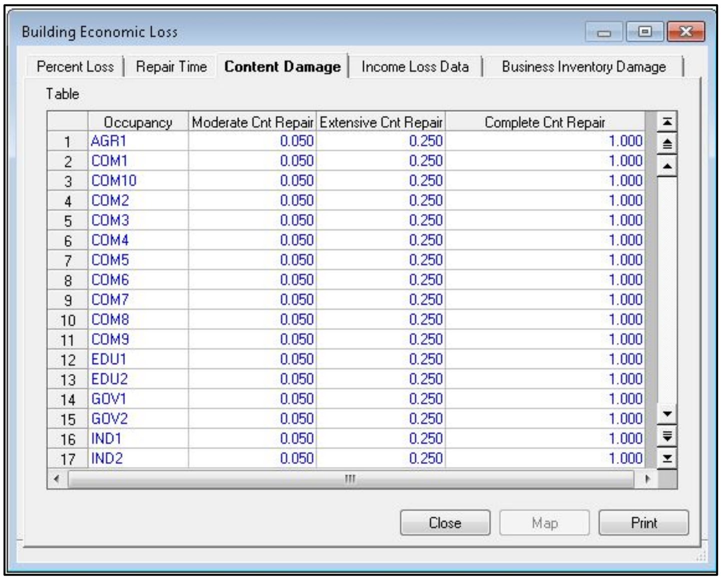
Figure 148: Repair Time Parameters



12.2.3 Building Contents

Building Contents are defined as furniture, equipment that is not integral with the structure, computers, and supplies. Contents (**Figure 149**) do not include inventory or non-structural components such as lighting, ceilings, or mechanical and electrical equipment and other fixtures. The damage to contents is expressed in terms of the percentage of damage to the contents based upon the depth of water at the building relative to the finished floor. The contents-damage percentages are based upon the assumption that for the complete damage state some percentage of contents, 50%, can be retrieved in the event of an earthquake. For tsunamis, as the saturated or washed away contents are less likely to be salvaged, it is assumed that 100% of the contents for complete damage states are lost. The default-contents-damage percentages are the same for all occupancies.

Figure 149: Content Damage Parameters



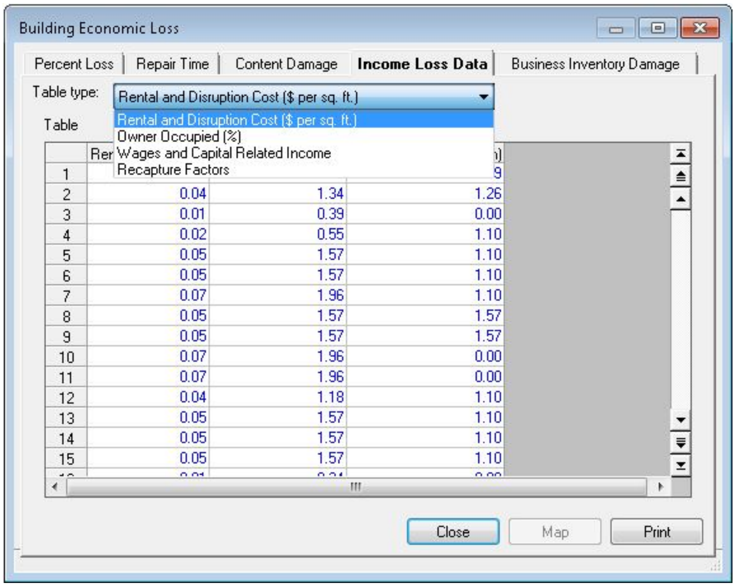
	Occupancy	Moderate Cnt Repair	Extensive Cnt Repair	Complete Cnt Repair
1	AGR1	0.050	0.250	1.000
2	COM1	0.050	0.250	1.000
3	COM10	0.050	0.250	1.000
4	COM2	0.050	0.250	1.000
5	COM3	0.050	0.250	1.000
6	COM4	0.050	0.250	1.000
7	COM5	0.050	0.250	1.000
8	COM6	0.050	0.250	1.000
9	COM7	0.050	0.250	1.000
10	COM8	0.050	0.250	1.000
11	COM9	0.050	0.250	1.000
12	EDU1	0.050	0.250	1.000
13	EDU2	0.050	0.250	1.000
14	GOV1	0.050	0.250	1.000
15	GOV2	0.050	0.250	1.000
16	IND1	0.050	0.250	1.000
17	IND2	0.050	0.250	1.000

12.2.4. Income Loss Data

Relocation costs may be incurred when the level of building damage is such that the building or portions of the building are unusable while repairs are being made. While relocation costs may include a number of expenses, Hazus only considers disruption costs that may include the cost of shifting and transferring and the rental of temporary space. Relocation expenses are assumed to be incurred only by building owners and measured in dollars per square foot per month. A renter who has been displaced from a property due to earthquake damage will cease to pay rent to the owner of the damaged property and will only pay rent to the new landlord. Therefore, the renter has no new rental expenses. It is assumed that the owner of the damaged property will pay the disruption costs for his renter. If the damaged property is owner occupied, the owner will have to pay for his own disruption costs in addition to the cost of rent while he is repairing his building. Relocation expenses are therefore a function of the floor area, rental costs per day per square foot, disruption costs, and the expected days of loss of function for each damage state.

Capital-related income is a measure of the profitability of a commercial enterprise. Income losses occur when building damage disrupts commercial activity. Income losses are the product of floor area, income realized per square foot, and the expected days of loss of function for each damage state. The U.S. Department of Commerce's Bureau of Economic Analysis reports regional estimates of capital-related income by economic sector. Capital-related income per square foot of floor space can then be derived by dividing income by the floor space occupied by a specified sector. Income will vary considerably depending on regional economic conditions. Therefore, default values need to be adjusted for local conditions. Default values derived from information in Table 4.7 of ATC-13. Income Loss Data are Summarized in **Figure 150**.

Figure 150: Income Loss Data



12.2.5 Business Inventory Damage

Business inventories vary considerably with occupancy. For example, the value of inventory for a high-tech manufacturing facility would be very different from that of a retail store. Thus, the default values of business inventory for this model are derived from annual gross sales by assuming that business inventory is some percentage of annual gross sales. These default values are based on judgement as displayed in **Figure 151**.

Figure 151: Business Inventory Damage