Hazus Earthquake Model

FEMA Standard Operating Procedure for Hazus Earthquake Data Preparation and Scenario Analysis

FEMA

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Credits

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Jesse Rozelle, GISP
Program Manager
Natural Hazards Risk Assessment Program | Hazus
FEMA HQ | RMD | Actuarial and Catastrophic Modeling Branch
jesse.rozelle@fema.dhs.gov

Doug Bausch
Risk Analytics Program Manager, NiyamIT, Inc.
dbausch@niyamit.com

Hope A. Seligson
Seligson Consulting
haseligson@gmail.com

Reviewers:

Casey Zuzak, GISP
Natural Hazards Risk Assessment Program | Hazus
FEMA HQ | RMD | Actuarial and Catastrophic Modeling Branch
casey.zuzak@fema.dhs.gov

Jordan Burns
Risk Analysis Lead, Risk Analytics Program, NiyamIT, Inc.
jburns@niyamit.com

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1. SOP Introduction

The Federal Emergency Management Agency (FEMA) developed Hazus and released the first model - the earthquake loss estimation model - in 1997. FEMA subsequently added flood, hurricane, and tsunami loss capabilities, while continuing to improve the earthquake model. Over time, a broad range of applications for Hazus results have emerged, including the development of mitigation strategies, scenario driven catastrophic planning, exercise support, and recovery and preparedness planning. For more information on Hazus, see: https://www.fema.gov/hazus.

This Standard Operating Procedure (SOP) describes the process of executing scenario analyses in the Hazus Earthquake Model, including integrating Hazus with the USGS's ShakeMap products, as well as the process of mapping and communication its results. Hazus includes an interface to directly import USGS ShakeMap XML grid files for both actual events, as well as scenarios. FEMA and the USGS have coordinated on the development of an extensive library of ShakeMap scenarios, largely based on the USGS National Seismic Hazard Map sources. These scenarios are accessible via an on-line map viewer, as shown in **Figure 1.1**; http://usgs.maps.arcgis.com/apps/webappviewer/index.html?id=14d2f75c7c4f4619936dac0d14e1e468. (Additional ShakeMap scenario data are available through a variety of legacy catalogs, accessible from: https://earthquake.usgs.gov/scenarios/catalog/.)

By clicking on an event's epicenter (the star symbol) in the on-line viewer, the user can select a rupture scenario (**Figure 1.2**), view metadata about the event (**Figure 1.3**), and access the available ShakeMap products (**Figure 1.4**). ShakeMap products include GIS data, KML/KMZ files, and XML files used for visualization, loss estimation, ShakeCast (Wald and others, 2008), Prompt Assessment of Global Earthquakes for Response (PAGER), and for other systems. These scenarios can be analyzed in Hazus, and the results can be used to support a broad range of emergency management activities, including mitigation, recovery and preparedness planning, as well as exercises for response.

Frequently, scenario selection is completed by users that want to test components of their emergency response capabilities without considering whether the scenario is credible. The selection of a credible scenario is especially critical for the promotion of mitigation of the vulnerabilities identified. Federal, State and local governments are unlikely to invest in mitigation if the scenarios are not considered reasonable. Deterministic scenarios based largely on the National Seismic Hazard Map sources, such as those described above, provide a uniform method of selecting scenarios, as well as a more effective communication of the risk to a community from these sources, as compared to the probabilistic approach.

Figure 1.1 USGS Earthquake Scenario Map (BSSC 2014) Viewer

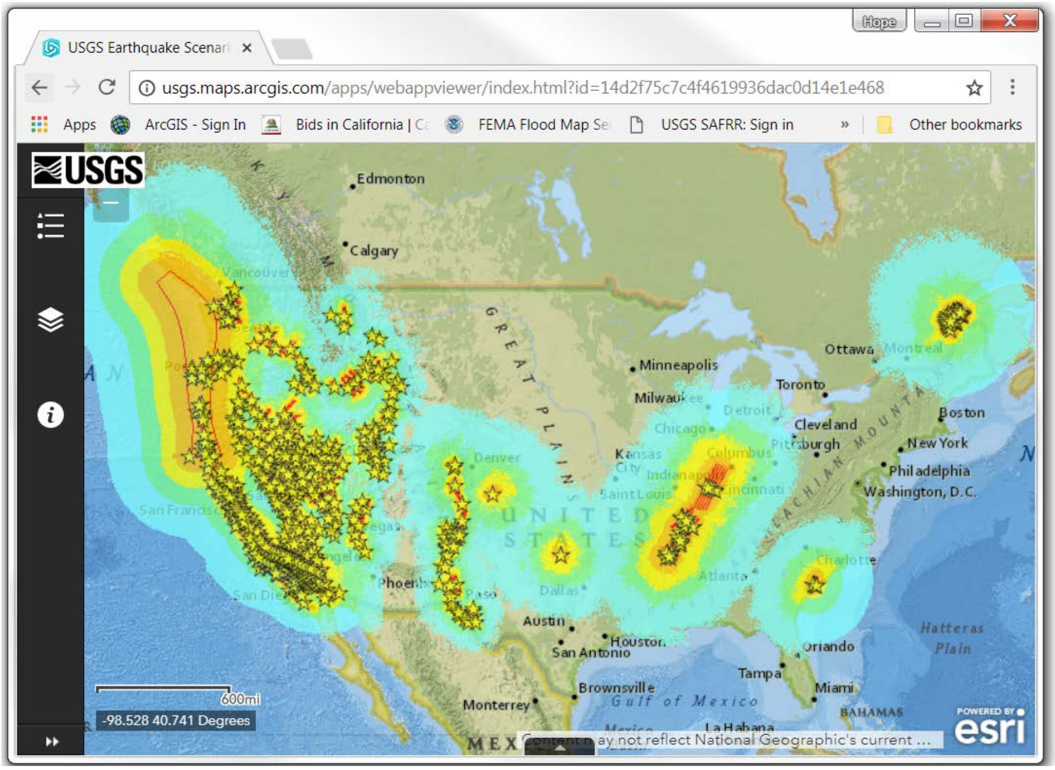


Figure 1.2 USGS Earthquake Scenario Map Viewer – Scenario Rupture Selection

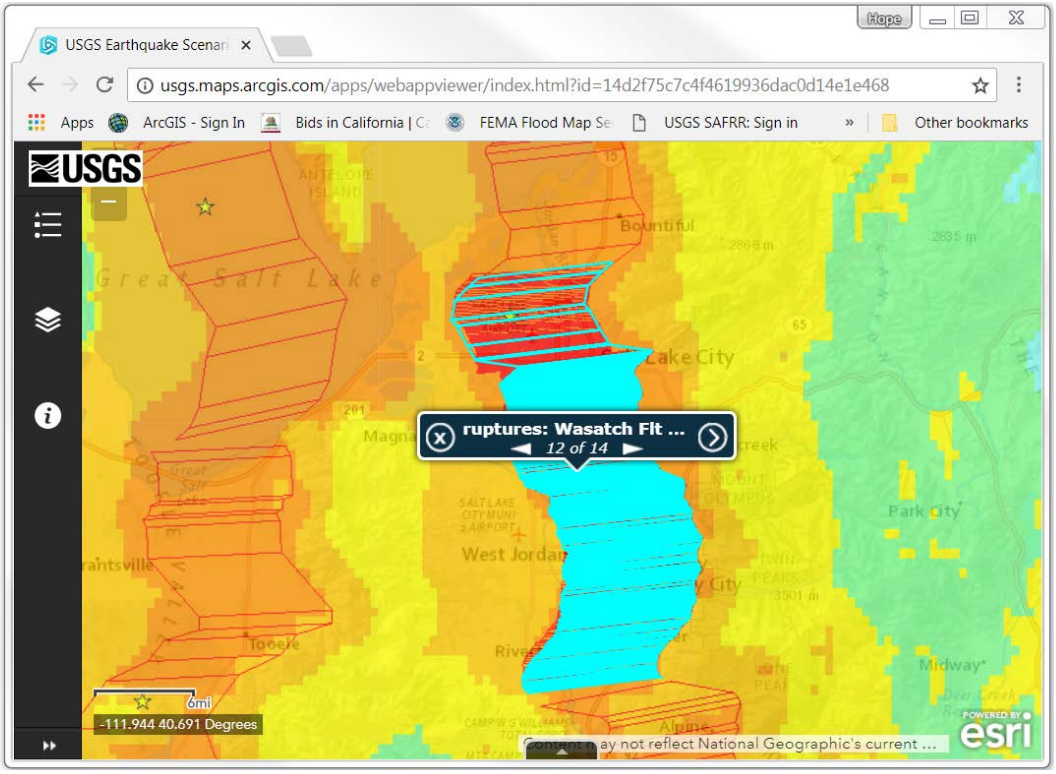


Figure 1.3 USGS Earthquake Scenario Map Viewer – Scenario Rupture Metadata

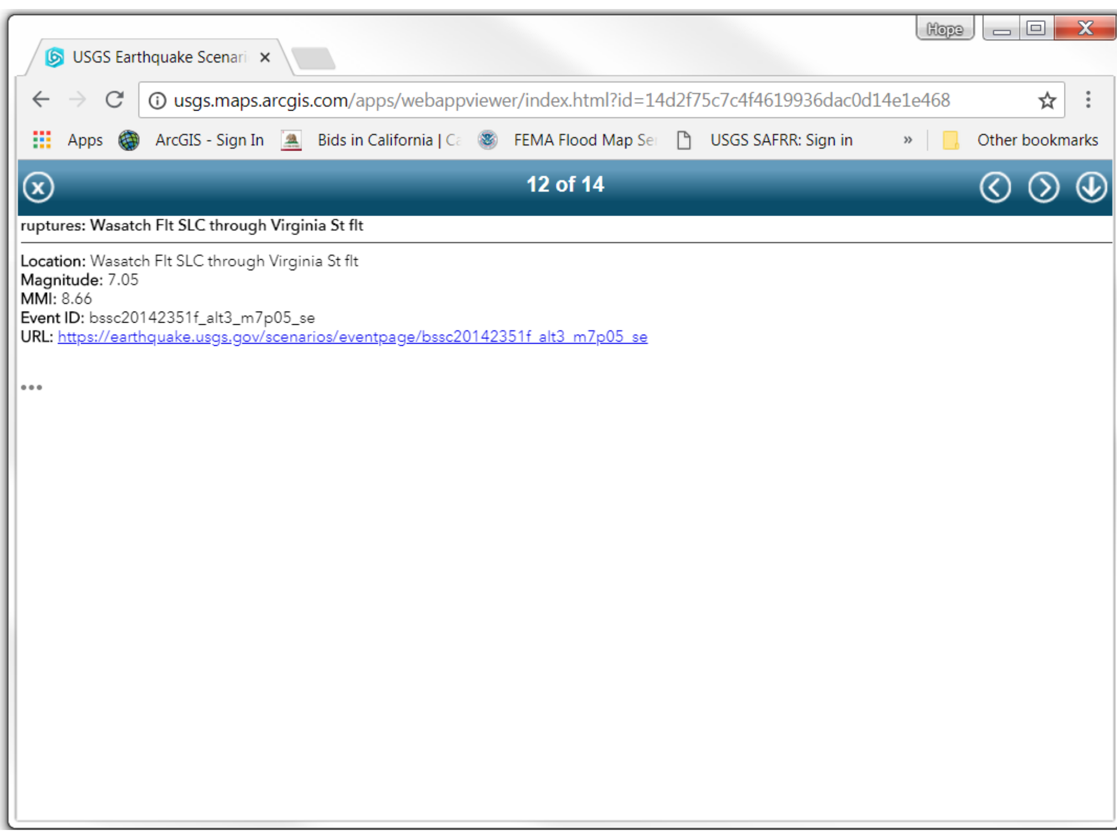
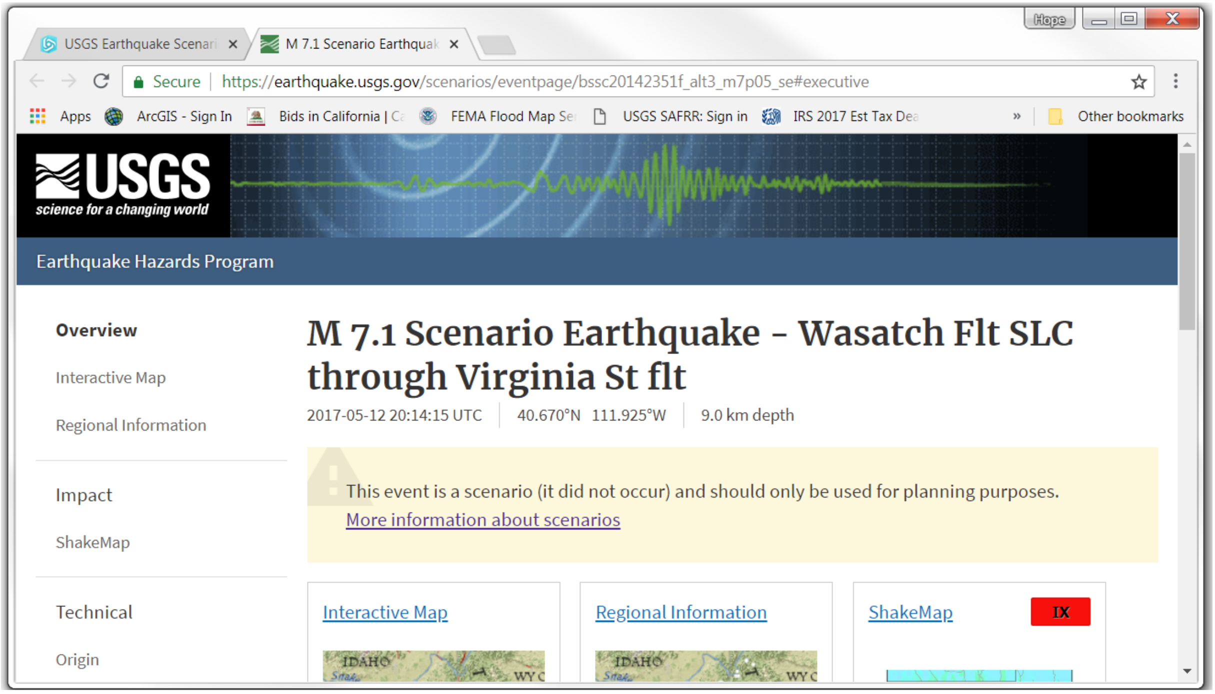


Figure 1.4 USGS Earthquake Scenario Map Viewer – Scenario ShakeMap Page



In addition to incorporating data on regional ground shaking, Hazus users can also incorporate other seismic hazard data into their analysis, such as regional maps of soils or surficial geology, liquefaction susceptibility, depth to groundwater, and/or landslide susceptibility; these data are discussed further in Section 2.3. While these types of hazard data are readily available in selected areas[1], nationwide data sets do not exist. In conducting a scenario analysis, available local hazard maps should be sought; the USGS and equivalent state geological agencies are good resources, as are regional planning consortia (such as the Central Unites States Earthquake Consortia, CUSEC, which houses GIS data for liquefaction susceptibility and soil type for its eight (8) member states, see: https://cusec.org/earthquake-maps-data/).

Depending on the focus of your scenario modeling efforts (e.g., regional economic loss and population impacts, utility and transportation infrastructure performance), and the availability of local hazard data, the potentially significant investment required to develop new hazard data may or may not be justified:

[1] e.g., liquefaction susceptibility maps of the San Francisco Bay Area are available from the USGS: https://pubs.usgs.gov/of/2006/1037/

- If USGS ShakeMaps will be used for the scenario analysis, as recommended here, regional soils data are not required as these data are built into the ShakeMap development process.
- Maps of liquefaction susceptibility and depth to groundwater are used together to estimate the severity of liquefaction-induced permanent ground deformation. If liquefaction susceptibility data are not available, data on depth to groundwater are not needed. If liquefaction susceptibility data are available but depth to groundwater data are not, a simplified uniform assumption may suffice (the conservative Hazus default assumption of "shallow" groundwater is a depth of 5 feet). In areas of significant liquefaction susceptibility exposure, a considerable increase in losses may be expected. For example, in the recent M7.0 "HayWired" Scenario Hazus analysis (Seligson, et al., 2018), liquefaction modeling within Hazus added 14% to the estimated regional building damage produced by ground shaking alone, in the seven (7) Counties in which liquefaction data were modeled using the standard Hazus approach. The contribution of ground failure to overall losses will vary based on conditions in each region. It should be noted that ground failure can be highly disruptive to lifelines, and that highways, airport runways and other surface-built infrastructure are only vulnerable to ground deformation and will suffer no predicted damage under shaking hazards alone.
- Landslide hazards are quite localized; depending on the prevalence of landslide hazards in your community, the level of effort required to develop landslide susceptibility maps may be difficult to justify. In the "HayWired" Scenario Hazus analysis (Seligson, et al., 2018), detailed (pixel-level) landslide mapping and application of Hazus methods in nine (9) counties produced landslide-related building damage that added just 1% to the regional building damage estimates produced by ground shaking. Nevertheless, landslide hazards can be extremely disruptive to lifelines and elevate overall losses in susceptible regions. The USGS has recently added companion products to ShakeMap that communicate the potential for both liquefaction- and landslide-induced ground failure, including potential population exposure, available from the USGS earthquake event web page for significant events[2].

Hazus includes more than 240 analysis modules that estimate losses ranging from building damage to social losses including casualties and displaced households. Since Hazus operates in a powerful GIS platform, a variety of results with critical base layers can be displayed. These maps and results can effectively communicate risk before the earthquake happens, as well as immediately after the earthquake for response and

[2] See for example: https://earthquake.usgs.gov/earthquakes/eventpage/us70003a63/ground-failure/summary

recovery applications. This SOP includes descriptions of various standard Hazus results, along with recommended symbology information, and terminology definitions.

Integrating USGS ShakeMap data based on the National Seismic Hazard Map sources into Hazus will ensure that scenarios are developed based on authoritative sources and provide consistency with the hazard maps widely used for building codes. Use of this SOP also ensures consistency in the presentation of results for different earthquake scenarios and establishes a standard protocol for Hazus Earthquake results symbology. Results can readily be used in a variety of applications, including the development of mitigation strategies, scenario driven catastrophic planning, exercise support, and recovery and preparedness planning.

2. Inventory/Hazard Data

2.1 Hazus Default Inventory Data

*If you are *not* planning on making inventory updates or incorporating hazard data other than ground shaking, you can proceed to Section 3 "Study Regions".

Hazus comes with nationwide default databases for the following categories:

1. General Building Stock: aggregated data on the census block or census tract level (tract level in the earthquake model) representing building use types, construction types, and seismic design levels for the following occupancy types:
   - Residential
   - Commercial
   - Industrial
   - Agricultural
   - Religious
   - Government
   - Educational

2. Essential Facilities
   - Medical care facilities (i.e., hospitals)
   - Emergency operations centers
   - Police stations
   - Fire stations
   - Schools

3. High Potential Loss Facilities
   - Dams and levees[3]
   - Nuclear power facilities[3]
   - Military installations[3]
   - Hazardous materials facilities[3]

4. Transportation
   - Highway segments, tunnels, and bridges
   - Railway track segments, tunnels, bridges, and facilities
   - Light rail track segments, tunnels, bridges, and facilities
   - Bus facilities
   - Port and harbor facilities
   - Ferry facilities
   - Airport facilities and runways

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[3] Placeholder only - no default data

5. Utility Systems
    - Potable water facilities, pipeline segments[3], and distribution lines[4]
    - Waste water facilities, pipeline segments[3], distribution lines[4]
    - Crude and refined oil facilities, pipeline segments[3]
    - Natural gas facilities, pipeline segments[3], and distribution lines[4]
    - Electric power facilities
    - Communication facilities

6. Population Demographics
    - Total population and households
    - Number of people by gender and age, by ethnicity, and households by income
    - Housing characteristics, such as housing units built by decade, median year built and units by type and ownership
    - Population working in various job sectors

2.2 User Updated Inventory Data

The default databases provided with Hazus are a great nationwide dataset, but the incorporation of more detailed local data can greatly enhance the accuracy of the model. Any of the default databases identified above can either be edited, replaced, or appended to by the user. Hazus has a comparison tool developed by FEMA called the CDMS (Comprehensive Data Management System) for updating inventory data for your state of interest. (For more information, see: https://www.fema.gov/comprehensive-data-management-system).

Updating the inventory data can be quite time consuming and should be done in advance of use of the earthquake model. It will require database management, GIS data processing and Hazus testing to ensure that data formats are compatible with Hazus. To learn more, visit the CDMS link above, consult the Hazus earthquake technical manual, or there is a course available called E0317 "Comprehensive Data Management for Hazus" at the Emergency Management Institute https://www.fema.gov/hazus-mh-training.

Lessons learned during previous FEMA-funded studies are also instructive. In 2007-2009, FEMA funded three "Essential Facilities Risk Assessment Studies" in Orange, Riverside and San Bernardino Counties, California. Each study included an update of default essential facilities data, as well as an update of the Hazus General Building Stock inventory databases, using available Assessor's data. The studies produced a Risk Assessment Report for each county to use in subsequent mitigation planning. A Guidelines document

[4] Aggregate distribution line length by census tract

was also produced to facilitate similar improvements in other areas.

Inventory data updates can significantly change the losses calculated by the Hazus earthquake model. For example, the Hazus 4.2 default general building stock number of URM (Unreinforced Masonry) buildings for the state of Utah is 21,549. The FEMA Region VIII office updated the general building stock for the State of Utah using assessor's data for Salt Lake County first in 2010, and most recently in 2018 to better represent the significant number of URM structures. After incorporating the most recent assessor's data derived URM counts for Salt Lake County, the URM totals for the State of Utah increased to 91,773 URM structures. This caused a significant increase in losses estimated in a statewide annualized loss analysis of Utah (**Table 2.1**), as URMs are extremely vulnerable to seismic activity and contribute the majority of severe casualties.

Table 2.1: 2013 Utah AAL Results for URM for Default and Improved Data

Scenario	URM Count	Direct Economic Losses	Level 1 Casualties 2pm	Level 2 Casualties 2pm	Level 3 Casualties 2pm	Level 4 Casualties 2pm
Utah Statewide Annualized Loss with Default MR4 Data	19,192	95M	56	16	3	5
Utah Statewide Annualized Loss with Updated Inventory	188,427	160M	106	31	5	10

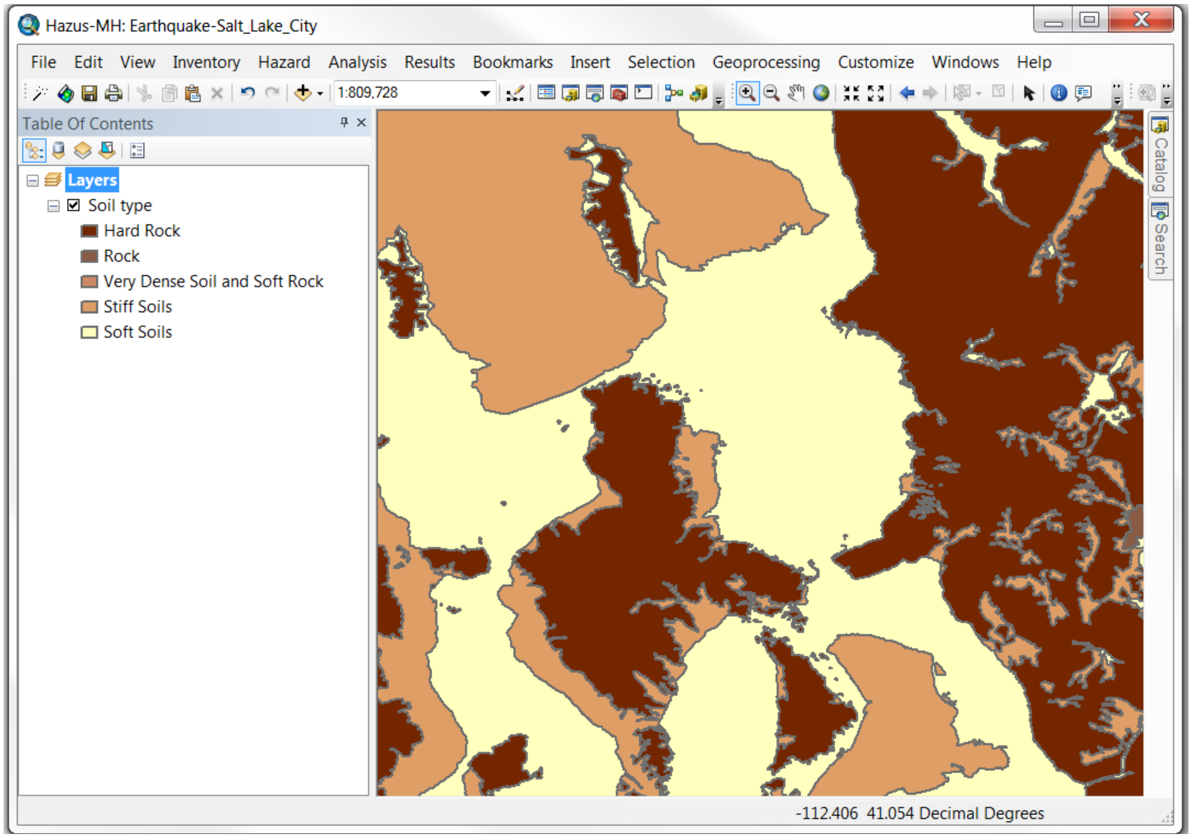
2.3 Hazard Data

The incorporation of user supplied hazard data can further increase the accuracy of your results, where data are available. Hazard data are added after study region creation, and before running the hazard scenario analysis. When user supplied hazard data is not provided, default values are applied. The following hazard data types are commonly used and their required format are described below. The incorporation of these data types is explained in Section 4.3.

2.3.1 Soils Data

Soils data (**Figure 2.1**) can be applied to represent the soil type at any given point. Incorporating soils data is most important when non-ShakeMap scenarios are being modeled, using Hazus' built-in ground motion estimation procedure, or when probabilistic scenarios are used and/or Average Annual Losses (AALs) are being computed. ShakeMaps already consider variation in local soil conditions, so incorporating a soils layer is not necessary when ShakeMaps are used. As of the release of Hazus 4.2 Service Pack 02 (Hazus 4.2.2), the USGS probabilistic hazard data provided with Hazus incorporate soil amplification by default, however, more refined soil maps can be provided by the user and override the default. Soil type is applied to site specific structures, and an average soil type value is assigned to each census tract to influence the amplification of ground shaking and the losses calculated for the general building stock. If no soils data are given, a soil type of D (stiff soils) is assumed by default. If the soils map as input does not cover the entire Hazus study region, Hazus will apply the default soil type (D) in areas beyond the limits of the user-input map.

Figure 2.1: Example Soils Dataset for the Wasatch Front, Utah

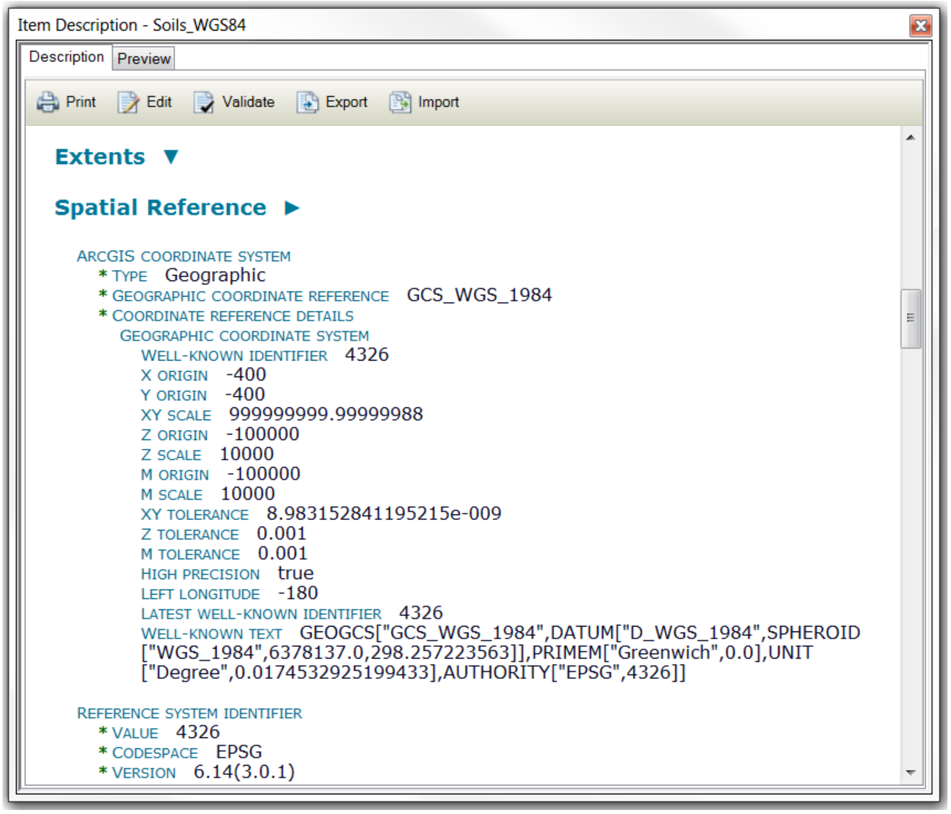


In order to incorporate a soil type dataset, it must be formatted to a Hazus ready format. First, the soil types must all be categorized into Hazus format soil classes (**Table 2.2**) from the Hazus Earthquake Technical Manual) with the site class (A – E) as the identifier. The soils data will also have to be imported into an ESRI personal geodatabase, using the World Geodetic System 1984 (WGS84) geographic coordinate system. (**Figure 2.2**).

Table 2.2: Hazus Site Classes

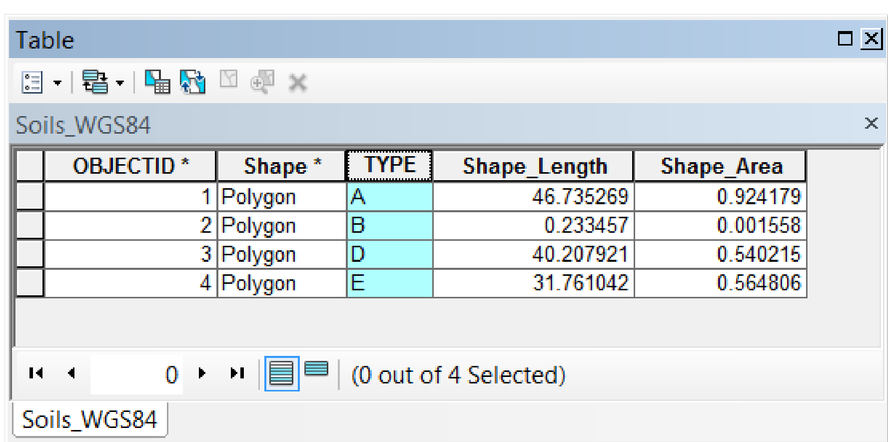
Site Class	Site Class Description	Shear Wave Velocity (m/sec)	
		Minimum	Maximum
A	**HARD ROCK** Eastern United States sites only	1500	
B	**ROCK**	760	1500
C	**VERY DENSE SOIL AND SOFT ROCK** Undrained shear strength $u_s \geq$ 2,000 psf ($u_s \geq$ 100 kPa) or N ≥ 50 blows/ft	360	760
D	**STIFF SOILS** Stiff soil with undrained shear strength 1,000 psf ≤ u_s ≤2,000 psf (50 kPa ≤ u_s ≤ 100 kPa) or 15 ≤ N ≤ 50 blows/ft	180	360
E	**SOFT SOILS** Profile with more than 10 ft (3 m) of soft clay defines as soil with plasticity index PI > 20, moisture content *w* > 40% and undrained shear strength u_s < 1,000 psf (50 kPa) or N<50 blows/ft		180
F	**SOILS REQUIRING SITE SPECIFIC EVALUATIONS** 1. Soils vulnerable to potential failure or collapse under seismic loading, e.g., liquefiable soils, quick and highly sensitive clays, collapsible weakly cemented soils 2. Peats and/or highly organic clays, 10 ft (3 m) or thicker layer 3. Very high plasticity clays, 25 ft (8 m) or thicker layer with plasticity index > 75 4. Very thick soft/medium stiff clays, 120 ft (36 m) or thicker layer		

Figure 2.2: Example Metadata Showing Hazus' Required Coordinate System



The field containing the lettered soil type must be called "Type" and use Text data type of length = 1 (**Figure 2.3**). All values within this column must fall between A and E. Any other values, or "Null" values will cause Hazus to crash upon import. If using a high-resolution dataset, it is recommended that users *dissolve* the dataset on the "Type" field before use in Hazus (undissolved high-resolution data may result in maps not correctly applying hazard values.) This will yield a layer containing one feature for each "Type" value present, as shown in **Figure 2.3**.

Figure 2.3: Example Attribute Data for Site Class as Stored in the "Type" field



OBJECTID *	Shape *	TYPE	Shape_Length	Shape_Area
1	Polygon	A	46.735269	0.924179
2	Polygon	B	0.233457	0.001558
3	Polygon	D	40.207921	0.540215
4	Polygon	E	31.761042	0.564806

2.3.2 Landslide Susceptibility Data

Landslide susceptibility data (**Figure 2.4**) can be applied to represent the landslide susceptibility at any given point. This landslide susceptibility is then applied to site specific structures, and an average landslide susceptibility value is assigned to each census tract. Landslide susceptibility data in Hazus is measured on a scale of 0 – 10 (*None* to *X* in Roman numerals), considering geologic group, slope angle, and groundwater conditions, with 0 meaning "None", and a 10 meaning "Severe" (**Table 2.3**). If no landslide susceptibility data is applied, a default susceptibility value of "None" is applied.

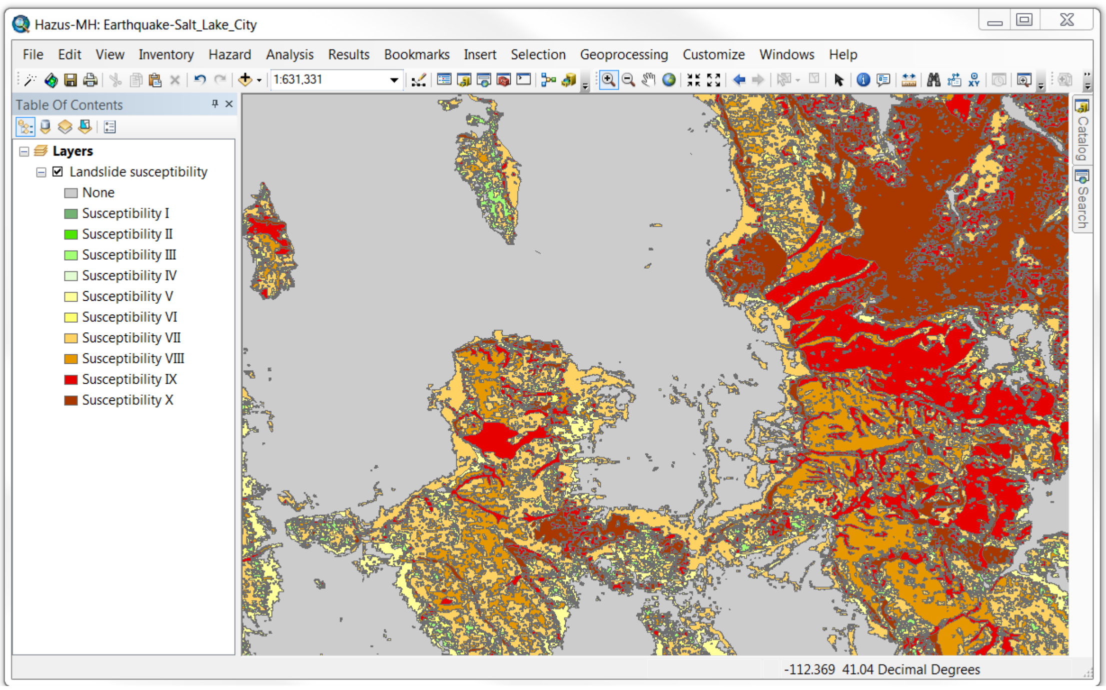


Figure 2.4: Example Landslide Susceptibility Dataset for the Wasatch Front, Utah

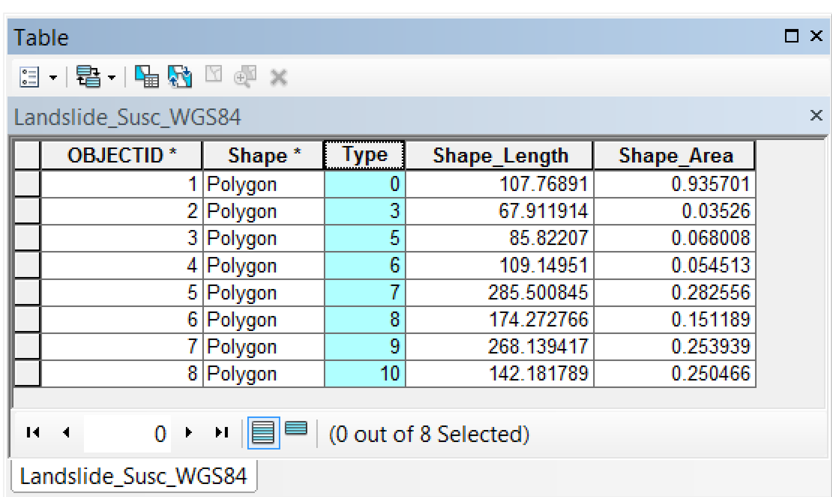
Table 2.3: Hazus Landslide Susceptibility Classes

Geologic Group		Slope Angle, degrees					
		0–10	10–15	15–20	20–30	30–40	>40
(a) DRY (groundwater below level of sliding)							
A	Strongly Cemented Rocks (crystalline rocks and well-cemented sandstone)	None	None	I	II	IV	VI
B	Weakly Cemented Rocks and Soils (sandy soils and poorly cemented sandstone)	None	III	IV	V	VI	VII
C	Argillaceous Rocks (shales, clayey soil, existing landslides, and poorly compacted fills)	V	VI	VII	IX	IX	IX
(b) WET (groundwater level at ground surface)							
A	Strongly Cemented Rocks (crystalline rocks and well-cemented sandstone)	None	III	VI	VII	VIII	VIII
B	Weakly Cemented Rocks and Soils (sandy soils and poorly cemented sandstone)	V	VIII	IX	IX	IX	X
C	Argillaceous Rocks (shales, clayey soil, existing landslides, and poorly compacted fills)	VII	IX	X	X	X	X

** Landslide susceptibility is measured on a scale of I to X, with X being the most susceptible*

In order to incorporate a landslide susceptibility dataset, it must be formatted to a Hazus ready format. First, the landslide susceptibility types must all be categorized into Hazus format classes with a numeric susceptibility value between 0 and 10. The dataset will then have to be imported into an ESRI personal geodatabase, with a World Geodetic System 1984 (WGS84) coordinate system (**Figure 2.2**). The column containing the landslide susceptibility value should be called "Type" and have a short integer numeric data type (**Figure 2.5**). All values within this column must fall between 0 and 10. Any other values, or "Null" values will cause Hazus to crash upon import. As noted above, if using a high-resolution dataset, it is recommended that users *dissolve* the dataset on the "Type" field before use in Hazus.

Figure 2.5: Example Attribute Data for Landslide Susceptibility as Stored in the "Type" field



OBJECTID *	Shape *	Type	Shape_Length	Shape_Area
1	Polygon	0	107.76891	0.935701
2	Polygon	3	67.911914	0.03526
3	Polygon	5	85.82207	0.068008
4	Polygon	6	109.14951	0.054513
5	Polygon	7	285.500845	0.282556
6	Polygon	8	174.272766	0.151189
7	Polygon	9	268.139417	0.253939
8	Polygon	10	142.181789	0.250466

2.3.3 Liquefaction Susceptibility Data

Liquefaction susceptibility data (**Figure 2.6**) can be applied to represent the liquefaction susceptibility of the ground at any given point. This value is then applied to site specific structures, and an average liquefaction susceptibility value is assigned to each census tract. Liquefaction susceptibility in Hazus is measured on a scale of 0 – 5, with 0 representing "None", and 5 representing "Very High" (**Table 2.4**). If no liquefaction data is applied, a default value of "None" is applied.

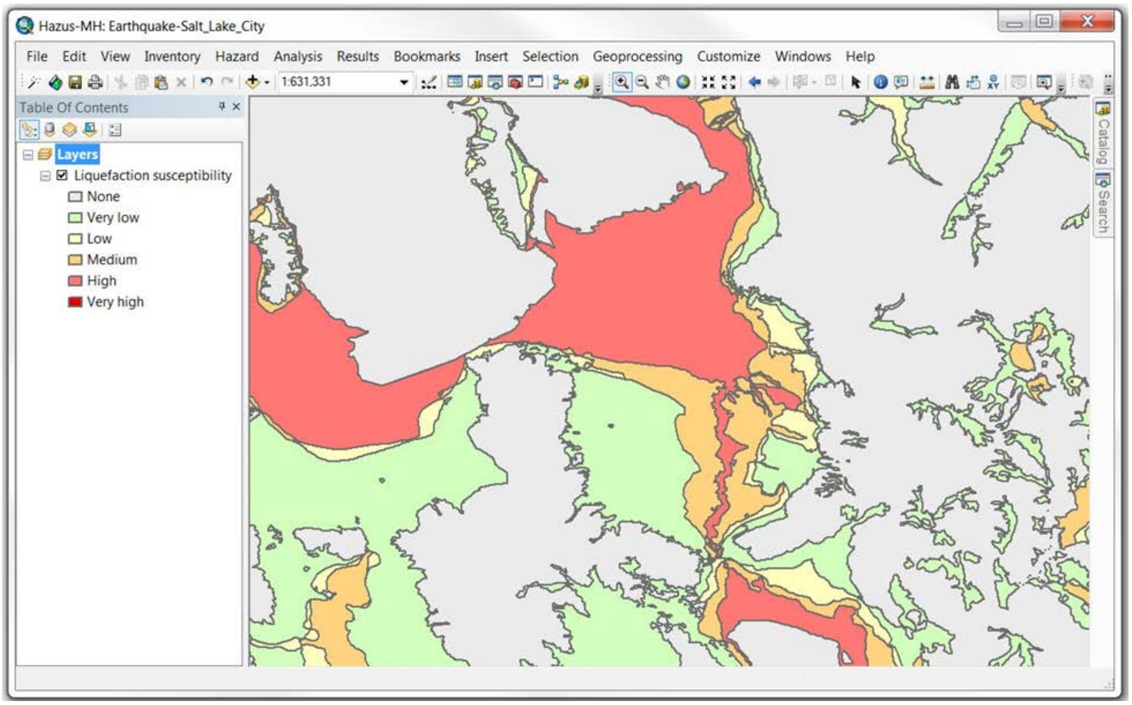


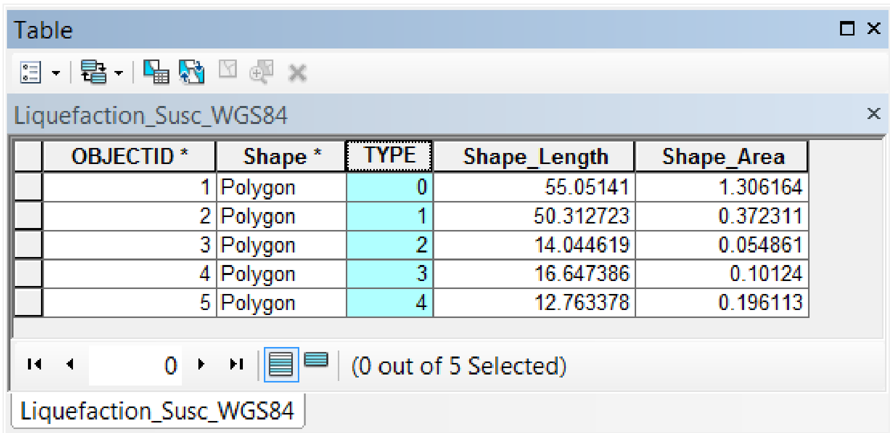
Figure 2.6: Example Liquefaction Susceptibility Dataset for the Wasatch Front, Utah

Table 2.4: Hazus Liquefaction Susceptibility Classes

Type of Deposit	General Distribution of Cohesionless Sediments in Deposits	Likelihood that Cohesionless Sediments when Saturated Would Be Susceptible to Liquefaction (by Age of Deposit)			
		< 500 yr Modern	Holocene < 11 ka	Pleistocene 11 ka – 2 Ma	Pre-Pleistocene 11 ka – 2 Ma
(a) Continental Deposits					
River channel	Locally variable	Very High	High	Low	Very Low
Flood plain	Locally variable	High	Moderate	Low	Very Low
Alluvial fan and plain	Widespread	Moderate	Low	Low	Very Low
Marine terraces and plains	Widespread	—	Low	Very Low	Very Low
Delta and fan-delta	Widespread	High	Moderate	Low	Very Low
Lacustrine and playa	Variable	High	Moderate	Low	Very Low
Colluvium	Variable	High	Moderate	Low	Very Low
Talus	Widespread	Low	Low	Very Low	Very Low
Dunes	Widespread	High	Moderate	Low	Very Low
Loess	Variable	High	High	High	Unknown
Glacial till	Variable	Low	Low	Very Low	Very Low
Tuff	Rare	Low	Low	Very Low	Very Low
Tephra	Widespread	High	High	?	?
Residual soils	Rare	Low	Low	Very Low	Very Low
Sebka	Locally variable	High	Moderate	Low	Very Low
(b) Coastal Zone					
Delta	Widespread	Very High	High	Low	Very Low
Estuarine	Locally variable	High	Moderate	Low	Very Low
Beach - High Wave Energy	Widespread	Moderate	Low	Very Low	Very Low
Beach - Low Wave Energy	Widespread	High	Moderate	Low	Very Low
Lagoonal	Locally variable	High	Moderate	Low	Very Low
Fore shore	Locally variable	High	Moderate	Low	Very Low
(c) Artificial					
Uncompacted Fill	Variable	Very High	—	—	—
Compacted Fill	Variable	Low	—	—	—

In order to incorporate a liquefaction susceptibility dataset, it must be formatted to a Hazus ready format. First, the liquefaction susceptibility types must all be categorized into Hazus format classes with a numeric susceptibility value between 0 and 5, where 0 is “None” and 5 is “Very High”. The dataset will then have to be placed in an ESRI personal geodatabase, with a World Geodetic System 1984 (WGS84) projection (**Figure 2.2**). The column containing the liquefaction susceptibility value should be called “Type” and have a short integer numeric data type (**Figure 2.7**). All values within this column must fall between 0 and 5. Any other values, or “Null” values will cause Hazus to crash upon import. As noted above, if using a high-resolution dataset, it is recommended that users *dissolve* the dataset on the “Type” field before use in Hazus.

Figure 2.7: Example Attribute Data for Liquefaction Susceptibility as Stored in the “Type” field



OBJECTID *	Shape *	TYPE	Shape_Length	Shape_Area
1	Polygon	0	55.05141	1.306164
2	Polygon	1	50.312723	0.372311
3	Polygon	2	14.044619	0.054861
4	Polygon	3	16.647386	0.10124
5	Polygon	4	12.763378	0.196113

2.3.4 Groundwater Depth Data

Groundwater depth data (**Figure 2.8**) is utilized in the assessment of liquefaction impacts and can be applied to represent the depth of the groundwater table at any given point. This value is then applied to site specific structures, and an average groundwater depth value is assigned to each census tract. Groundwater depth data in Hazus is measured numerically in feet. If no ground water depth data is applied, a default groundwater depth of 5 feet is applied.

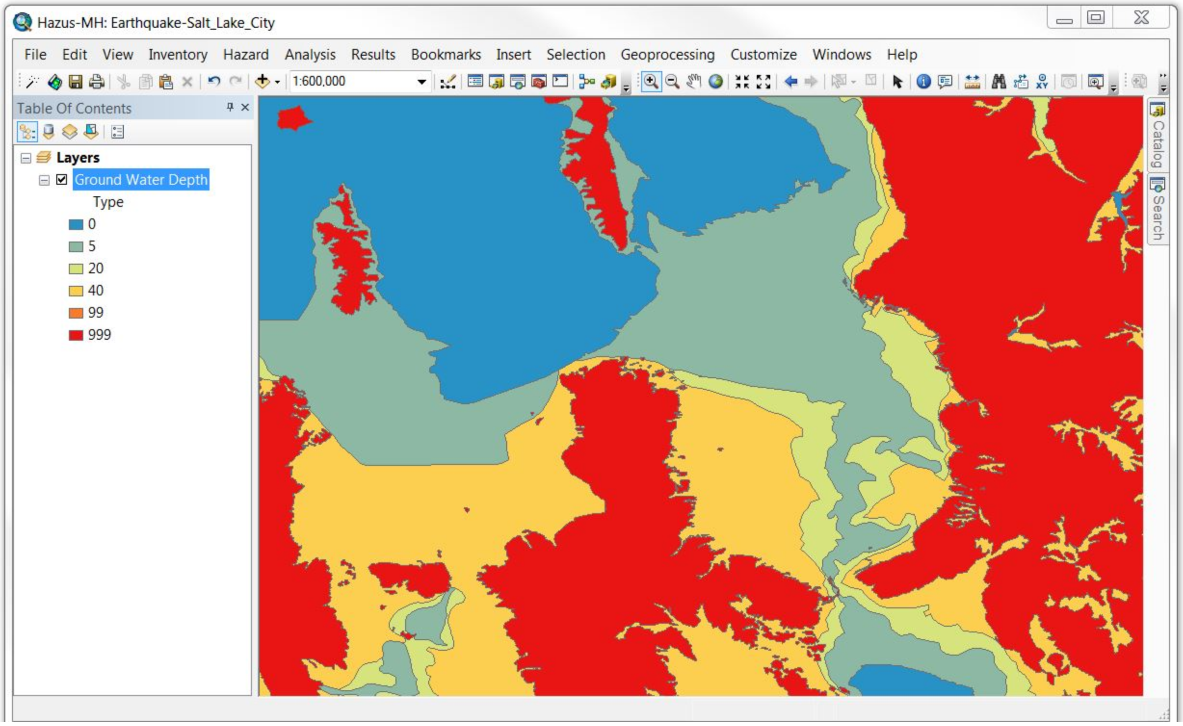


Figure 2.8: Example Groundwater Depth Dataset for the Wasatch Front, Utah

In order to incorporate a groundwater depth dataset, it must be formatted to a Hazus ready format. First, the groundwater depth values need to be in feet. If the depths are in another system of measurement, it must first be converted to feet. The dataset will then have to be placed in an ESRI personal geodatabase, with a World Geodetic System 1984 (WGS84) projection (**Figure 2.2**). The column containing the water depth value should be called "Type" and have a Double numeric data type (**Figure 2.9**). All values within this column must be numerical. Any other values, or "Null" values will cause Hazus to crash upon import. As noted above, if using a high-resolution dataset, it is recommended that users *dissolve* the dataset on the "Type" field before use in Hazus. Caution should be used in selecting a value to represent very deep groundwater (e.g., 999 in **Figure 2.9**); Hazus computes an area-weighted average groundwater depth value to assign to census tracts and very large place-holder values will skew the results.

Figure 2.9: Example Attribute Data for Groundwater Depth as Stored in the "Type" field

Table

groundwater_depth_WGS84

OBJECTID *	Shape *	TYPE	Shape_Length	Shape_Area
1	Polygon	0	9.446445	0.380641
2	Polygon	5	20.829825	0.26887
3	Polygon	20	12.559132	0.089511
4	Polygon	40	45.947512	0.366213
5	Polygon	99	0.23336	0.001558
6	Polygon	999	46.949725	0.923965

0 (0 out of 6 Selected)

groundwater_depth_WGS84

There are other hazard data types that can be incorporated into the Hazus earthquake model, but these four are the most commonly used. To learn more about the other hazard data types, consult the Hazus Earthquake Technical Manual.

2.4 Inventory/Hazard Data Summary

The inclusion of improved inventory and hazard data can greatly increase the accuracy of your analysis results. The 2010 table shown below (**Table 2.5**) is a good example of the difference in losses once can expect when incorporating updated inventory data, or hazard data.

Table 2.5: Differences in Losses – Comparison with and without Improved Inventory and Hazard Data (Salt Lake City Segment Scenario, 2010)

Inventory Data	Hazard Data	URM Count	Direct Economic Losses ($B)	Level 1 Casualties 2 pm	Level 2 Casualties 2 pm	Level 3 Casualties 2 pm	Level 4 Casualties 2 pm
Default MR4 Data	No Hazard Data	15,960	21.26	14,044	4,376	764	1,459
Updated Inventory	No Hazard Data	172,281	33.86	21,855	6,776	1,151	2,206
Default MR4 Data	Hazard Data	15,960	24.70	14,930	4,619	805	1,526
Updated Inventory	Hazard Data	172,281	35.40	22,832	7,057	1,201	2,289

3. Study Regions

3.1 Determining Which Counties to Include in Your Study Region

Before you create your study region for an earthquake analysis, it is important to know which Counties to include. It is recommended that you include all Counties with earthquake ground motions, in terms of peak ground acceleration (PGA), in excess of about 0.1g, as this is generally considered to be the threshold for the onset of damage to poorly constructed buildings. There are various ways to identify which Counties should be included, ranging from a simple visual review of on-line ShakeMaps, to downloading ShakeMap GIS data and comparing to County boundary data. The latter method is strongly recommended, but both of these options will be discussed briefly here.

The simplest way to determine the impacted counties is to look at the event's ShakeMap. For example, for the 2012 M7.0 Utah ShakeOut event, you could review the intensity map (**Figure 3.1**) or the PGA map (**Figure 3.2**). While both of these maps include selected city locations, neither includes County boundaries, so you will need to compare them to the County boundary map of your choice (e.g., in GIS, or on-line, such as on geology.com, https://geology.com/county-map/utah.shtml, see **Figure 3.3**). Using the 9% g contour on the PGA map, an initial impacted County list (from north to south) might include seven counties: Weber, Davis, Morgan, Salt Lake, Summit, Utah and Wasatch Counties.

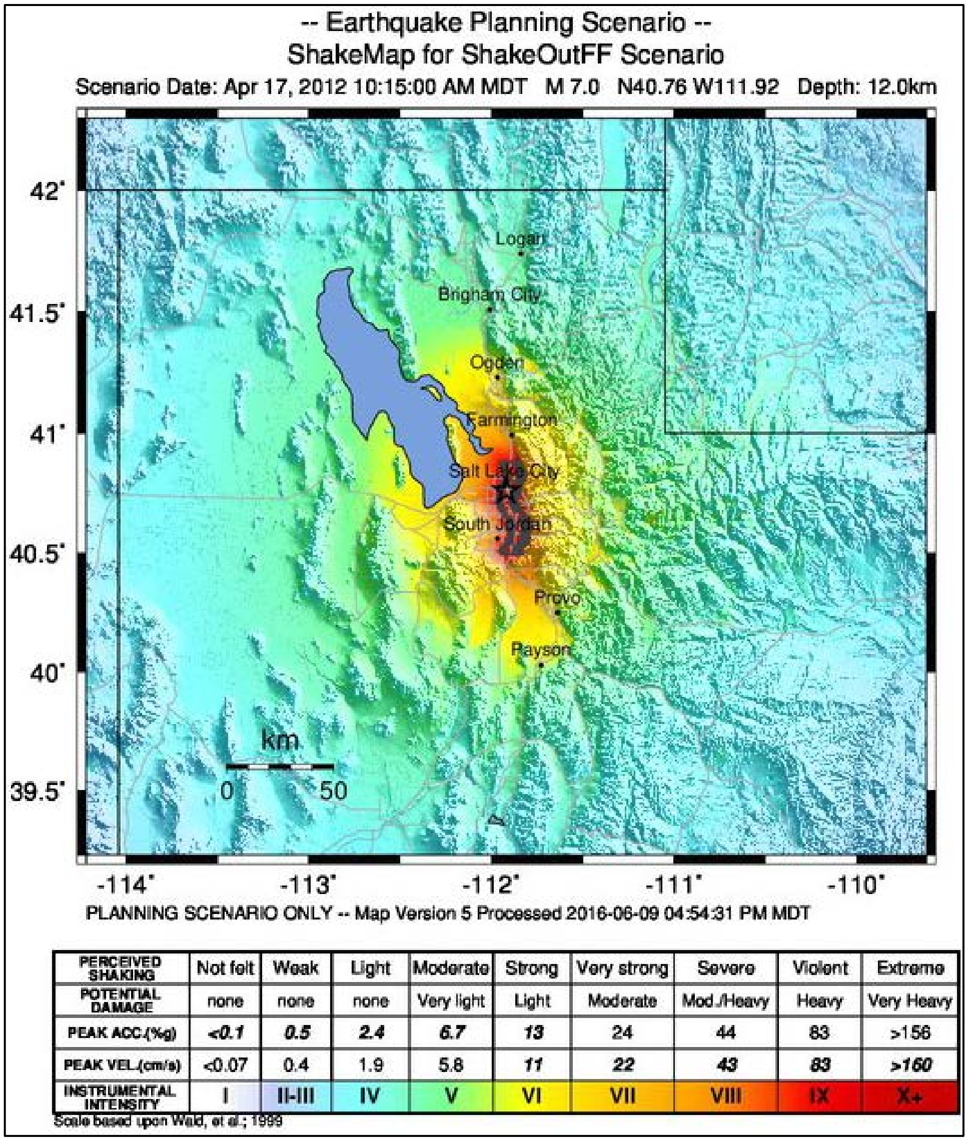


Figure 3.1 Utah ShakeOut ShakeMap Intensity Map
(source: https://earthquake.usgs.gov/scenario/product/shakemap-scenario/uulegacyshakeoutff_se/us/1465519638328/download/intensity.jpg)

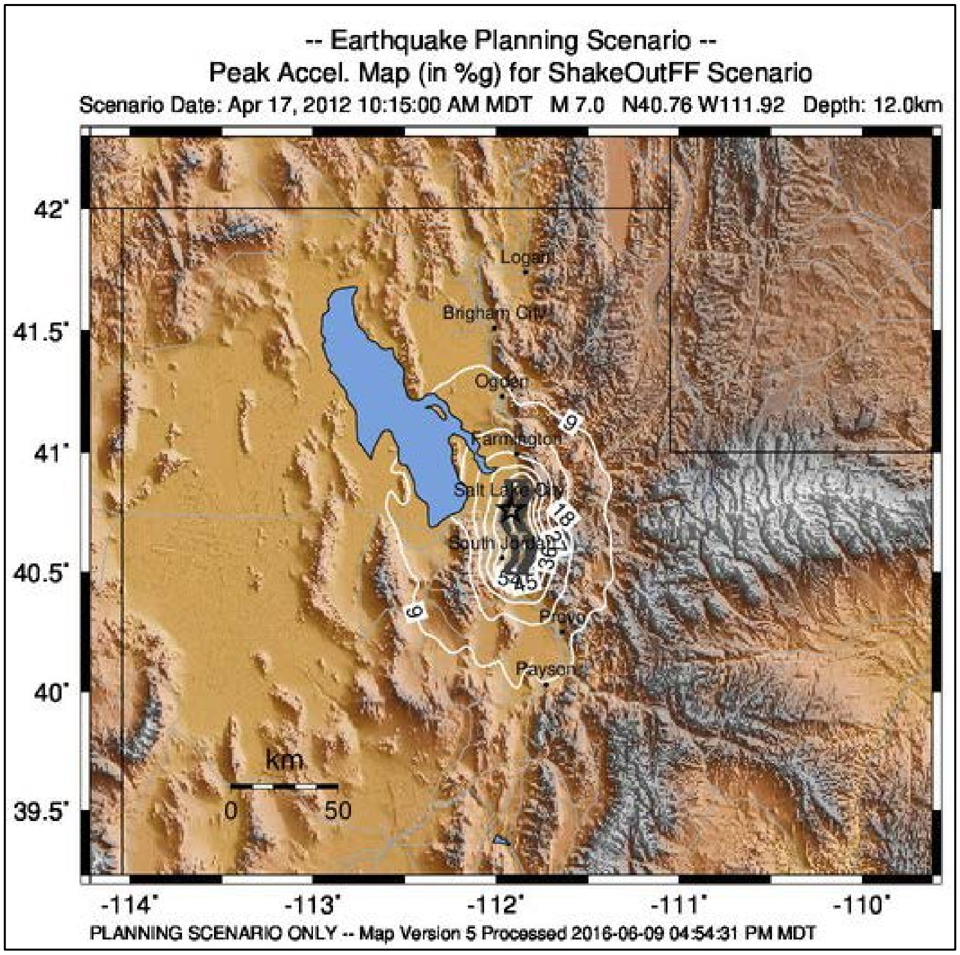


Figure 3.2 Utah ShakeOut ShakeMap PGA Map
(source: https://earthquake.usgs.gov/scenario/product/shakemap-scenario/uulegacyshakeoutff_se/us/1465519638328/download/pga.jpg)

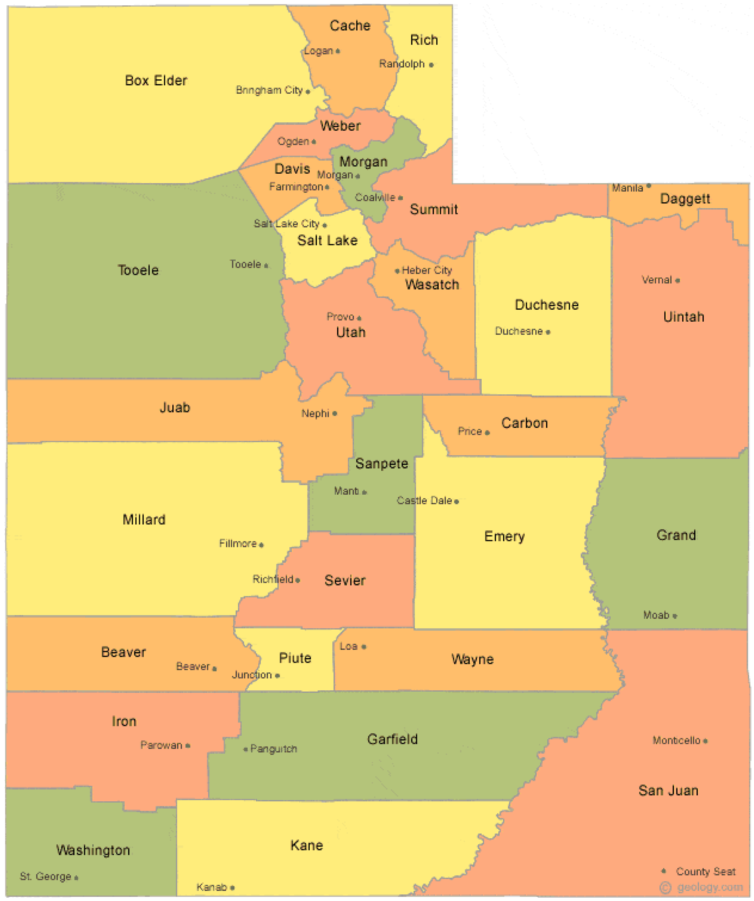


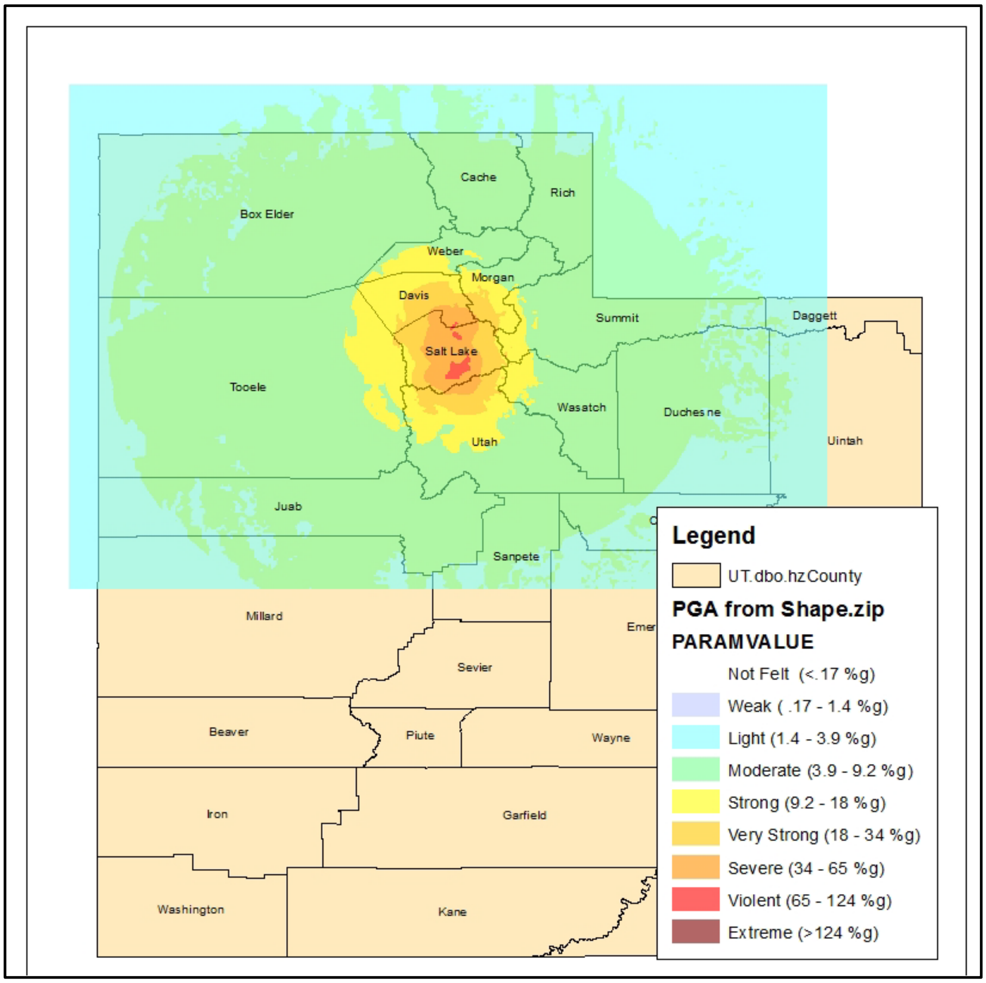
Figure 3.3 Utah State County Boundary Map
(Source: https://geology.com/county-map/utah.shtml)

A more comprehensive approach to determining which counties to include will require the download of ShakeMap GIS data. From the ShakeMap download page, download the general-purpose GIS shape files stored as "Shape.zip"[5]. For later use, it might also be useful to download the XML grid file of ground motions.

Unzip the Shape.zip file and extract the PGA shape file data. In ArcGIS, create a new project, add County boundary data of your choice (e.g., from the Hazus state database or from ESRI Data and Maps for ArcGIS "USA Counties.lyr") and add the PGA layer, using the USGS-provided layer settings (PGA.LYR), if available (**Figure 3.4** for the Utah example). Identify all Counties containing areas of "Strong" or greater shaking (9.2% g, shown in yellow, and greater). For our Utah ShakeOut example, this includes eight counties (from north to south): Weber, Davis, Morgan, Summit, Salt Lake, Tooele, Utah and Wasatch Counties. By examining the GIS data, we were better able to determine that eastern Tooele County was impacted in the scenario and should be included in the study region.

[5] In our Utah ShakeOut example, this file is available from: https://earthquake.usgs.gov/scenario/product/shakemap-scenario/uulegacyshakeoutff_se/us/1465519638328/download/shape.zip

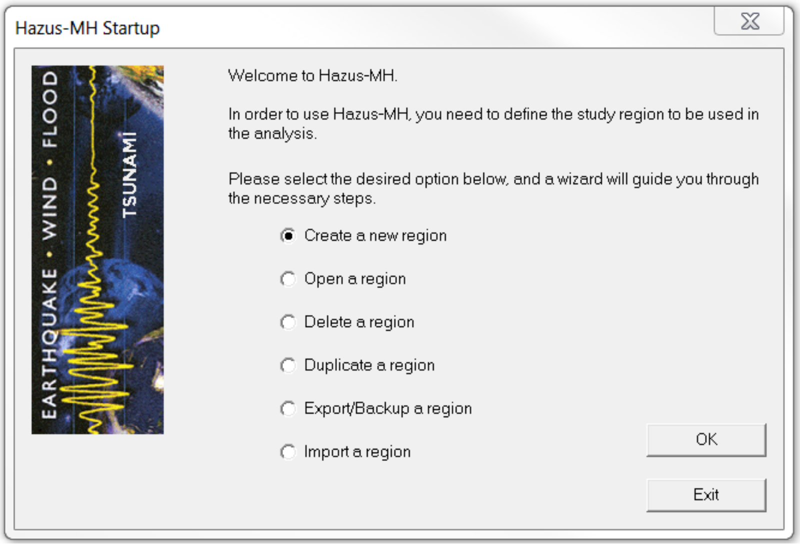
Figure 3.4 Utah State County Boundaries and the Utah ShakeOut ShakeMap PGA Map



3.2 Creating your Study Region

Now that you have determined which Counties to include, you can create your Hazus Study Region. Open Hazus. On the *Hazus-MH Startup* window (**Figure 3.5**), click the *Create a new region* radio button and click *OK*. When the *Welcome to the Create New Region Wizard* window appears, click *Next>* to continue.

Figure 3.5 Hazus-MH Startup Window



This will bring up the *Study Region Name* Window (**Figure 3.6**). Enter a meaningful name for your study region. Note that since the release of Hazus 3.0 and the migration of the Hazus database structure to SQL Server Spatial format, revised database name limitations apply. Your study region name can be no longer than 18 characters, and the use of certain characters (for example, a space or "-") is not allowed. Your study region name will appear on all pdf reports generated from your analysis. Including the optional regional description in the lower box can help differentiate between similar study regions when opening Hazus, but the description will not appear on pdf reports. When the name and optional description have been entered, click *Next>* to continue.

On the *Hazard Type* window (**Figure 3.7**), select the *Earthquake* radio button as your hazard type and click *Next>* to continue. On the *Aggregation Level* window (**Figure 3.8**), you are prompted to select the geographic level of aggregation for your study region; either State, County, or Census Tract. Running an entire State can require a significant amount of processing time and identifying all of the individual census tracts you want to include can be a challenge. The preferred method is to aggregate at the County level. Select the *County* radio button and click *Next>* to continue.

The next window to appear is the *State Selection* window (**Figure 3.9**). If the earthquake you are modeling only impacts one state, you can choose that state from the selection list by clicking on it. If you would like to model impacts to multiple states, select those states by clicking on the first state and selecting any additional states while holding down the *Ctrl* key. Once you have selected all the desired states, click *Next>* to continue.

Figure 3.6 Study Region Name Window

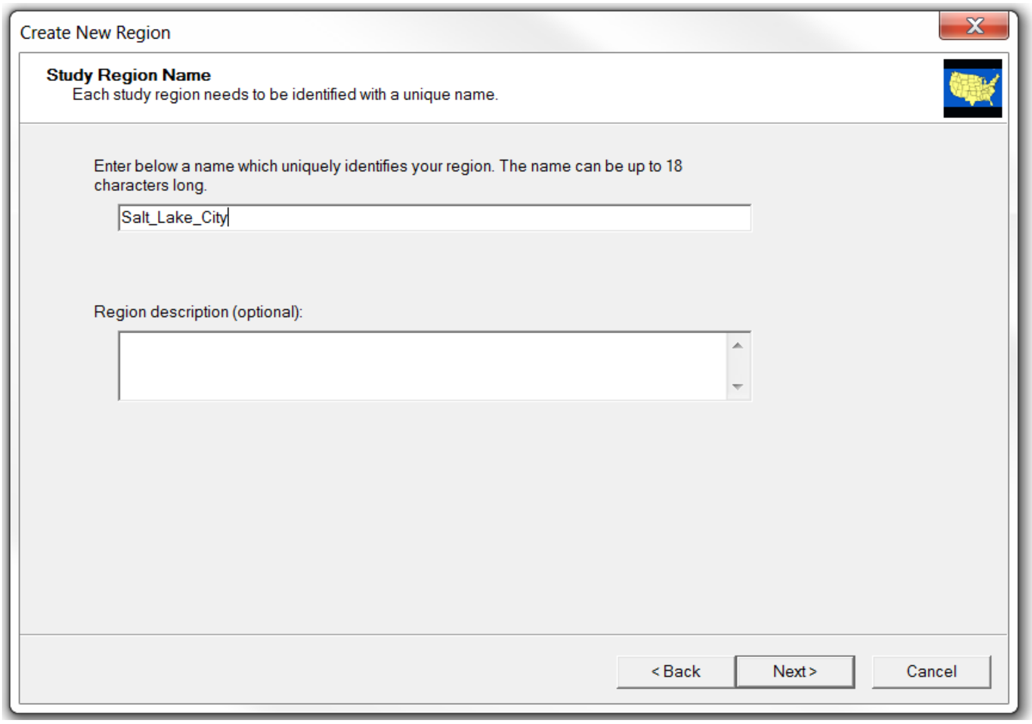


Figure 3.7 Hazard Type Window

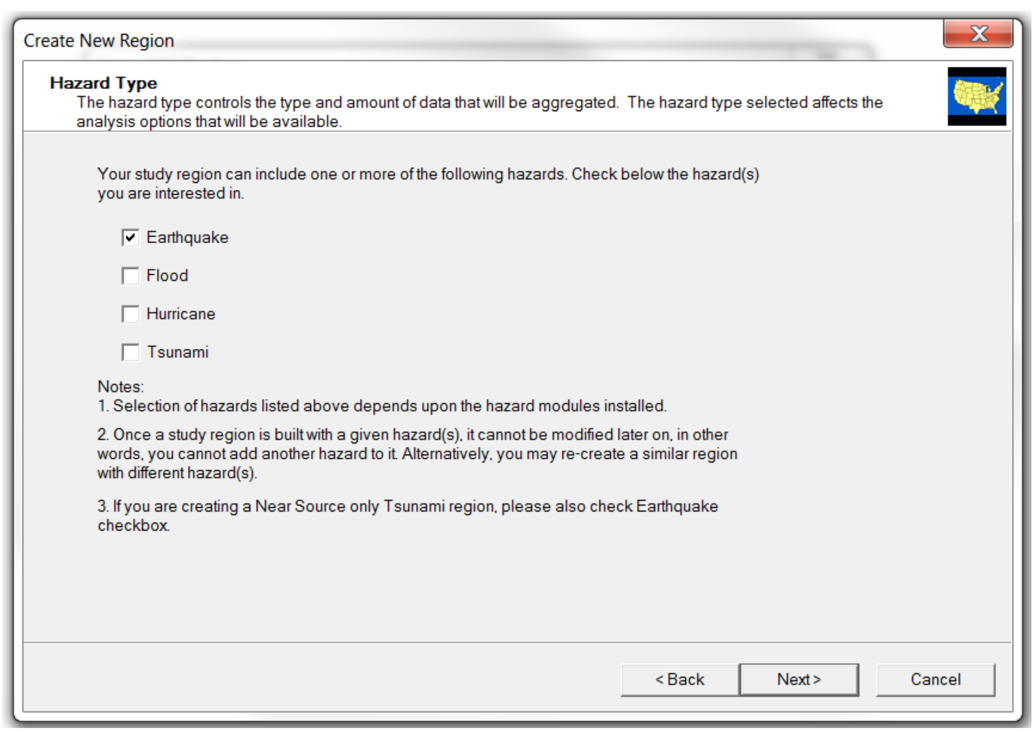


Figure 3.8 Aggregation Level Window

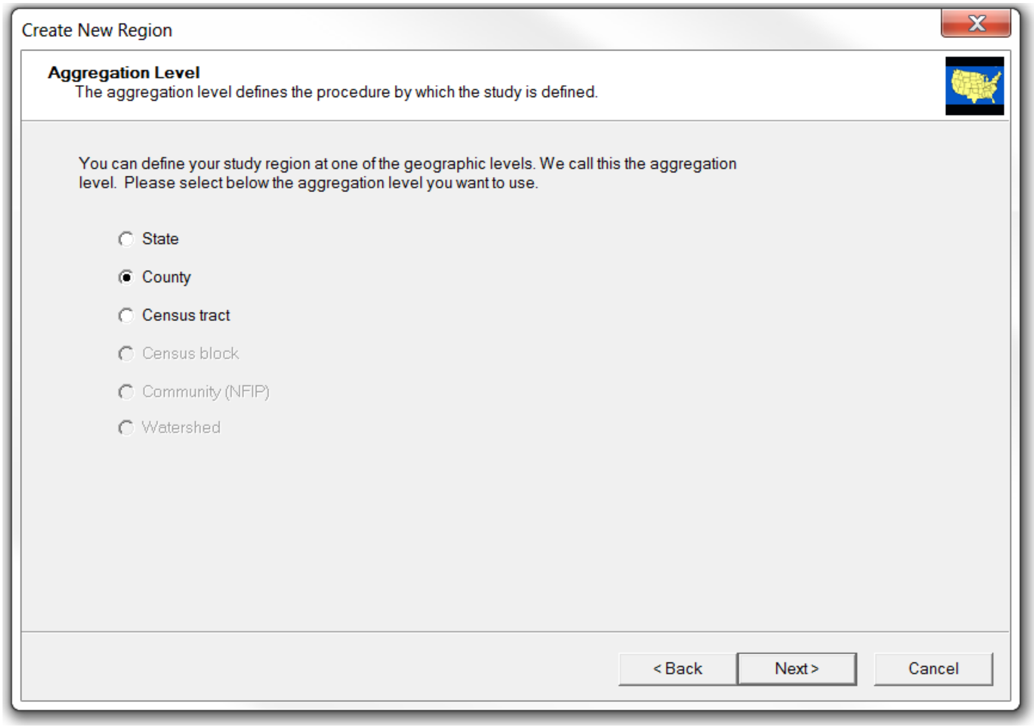
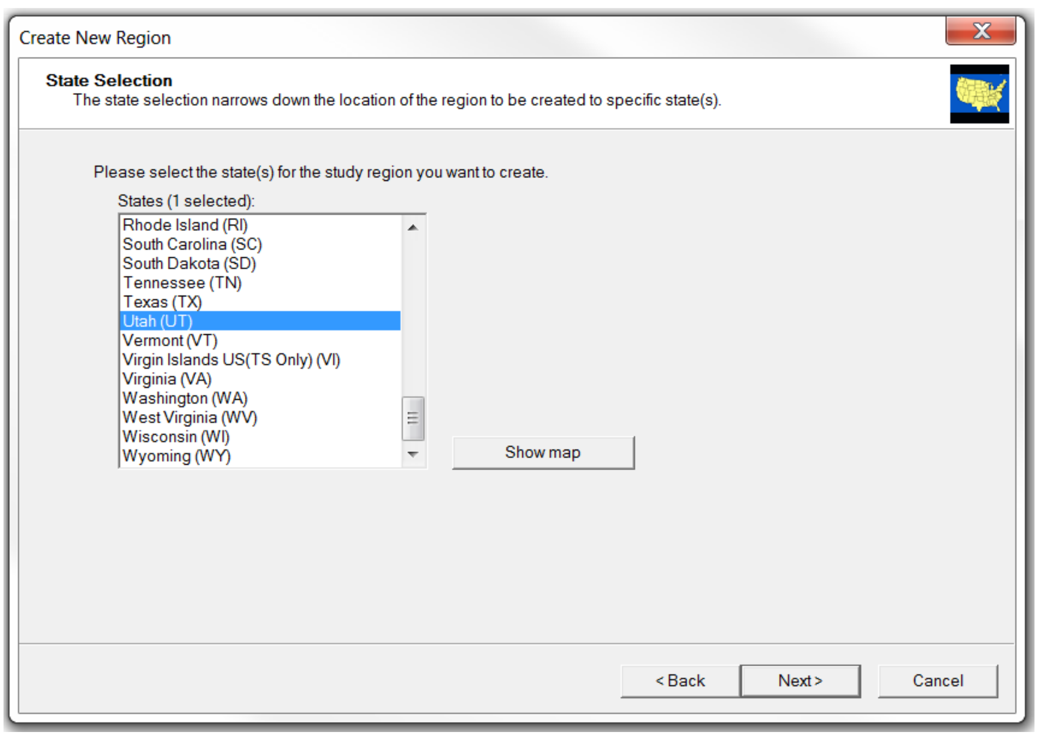


Figure 3.9 State Selection Window



If you selected County as the aggregation level, the next window to appear is the *County Selection* window (**Figure 3.10**). This window will list your selected State(s) on the left, and each State's Counties on the right. If you have one State in your Study Region, that state is already selected (highlighted in blue) in the State list. If you have more than one State in your Study Region, both will appear in the State list, and you may select Counties for inclusion in the Study Region one state at a time. For each State, select Counties by clicking on the County name, holding down the *Ctrl* key for multiple selections, as shown in **Figure 3.10** for the eight counties in Utah identified for ShakeOut scenario example.

Alternatively, you can select Counties geographically by clicking the *Show map* button on the *County Selection* window. This should bring up the map display as shown in **Figure 3.11**. Select each of the desired counties using the selection tool . You can either draw a selection box for the Counties of interest (click and drag) or select Counties individually by clicking on the County while holding down the Ctrl key. Note that hovering the mouse over the County will show its name. Once all Counties of interest have been selected, click the *Selection Done* button. This will return you to the *County Selection* window, and the Counties you selected on the map will be highlighted in the County list. Click *Next>* to continue. This will bring up the *Completing the Create New Region Wizard* window; click *Finish* to proceed. Hazus will now create the Study Region. During Study Region creation, various progress bars will appear on screen; a message box (**Figure 3.12**) will appear on screen once the process is complete.

Figure 3.10 County Selection Window

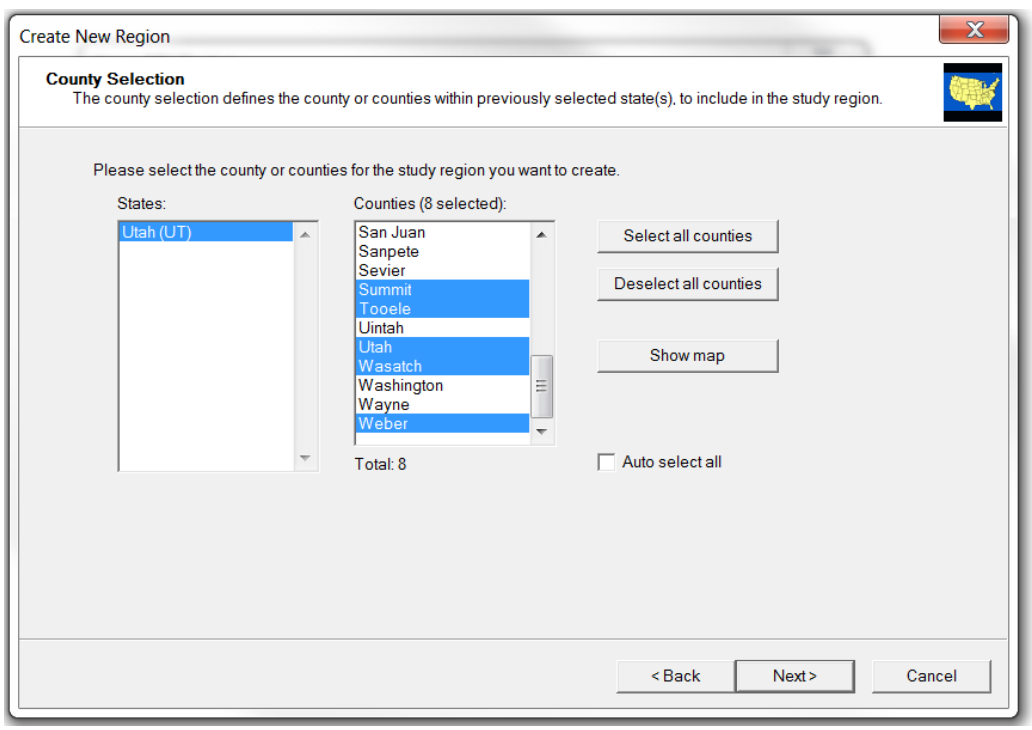


Figure 3.11 County Selection Map Window

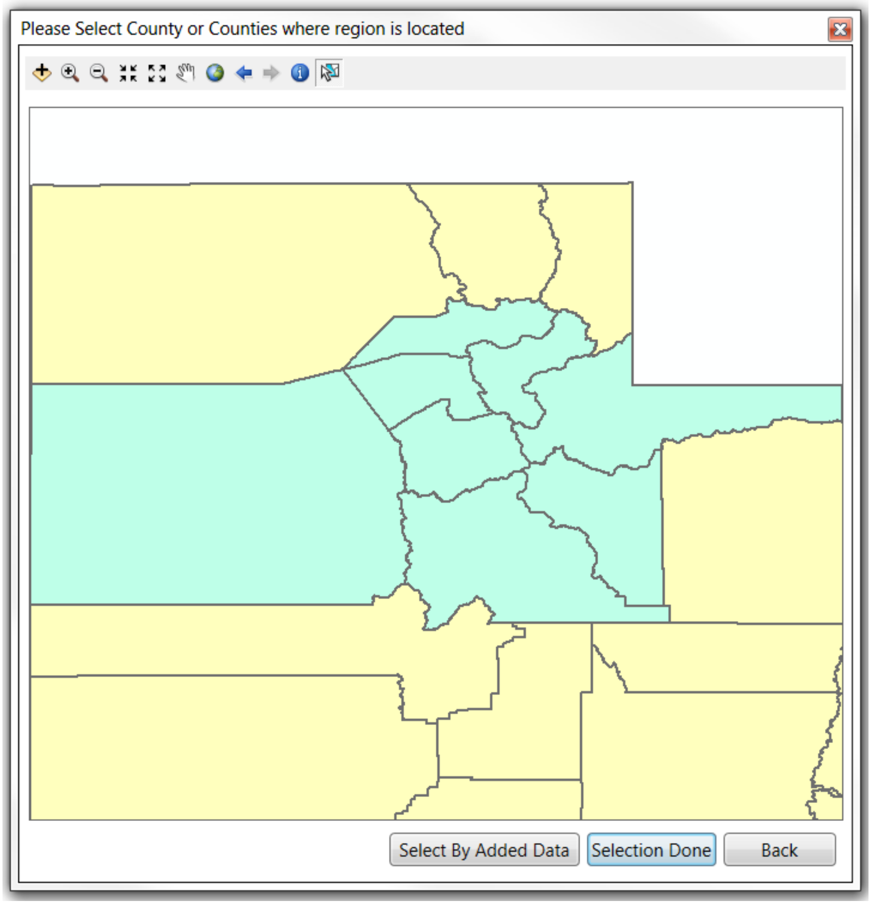
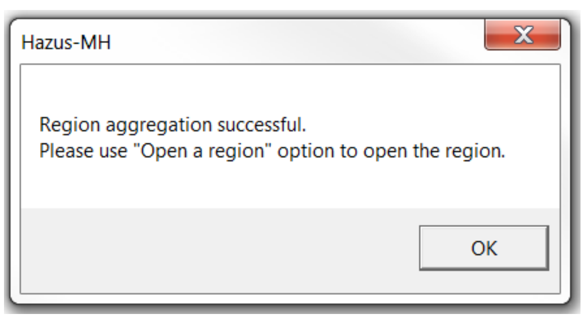


Figure 3.12 Region Aggregation Successful Message



4. Hazard Scenarios

4.1 Different Earthquake Hazard Scenario Options

Hazus has six (6) different options for defining your seismic hazard

1. Historical epicenter – defining your scenario based on a historical event
2. Source event – defining your scenario based on a seismic event from the source event database
3. Arbitrary event – defining your scenario based on fault type, event type, epicenter location, magnitude, depth, width, and fault rupture characteristics, used with an applicable attenuation function
4. Probabilistic hazard – defining your scenario based on return period and magnitude or annualized loss
5. User-supplied hazard – defining your scenario based on user supplied ground motion data.
6. USGS ShakeMap – defining your scenario based on a USGS ShakeMap XML grid file for a recent, historic or scenario event

The preferred method of defining your hazard scenario is option 6 – USGS ShakeMap. In this SOP the means of defining your scenario using the USGS ShakeMap XML grid ground motion data will be covered in detail.

4.2 Defining Your Scenario Using USGS ShakeMap XML grid data

In Hazus 3.2, a new hazard interface was added to the Earthquake Scenario Wizard to allow a user with an internet connection to directly import United States Geological Survey (USGS) ShakeMap products. The Earthquake module has been integrated with USGS ShakeMaps allowing the import of ground motion maps from significant earthquake events. If a user does not wish to use the new direct import functionality, the Earthquake module also preserves the ability for users to import their own Hazus-compliant ShakeMap data. Instructions for how to import ShakeMap XML grid data are provided below; instructions for importing USGS ShakeMap data as "User-supplied hazard" may be found in the recently updated *Hazus Earthquake Model User Guidance* document.

4.2.1 ShakeMap Overview

ShakeMap is a product of the USGS Earthquake Hazards Program in conjunction with regional seismic networks. The ShakeMap website (https://earthquake.usgs.gov/data/shakemap/) provides near-real-time maps and digital data of ground motion and shaking intensity following significant earthquakes, as well as predicted ground motions for hypothetical scenario events. In actual earthquakes, the ShakeMap may incorporate instrumental recordings of ground motions, as well as felt reports and detailed source parameter information, ensuring that the ShakeMap is the best product to use for loss estimation modeling in actual earthquakes. The loss estimates produced using ShakeMap data within Hazus can assist emergency personnel to respond appropriately in areas of immediate need. Federal, state, local agencies, and non-profits organizations uses these maps for post-earthquake response and recovery, public and scientific information, preparedness exercises, and disaster planning.

A ShakeMap is a representation of the ground shaking produced by an earthquake. ShakeMaps already consider amplification based on local soil conditions, so incorporating a soils layer is not necessary when ShakeMaps are used. The information it presents is different from the earthquake magnitude and epicenter that are reported after an earthquake, because ShakeMap focuses on the ground shaking produced by the earthquake, rather than the parameters describing the earthquake source. So, while an earthquake has one magnitude and one epicenter, it produces a range of ground shaking levels at sites throughout the region depending on distance from the earthquake, the rock and soil conditions at sites, and variations in the propagation of seismic waves from the earthquake due to complexities in the structure of the Earth's crust. More detailed scientific information for these maps can be found at USGS ShakeMap website.

The ground motion map types required by Hazus for loss estimation analysis are:

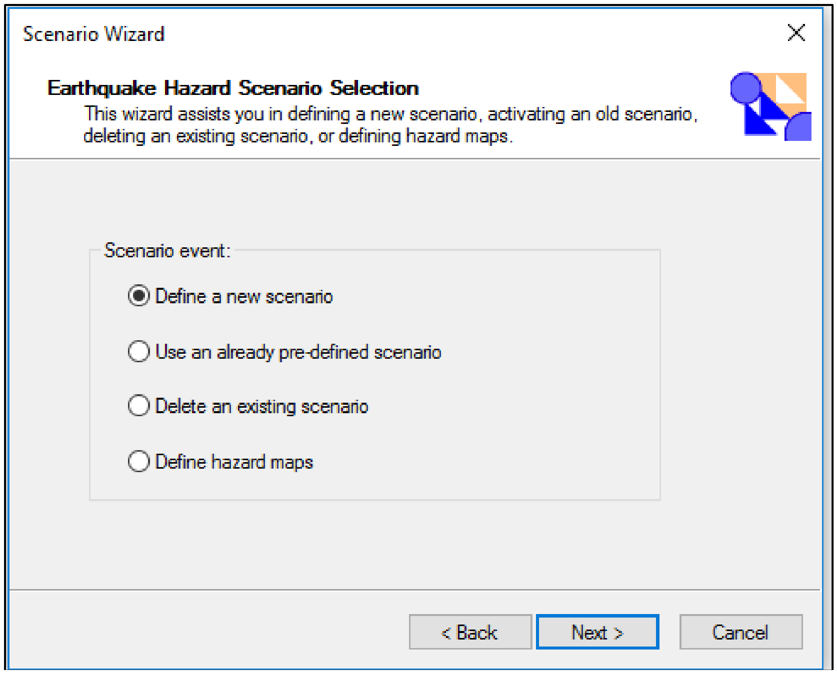
- Peak Ground Acceleration (PGA) Maps, in units of gravity (g)
- Peak Ground Velocity (PGV) Maps, in units of inches/second (in/sec)
- Spectral Response Maps at 0.3 seconds (SA 0.3), in units of gravity (g)
- Spectral Response Maps at 1.0 seconds (SA 1.0), in units of gravity (g)

4.2.2 Using the ShakeMap Download Interface in Hazus

Once the study region has been created, use the following steps to acquire the appropriate ShakeMap.

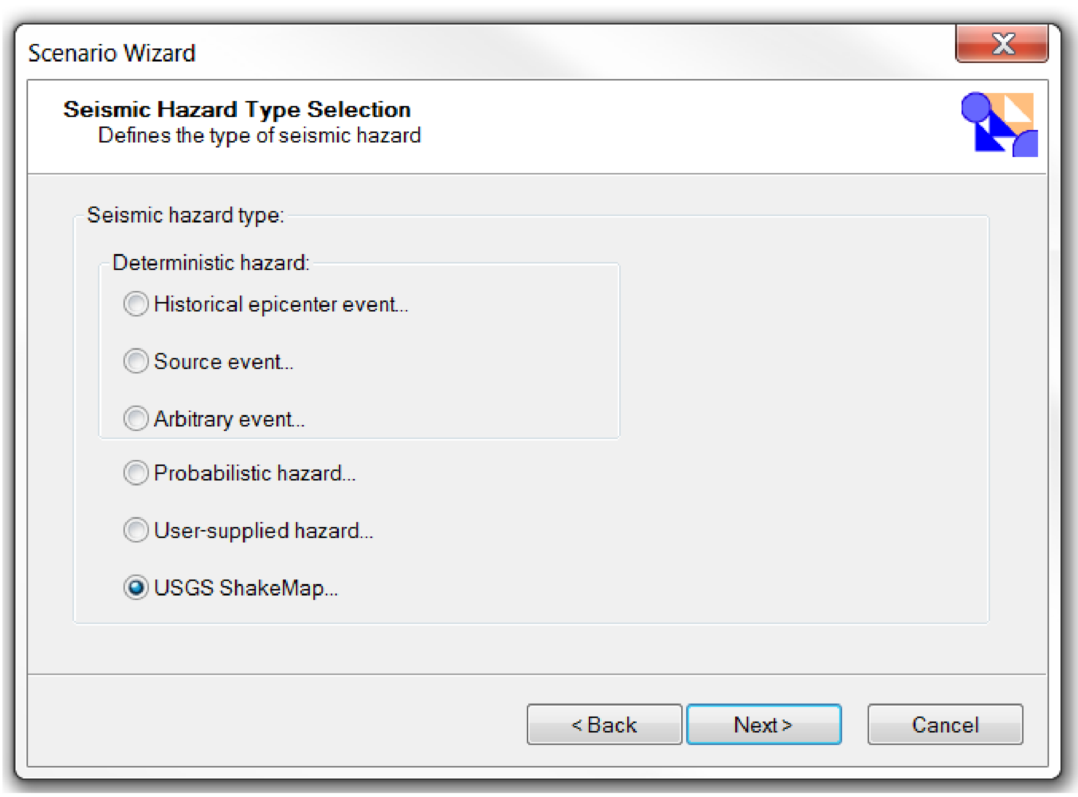
1. In the study region, go to *Hazard --> Scenario--> Next* and choose *Define a new Scenario* as shown in **Figure 4.1.** Click *Next>* to continue.

Figure 4.1 Earthquake Hazard Scenario Selection Window



2. On the *Seismic Hazard Type Selection* Window (**Figure 4.2**), choose *USGS ShakeMap…* and click *Next>* to continue**.**

Figure 4.2 Seismic Hazard Type Selection Window



3. The *ShakeMap Download* window will open (**Figure 4.3**). It may take a few moments for Hazus to search the USGS website for available ShakeMap data before the window appears. During this time, users may see a progress window (**Figure 4.4**). When the *ShakeMap Download* window opens, by default, the *ShakeMap Events* radio button will be selected in the upper left. Users can select a ShakeMap event for download from the left pane (recent earthquakes meeting the search various criteria identified at the top right will automatically appear in the list in the left pane), click the *ShakeMap Scenarios* radio button in the upper left to generate a list of applicable scenarios (**Figure 4.5**), or adjust the search parameters as needed to capture an event of interest. When the *ShakeMap Scenarios* option is selected, the *Earthquake Time Frame* search parameters are not applicable and will be removed from the menu. For each ShakeMap, the *Selected ShakeMap Properties* window includes the event's url; clicking the url will take you to the USGS event webpage which is particularly helpful for selecting an appropriate scenario. Highlighting an event in the left pane will display the properties and details in the two windows on the middle and lower right.

   In addition to adjusting the search parameters, the user can also make several other adjustments. Just above the *Selected ShakeMap Properties* pane, there are two *Study Region Upload Options* (*Exclude Gridcells Outside Study Region* and *Overwrite Existing ShakeMap Grid Data*); by default, both of these options are checked. It is recommended that you keep these default settings. There is also an *Earthquake Direction* option, which is checked, by default, to select *Apply Geomean*. Checking this box reduces the input ShakeMap standard peak ground motions by 15%. Geomean ground motions are the Hazus standard (the original USGS ShakeMap "hazus.zip" file applied a 15% reduction to peak ground motions to approximate geomean specifically for use in Hazus), and recent studies for the Hazus 2PAGER product have confirmed that geomean ground motions produce loss estimates that are in better agreement with recent historic events than peak motions. Accordingly, it is recommended that the *Apply Geomean* box remain checked.

Figure 4.3 ShakeMap Download Window - ShakeMap Events

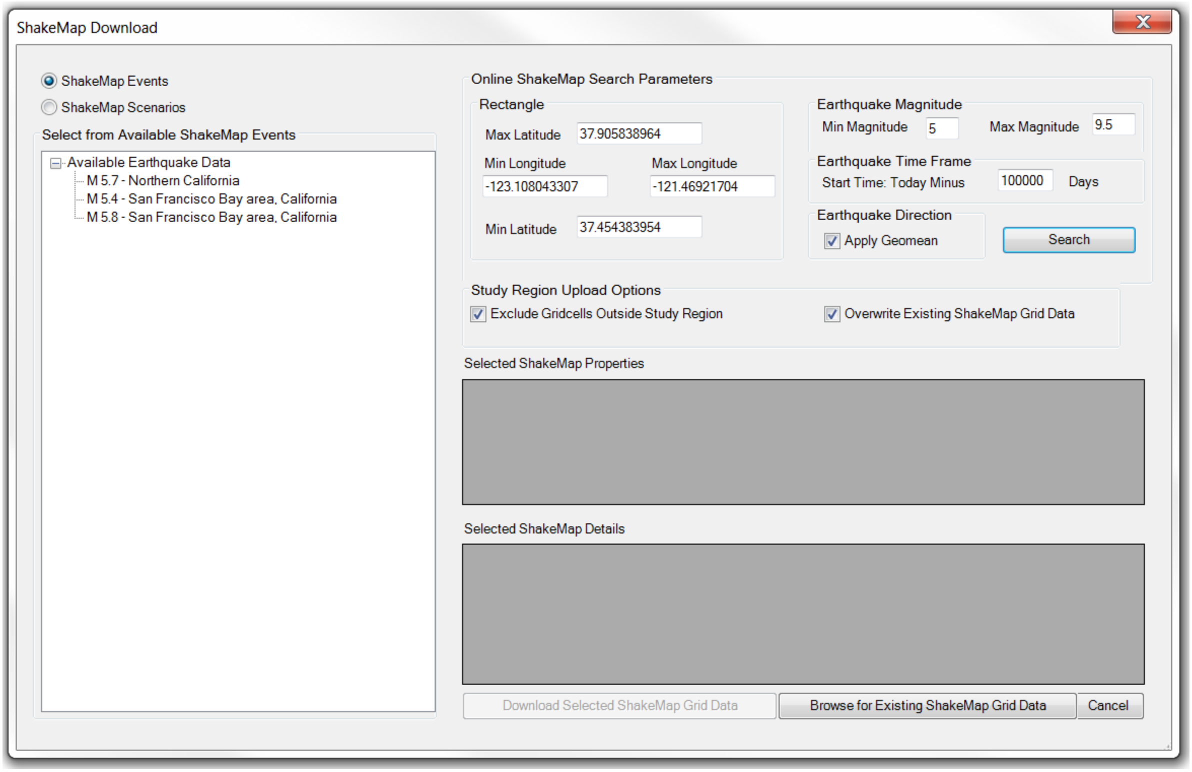


Figure 4.4 ShakeMap Event List Processing Message

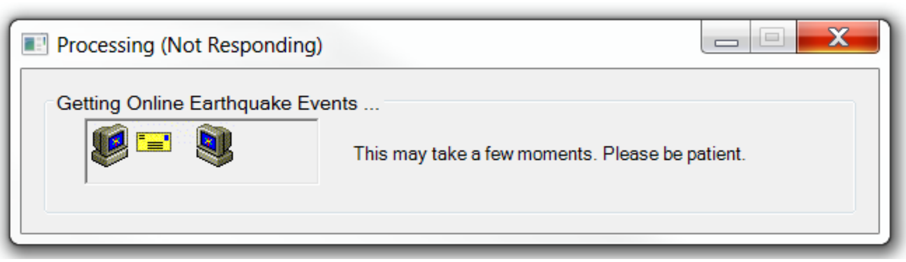
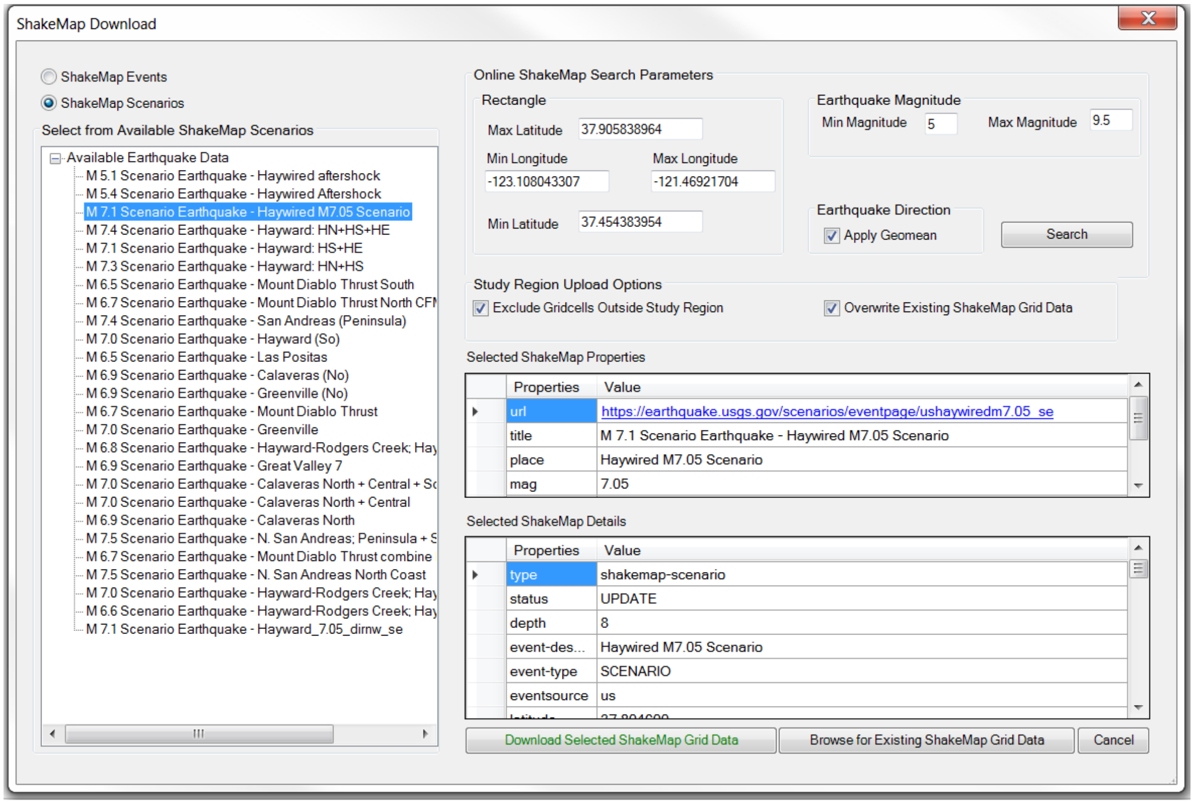


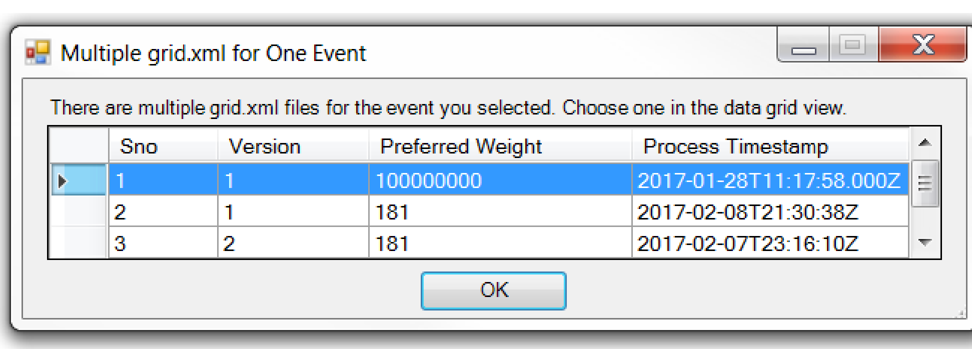
Figure 4.5 ShakeMap Download Window – ShakeMap Scenarios



For some events, the USGS may offer multiple grid files for download. In this case, a popup window (*Multiple grid.xml for One event*) will appear with a list of available files (**Figure 4.6**) asking the user to select one. A "preferred weight" value is provided for each file, and it is recommended the user select the largest preferred weight.

If a grid.xml file has been downloaded (for a catastrophic planning scenario for instance) and is stored on the local machine, users can browse to its file storage location for import using the *Browse for Existing ShakeMap Grid Data* button at the bottom of the *ShakeMap Download Window*.

Figure 4.6 ShakeMap Multiple grid.xml for One Event Window



4. Once an event is selected in the pane on the left (**Figure 4.7**), click *Download Selected ShakeMap Grid Data* to import the ShakeMap data into Hazus. For some ShakeMaps, a progress notice may appear to indicate the download is taking place (**Figure 4.8**). Although this progress message may indicate that Hazus is not responding, it does not mean the download has stopped. Please be patient; download and processing time will vary depending on the size of the event file and the speed of the user's internet connection.

Figure 4.7 ShakeMap Download Window with Available Grid Data

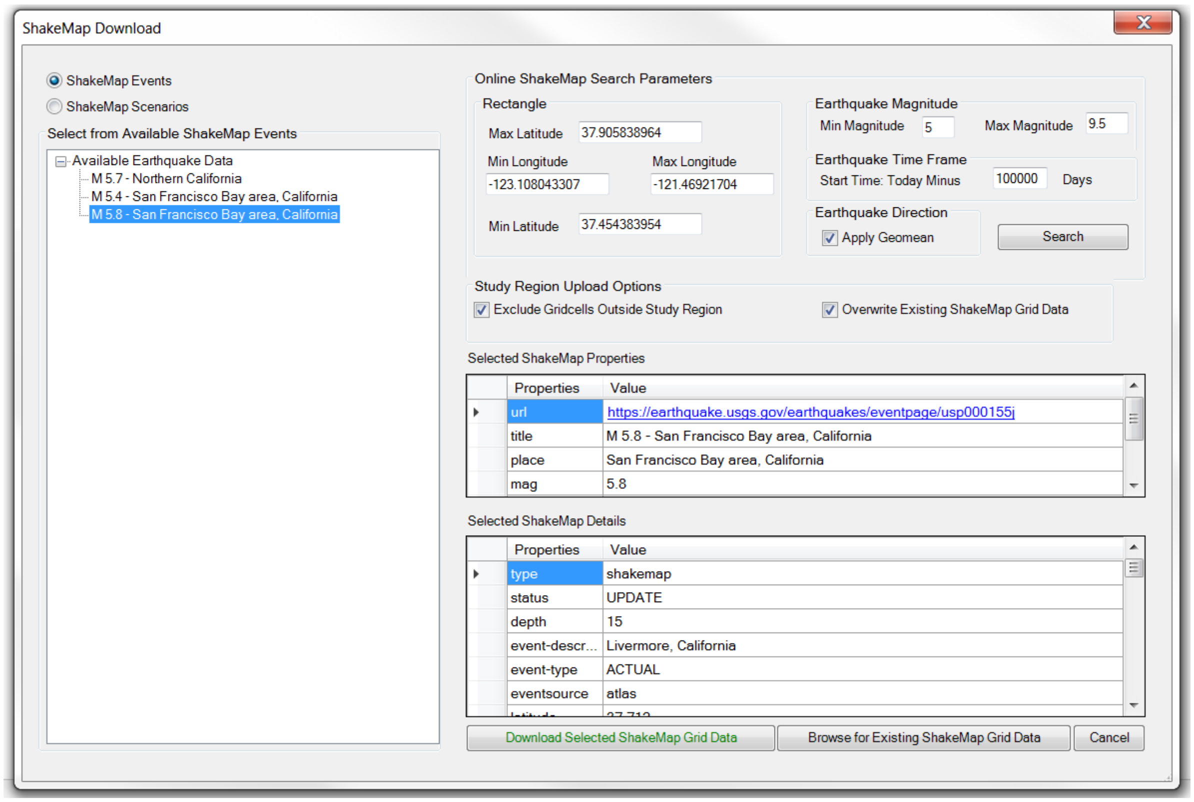


Figure 4.8 ShakeMap Download Processing Message

5. Once the download is complete, the *User-defined Hazard Option Window* (**Figure 4.9**) will open, automatically populated with ground shaking map layer names and the event magnitude. The user will need to confirm the remaining event parameters imported from ShakeMap before completing the wizard; clicking *Next>* will bring up

the *Hazard Scenario Event Name* window (**Figure 4.10**), automatically populated with the event name from the ShakeMap data. The event name will include the event magnitude, location, and the ShakeMap version number. Tracking the version number is particularly important when sharing results, as significant events (or events in areas with limited seismic instrumentation) may have multiple ShakeMap releases which could produce highly variable loss estimates. Clicking *Next>* again will bring up the *Completing the Scenario Definition Wizard* Window (**Figure 4.11**), which summarizes the ShakeMap scenario settings. Click *Finish* to complete the scenario definition.

Figure 4.9 ShakeMap User-Defined Hazard Options Window

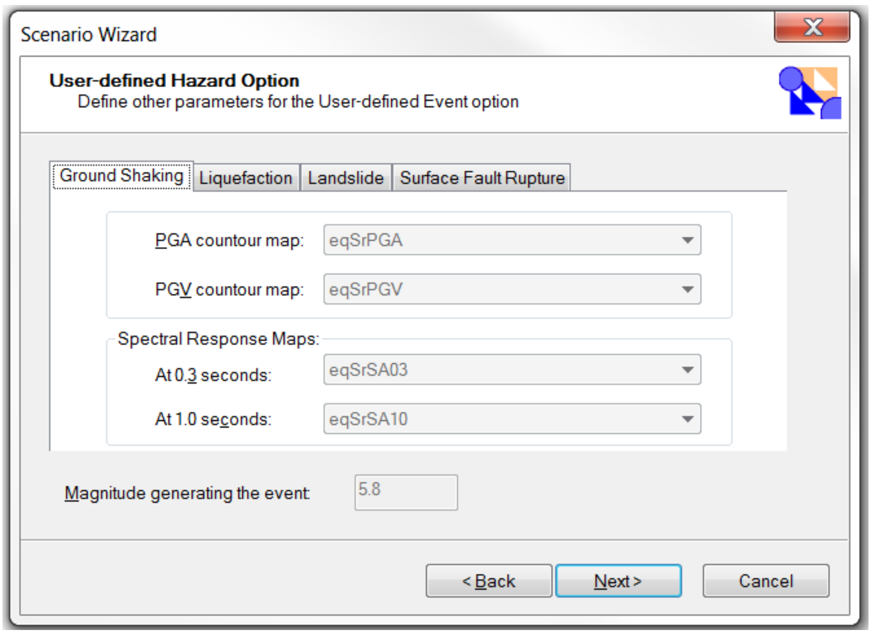


Figure 4.10 ShakeMap Hazard Scenario Event Name Window

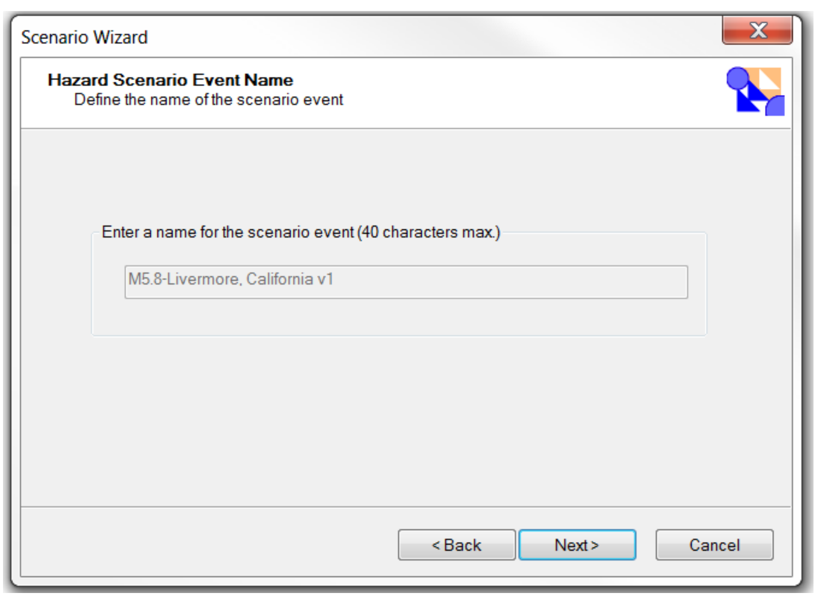
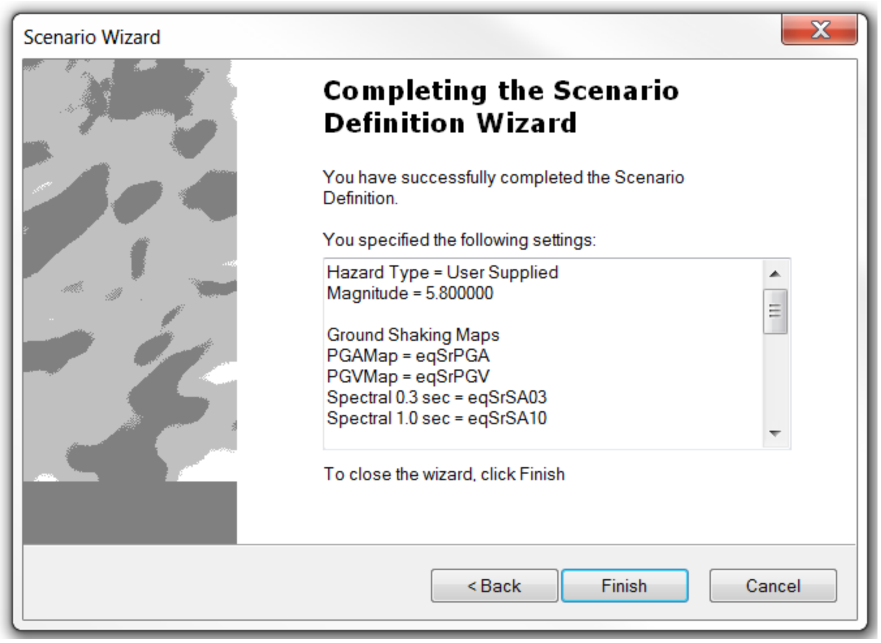


Figure 4.11 Completing the Scenario Definition Wizard Window



It should be noted that USGS may limit the types of ShakeMap data available for download into Hazus. By default, Hazus will search for events occurring within the last 90 days, with a magnitude of 5.0 or greater. The 90-day window and the geographic window can be manually adjusted within Hazus (see Step 3 above), however it may benefit the user to check the USGS "Latest Earthquakes" page (https://earthquake.usgs.gov/earthquakes/map/) for event availability prior to creating a study region (scenario ShakeMaps may be found as described in **Section 1**). It may also be the case that a ShakeMap of interest may not be discovered by the Hazus ShakeMap download tool due to incompatibility of the study region boundary and the geography of the ShakeMap.

4.3 Hazard Data Layers

If you have additional hazard data available for your scenario (e.g., liquefaction susceptibility, landslide susceptibility, soils, groundwater depth, etc.), you should add it at this time.

Open the study region you have created. To add your hazard data (formatted according to the instructions in Section 2.3), go to *Hazard --> Data Maps*. On the *Data Maps Dialog* window (**Figure 4.12**), click on *Add map to list…*, and navigate to location of the ArcGIS personal geodatabase containing your hazard map(s). On the *Data Map Attributes* window (**Figure 4.13**), type a name for hazard layer you plan to use ("LiqSusc", for example), choose the corresponding map type from the *Map type* pull-down list, and highlight the *Table name* corresponding to the data in your geodatabase.

Figure 4.12 Data Maps Dialog Window

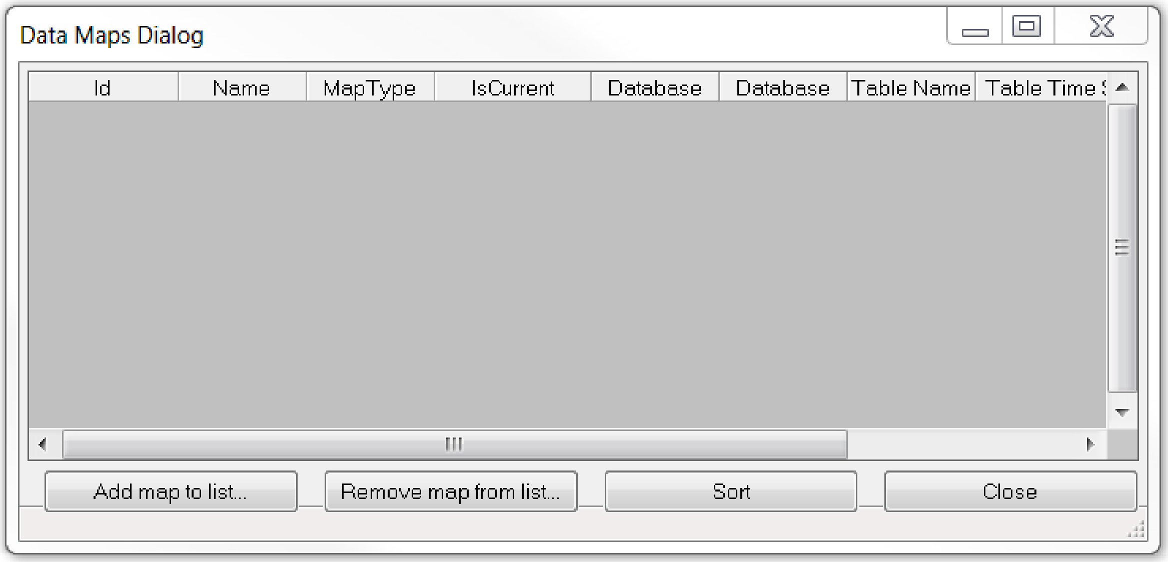
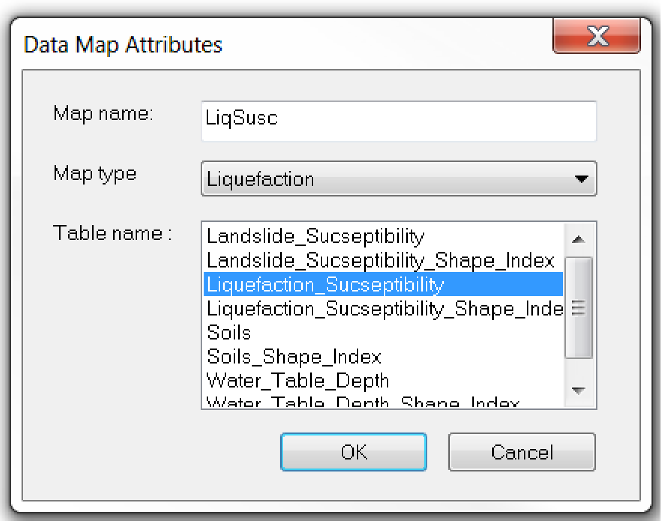


Figure 4.13 Data Map Attributes Window



Repeat this process for each hazard map you want to add. Once all of your hazard maps are added, close the data maps dialog box and link them to your scenario by going to *Hazard --> Scenario… --> Next > --> Define hazards maps* (**Figure 4.14**) --> *Next >*. From the *Define Hazard Maps Option* window (**Figure 4.15**), select any hazard maps you have added from the pull-down list under each map type.

Figure 4.14 Earthquake Hazard Scenario Selection Window

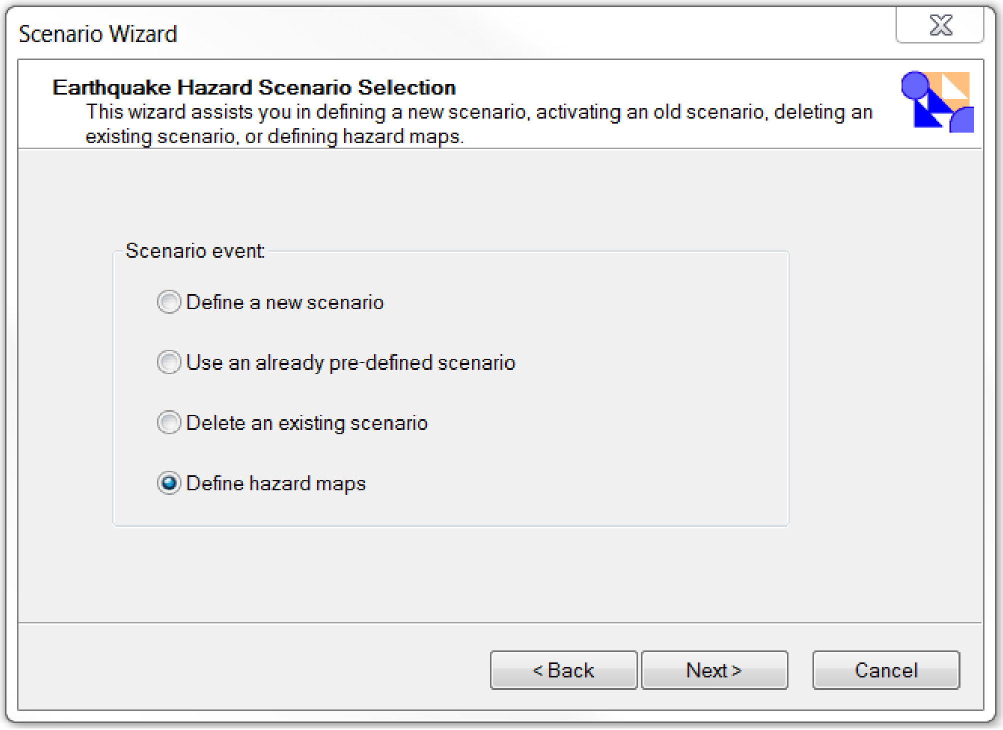
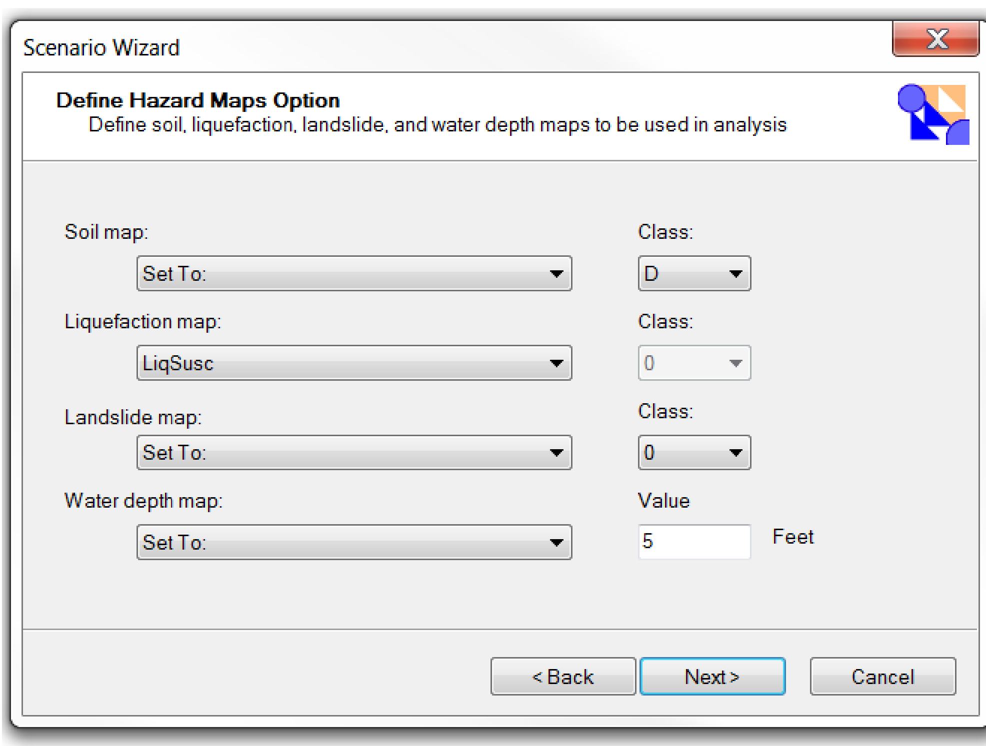
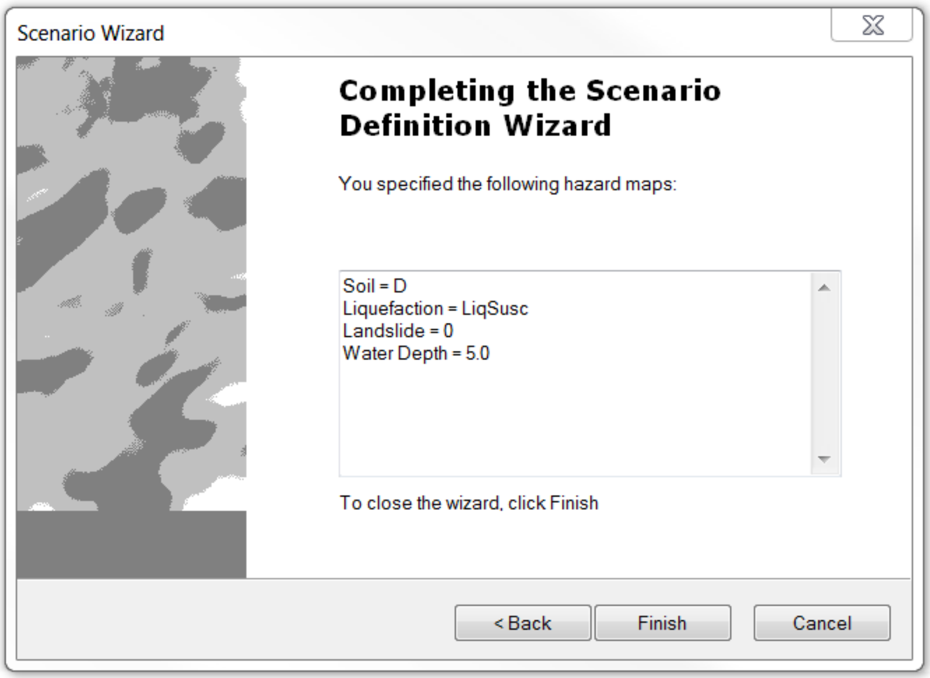


Figure 4.15 Define Hazard Maps Option Window



Once you've selected each of your hazard maps, click *Next >* to continue and you will be given a chance to review a summary of your hazard map settings (**Figure 4.16**). You should see the table name for any data map that you've added (e.g., "LiqSusc" for Liquefaction), and the default values for any map for which data was not added (e.g., 0 for Landslide). Once you've reviewed the settings click *Finish*. Hazus will now execute a review process which clips your hazard map to the Study Region limits and populates various tables. If your study area is large, this process could take a while. Once this process is complete, you've successfully attached your hazard data to the Study Region. Current hazard maps may be viewed by going to *Hazard --> Show Current --> Current Hazard Maps*, clicking on the Map type in the left-hand column, then clicking the Map button. Click Close to view your selected map(s) on screen.

Figure 4.16 Completing the Scenario Definition Wizard Window



Once your scenario has been defined, and all hazard maps are incorporated, you are ready to run the analysis. To execute the analysis, go to *Analysis --> Run…* to bring up the *Analysis Options* window (**Figure 4.17**). Select the analysis modules you wish to run either by clicking the *Select All* button or by selecting individual modules you wish to run by clicking in the box to the left of each module name. If you *Select All* modules, you will be prompted and asked if you want to create contour maps. This process can take several hours, so it is recommended that you skip this process. If contour maps are desired, you can always come back and run them later. Once you have selected the desired analysis modules, click *OK* to proceed, and then click *Yes* to confirm your analysis options (**Figure 4.18**).

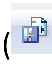
When the analysis is complete, Hazus will open a message box indicating the length of time the analysis required (**Figure 4.19**). At this point, you may explore the results from within Hazus, or use the *Hazus Export Tool* to export a pre-selected set of data and results as described in the next section. It is strongly recommended that you export the Hazus "Global Summary Report" for reference. Go to *Results* → *Summary Reports…* (**Figure 4.20**), click on the *Other* tab (**Figure 4.21**), then click on *Global Summary Report* and click *View* to generate the report. It may take a few minutes for Hazus to generate the 22-page "Global Summary Report" (**Figure 4.22**), which may be exported as a PDF file. To export the file, click on the Export Report button () in the upper left-hand corner to bring up the *Export* window (**Figure 4.23**). Click *OK* to bring up the *Export Options* window (**Figure 4.24**) and click *OK* to choose the location and file name for the report. Other reports that may be of use are the *Potable Water System Performance Report* (accessible from the *Lifelines* tab, *Performance* sub-menu) and *Debris Generated Report* (accessible from the *Induced* tab).

Figure 4.17 Analysis Options Window

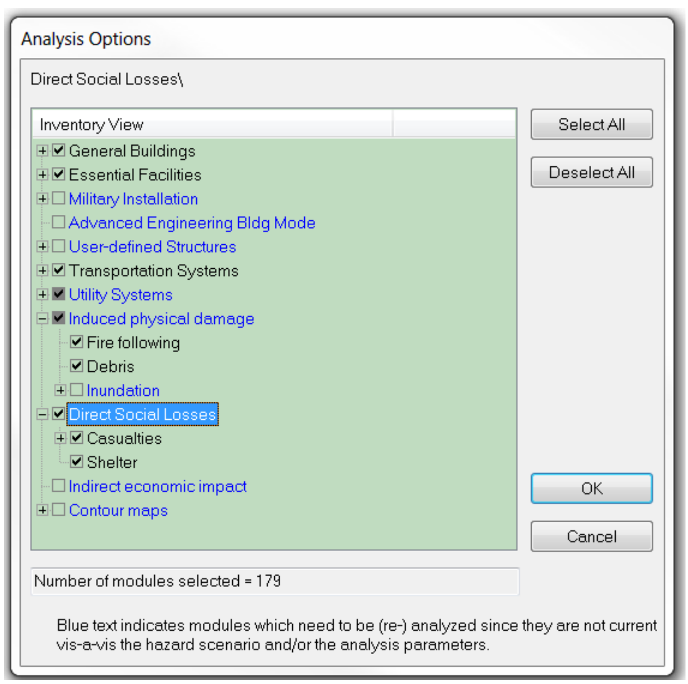


Figure 4.18 Confirm Analysis Options Window

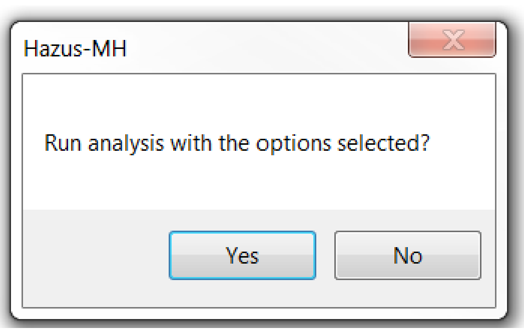


Figure 4.19 Analysis Completion Message

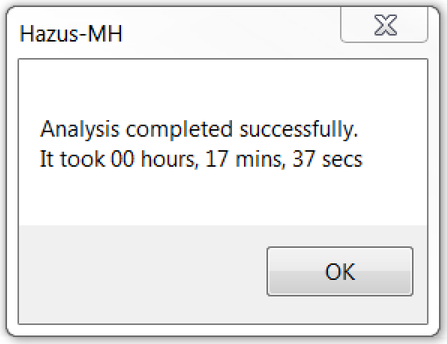


Figure 4.20 Earthquake Summary Reports Window (Inventory Tab)

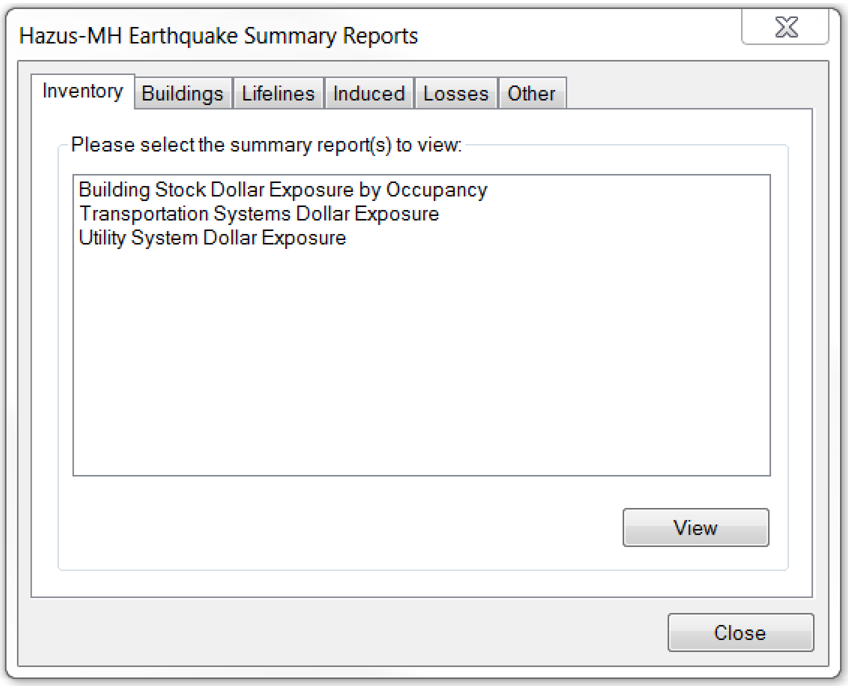


Figure 4.21 Earthquake Summary Reports Window (Other Tab)

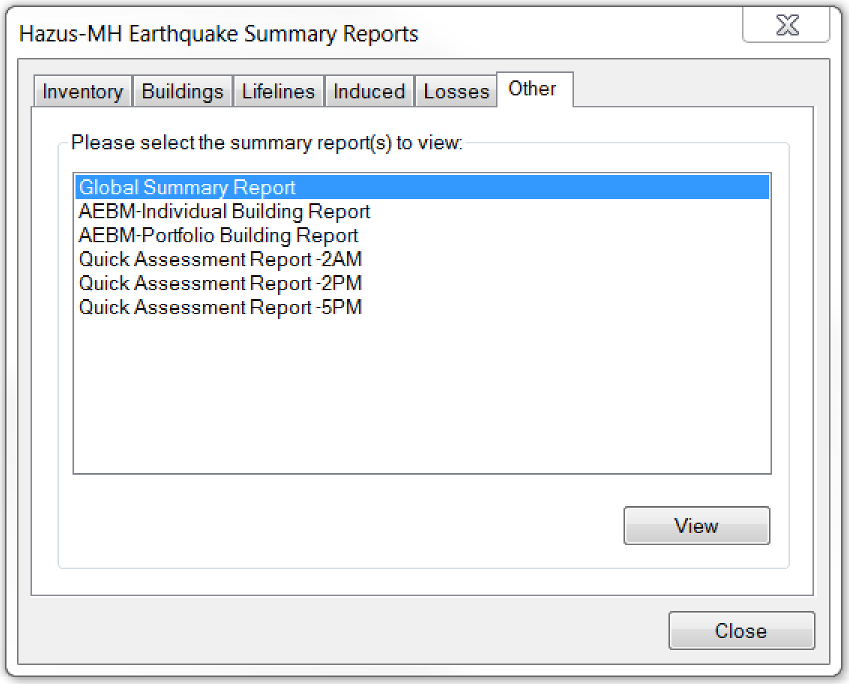


Figure 4.22 Global Summary Report Window

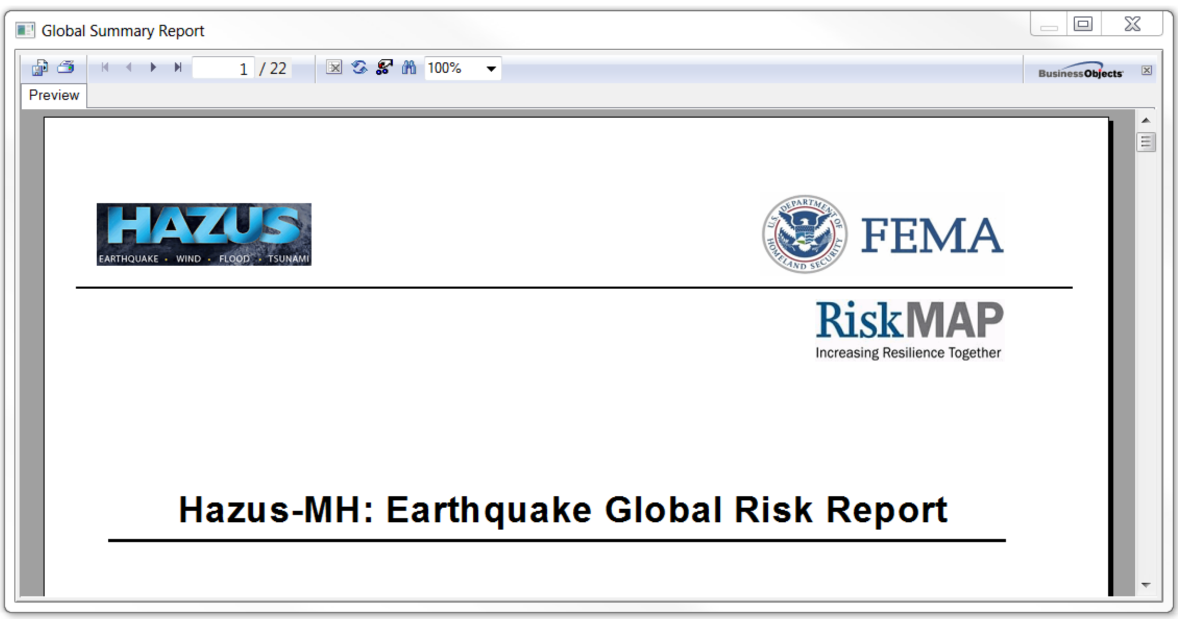


Figure 4.23 Export Report Window

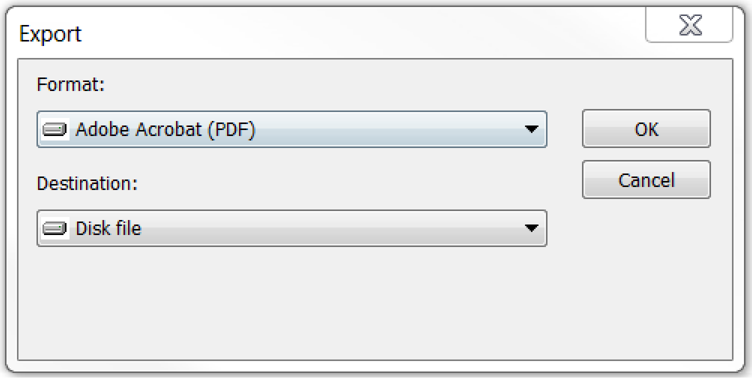
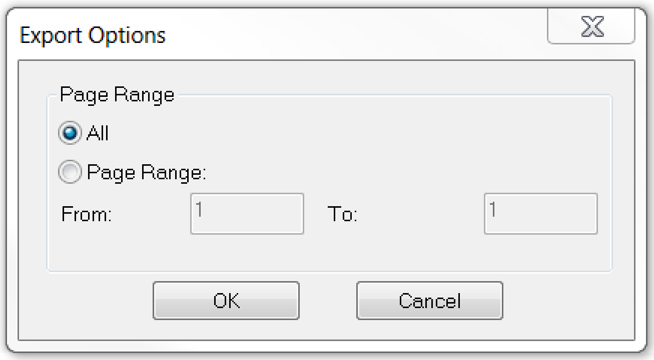


Figure 4.24 Export Options Window



5. Data Preparation

5.1 Use of the FEMA Hazus Export Tool

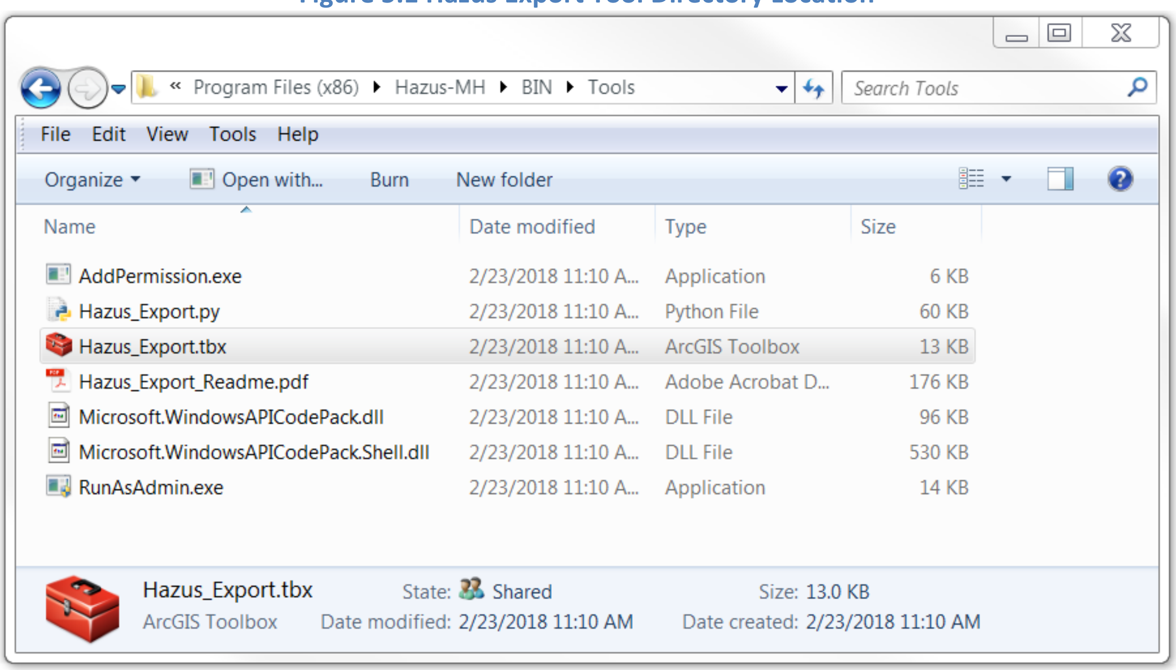
Description / Intent:

To facilitate mapping of Hazus results outside of Hazus, FEMA Region VIII (Jesse Rozelle, Austen Cutrell and Jordan Burns) created the *Hazus Export Tool* to export GIS layers and other data from completed Hazus study regions. The tool is compatible with Hazus versions 3.1, 3.2, 4.0, and 4.2. It currently works for the Hazus flood[6], earthquake, and hurricane models; Hazus Tsunami model export functionality will be added in late 2018. The current version of the *Hazus Export Tool* is Version 6.0, released 12/21/2017.

Instructions:

The *Hazus Export Tool* is provided with the Hazus software and can be found in the "C:\Program Files (x86)\Hazus-MH\BIN\Tools" directory (**Figure 5.1**). It is provided as an ArcGIS tool that is automatically added to the ArcGIS Toolbox by Hazus, when Hazus is in use. It can also be run directly using Python. In order to use the export tool, make sure that the python script (Hazus_Export.py) and ArcGIS Toolbox file (Hazus_Export.tbx) are located in the same folder.

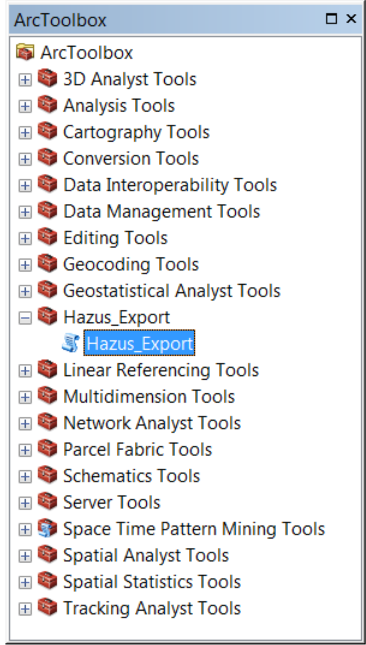
Figure 5.1 Hazus Export Tool Directory Location



[6] If using the export tool for Hazus flood results, note that the exported results are only valid for a **single return period** flood event.

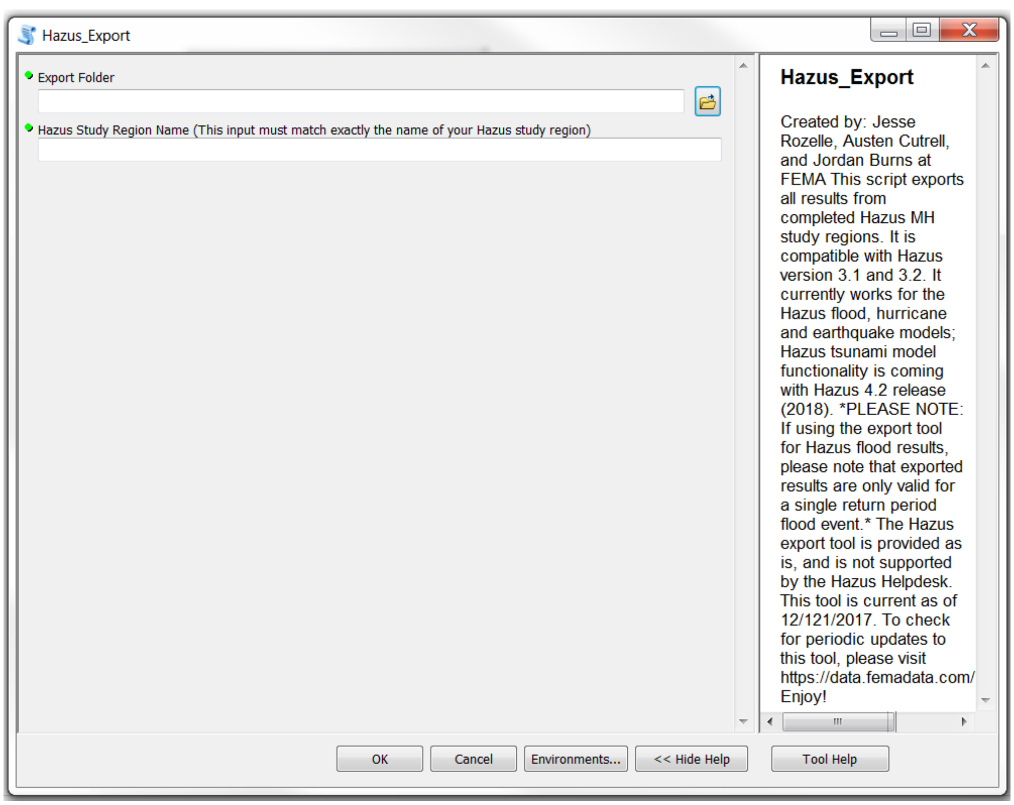
1) When Hazus is in use, the *Hazus Export Tool* can be accessed from ArcToolbox, as shown in **Figure 5-2**.

Figure 5.2 ArcToolbox Including Hazus Export Tool



2) Double click on the *Hazus Export Tool* (*Hazus_Export*) inside the toolbox to launch the tool and bring up the *Hazus_Export* Window (**Figure 5.3**).

Figure 5.3 Initial Hazus Export Window



3) Click on the *Browse File* button and navigate to the export folder where you would like your geodatabase of results to be stored, and then enter the name of the study region from which you would like to export results (**Figure 5.4**). Note that the study region name must be identical to the name used in Hazus. Click *OK* to begin the export process. Progress will be reported to the screen, as shown in **Figure 5.5**. Once the export has been successfully completed (**Figure 5.6**), click *Close* to exit the *Hazus Export Tool*.

Figure 5.4 Hazus Export Tool Window with Export Folder and Study Region Specified

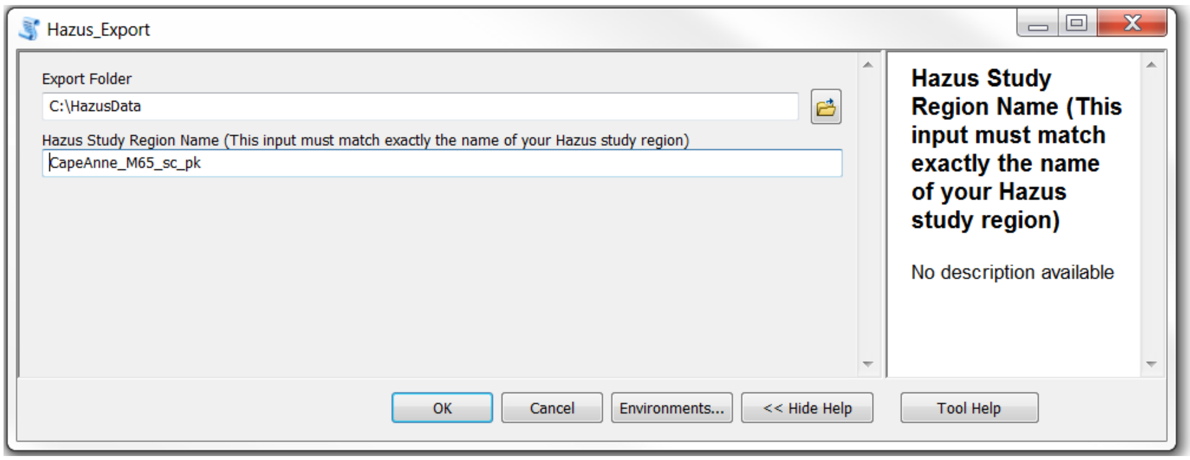


Figure 5.5 Hazus Export Execution Reporting – In Process

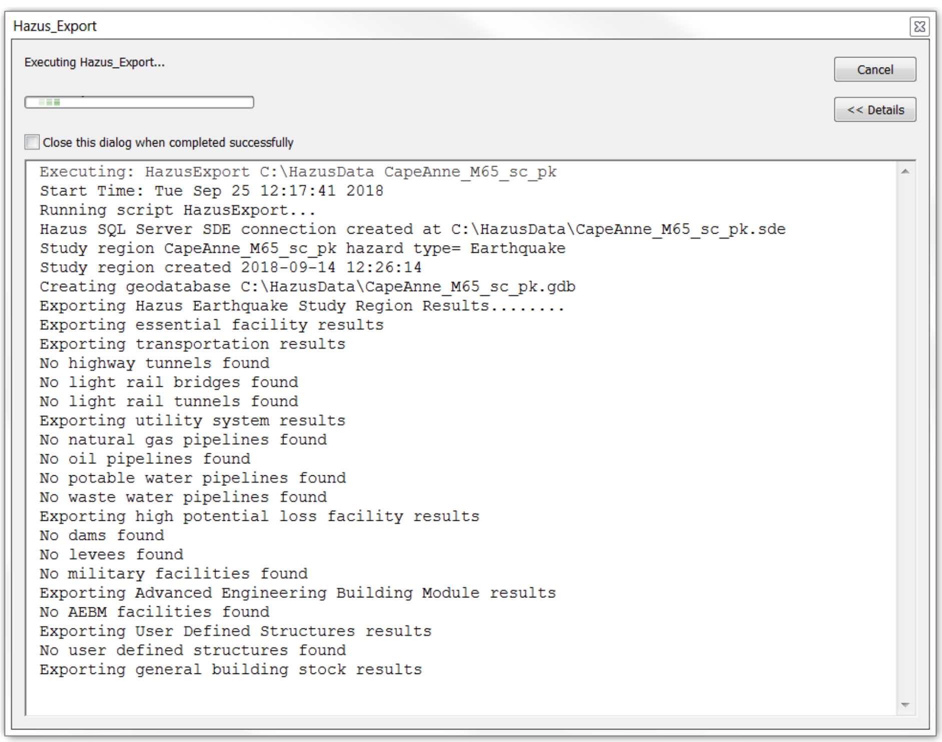
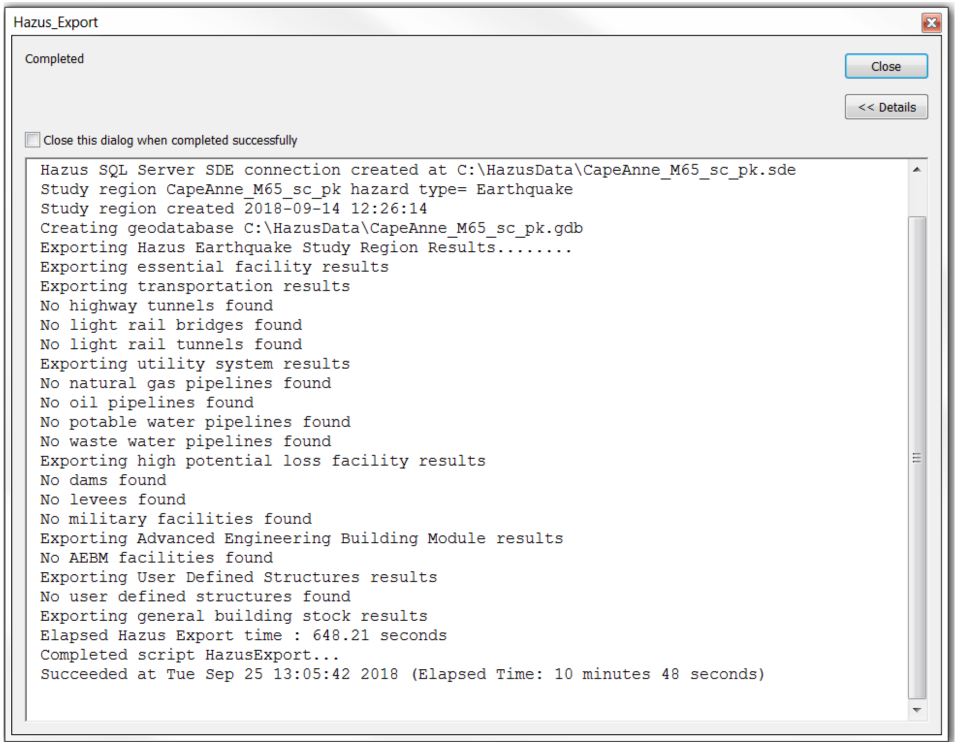
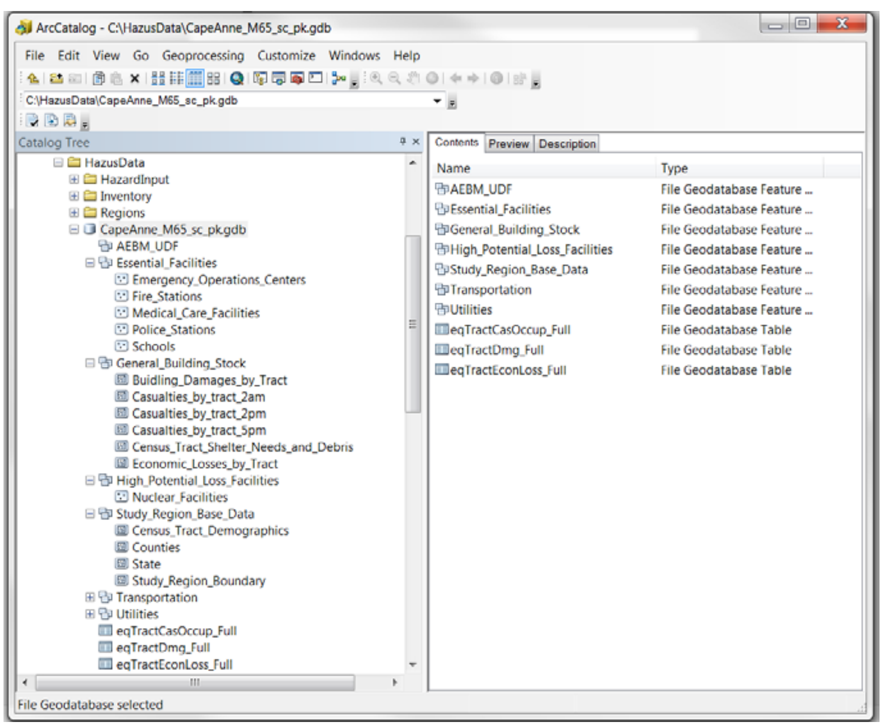


Figure 5.6 Hazus Export Execution Reporting - Completed



4) The *Hazus Export Tool* will export results for all modules that have been executed in the selected Hazus Study Region into a clean geodatabase with the same name as the Study Region. Specific layers may be viewed using ArcCatalog, as shown in **Figure 5.7**.

Figure 5.7 ArcCatalog Review of Exported Geodatabase Contents



5) The *Hazus Export Tool* will export results from the latest scenario run in your Study Region. If you modify and re-run your Study Region analysis in Hazus, you will need to re-run the *Hazus Export Tool* to capture the updated results. Caution should be used, as the *Hazus Export Tool* will overwrite the results geodatabase if you export the same study region to the same export folder.

5.2 Interpreting and Communicating Results

This section provides a description of the various layers exported by the *Hazus Export Tool*, provides field definitions for those layers, and recommends symbology for presenting the results using ArcGIS (i.e., outside Hazus).

5.2.1. Estimated Building Inspection Needs

*This layer will be created using the file geodatabase feature class named "Building_Damages_by_Tract", which is part of the "General_Building_Stock" file geodatabase feature dataset created by the *Hazus Export Tool*.

The intent of this layer is to depict building counts by extent of damage or tagging (complete/red, extensive/yellow or slight and moderate/green) and the number of building inspectors that would be required in the event of an earthquake in the study region. There is a critical need to inspect the safety of buildings after an earthquake. These inspections include high priority needs for shelters and other essential facilities, as well as keeping survivors out of dangerous buildings and moving them back into buildings that are safe. The purpose of this layer is to support the analysis of potential needs and gaps in the number and availability of building inspectors. Especially in significant events, a large gap may exist between the numbers of available building inspectors and the total number of building requiring inspection. FEMA provides training for the "Post-Disaster Inspection of Buildings" through the Applied Technology Council.

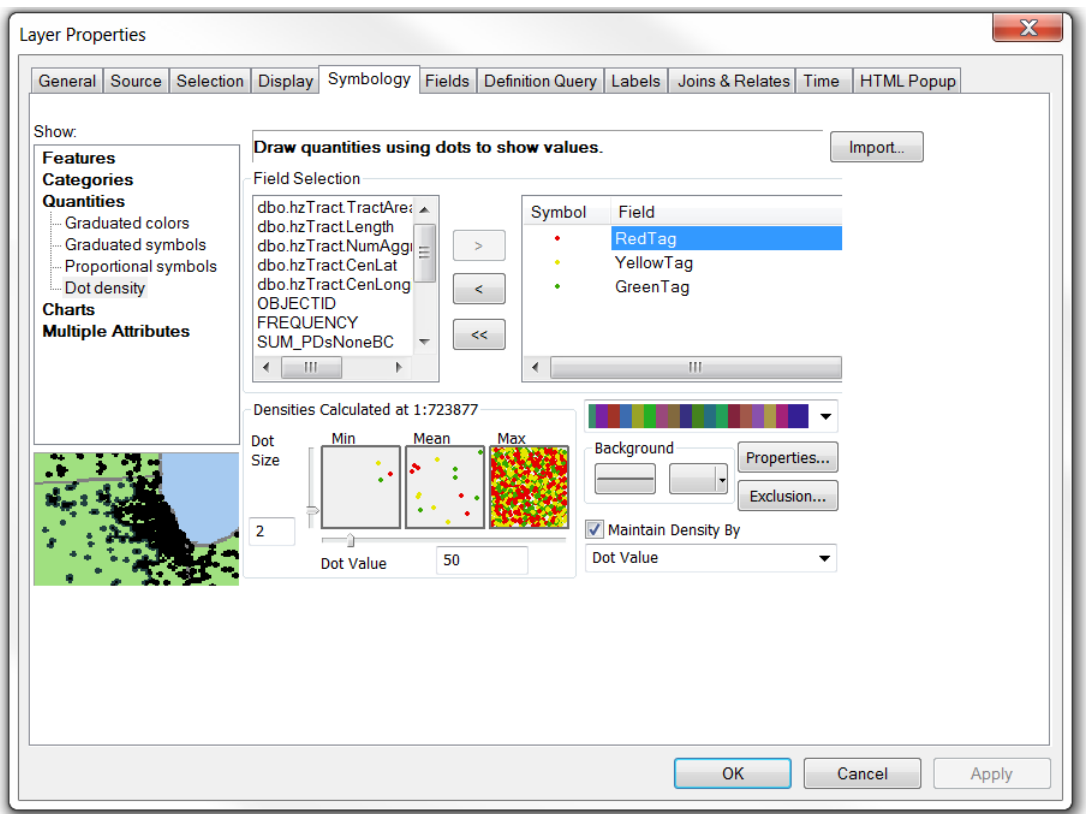
1. Add the "General_Building_Stock" feature dataset to your ArcGIS workspace to access the "Building_Damages_by_Tract" feature class. This census tract layer includes building damage data as attributes, as follows:
    a. *SUM_PDsNoneBC* – total count of buildings in each census tract in the "None" damage state
    b. *SUM_PDsSlightBC* - total count of buildings in the "Slight" damage state
    c. *SUM_PDsModerateBC* - total count of buildings in the "Moderate" damage state
    d. *SUM_PDsExtensiveBC* - total count of buildings in the "Extensive" damage state
    e. *SUM_PDsCompleteBC* - total count of buildings in the "Complete" damage state
    f. *GreenTag* – Total count of green-tagged buildings in the census tract; this is equal to the sum of the number of buildings in the Slight and Moderate damage states.

g. *YellowTag* - Total count of yellow-tagged buildings in the census tract; this is equal to the number of buildings in the Extensive damage state
h. *RedTag* - Total count of red-tagged buildings in the census tract; this is equal to the number of buildings in the Complete damage state

Review the attribute data by opening the layer's attribute table; right-click on the layer name in the table of contents and select "Open Attribute Table".

2. To set the layer's thematic settings, right-click on the layer name and select "Properties…". In the Layer Properties window (**Figure 5.8**), select the "Symbology" tab. In the table of contents on the left-hand side, select "Quantities" and "Dot density". In the Field Selection pick list, double-click on the fields *RedTag*, *YellowTag* and *GreenTag* (in that order, to ensure that the red and yellow tags are plotted on top of the green ones) to include them in the thematic map. Double-click on the "Symbol" to the right of each field name to open the Symbol Selector; adjust the color of each symbol accordingly. The dot size and dot value will vary from scenario to scenario. Click "OK" to accept your settings and draw the map.

Figure 5.8: Layer Properties Window for the Building_Damages_by_Tract Feature Class



3. In addition to mapping the locations of red, yellow and green tagged buildings, it may be helpful to estimate the number of building inspectors required. While the actual rate of inspection will vary based on a number of conditions, including access to damaged areas, complexity of the damage distribution, inspector availability, and the occurrence of aftershocks, approximate "rules of thumb" were developed

with input from experienced inspectors to support FEMA's Wasatch Fault Scenario, as follows:

- Red tagged buildings – a two-man inspection team could inspect 10 red tagged buildings per day; during a 30-day response, they could inspect 300 buildings. Estimate the required number of inspectors as [the number of red tagged buildings/150].
- Yellow tagged buildings – a two-man inspection team could inspect 5 yellow tagged buildings per day; during a 30-day response, they could inspect 150 buildings. Estimate the required number of inspectors as [the number of yellow tagged buildings/75].
- Green tagged buildings – a two-man inspection team could inspect 10 green tagged buildings per day; during a 30-day response, they could inspect 300 buildings. Estimate the required number of inspectors as [the number of green tagged buildings/150].

To determine the total number of red, yellow and green tagged buildings, right click on the "Building_Damages_by_Tract" feature class name, and open the attribute table. Scroll to the GreenTag column, right click on the column header to access the context menu, and select "Statistics…" to view field statistics, and note the value reported as the sum. Repeat for "YellowTag" and "RedTag". Example results for the Wasatch Fault M7.0 scenario earthquake are given in **Table 5.1** below. These estimates do not account for potential re-inspections required as a result of significant aftershocks.

These types of estimates are useful for planning purposes and are important for emergency response; keeping people out of hazardous buildings is critical because aftershocks could cause further damage while allowing people back into buildings that are safe to occupy supports recovery. Identifying the number of inspectors needed helps responding agencies gauge requirements for training programs and mutual assistance.

Table 5.1 Estimating Building Inspection Needs – Wasatch Fault M7.0 Scenario Example

Hazus Damage State	Building Tag	# Buildings	# Inspectors Required
Slight and Moderate	Green	175,500	1,170
Extensive	Yellow	57,600	768
Complete	Red	63,600	424
TOTAL		**296,700**	**2,362**

4. The "Building_Damages_by_Tract" feature class data may also be used to estimate the potential number of Individual Assistance (IA) claims. Building counts by damage state (*SUM_PDsSlightBC, SUM_PDsModerateBC, SUM_PDsExtensiveBC* and

SUM_PDsCompleteBC) can be associated with IA PDA damage classes, as shown in **Table 5.2**.

Table 5.2 Hazus Damage States and FEMA IA PDA Damage Classes

Hazus Damage State	FEMA IA PDA Damage Class	FEMA IA PDA Damage Class Definition
Slight	Affected	Some damage to the structure and contents, but still habitable
Moderate	Minor	Home is damaged and uninhabitable, but may be made habitable in short period of time with repairs
Extensive	Major	Substantial failure to structural elements of residence (e.g., walls, floors, foundation), or damage that will take more than 30 days to repair
Complete	Destroyed	Total loss of structure, structure is not economically feasible to repair, or complete failure to major structural components (e.g., collapse of basement walls/foundation, walls or roof)

5.2.2 Life Threatening Injuries and Fatalities

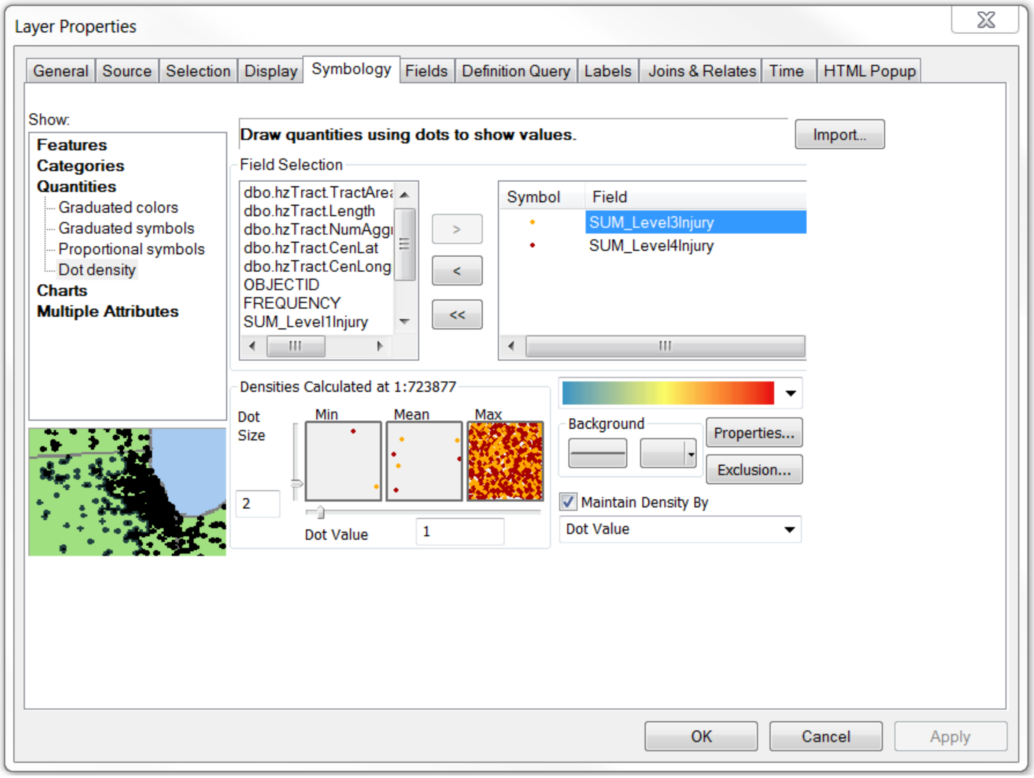
*This layer will be created using the file geodatabase feature class named “Casualties_by_tract_2pm” (or you can use “Casualties_by_tract_5pm” or “Casualties_by_tract_2am”, depending on the time of day of your scenario), which is part of the “General_Building_Stock” file geodatabase feature dataset created by the *Hazus Export Tool*.

1. Add the “General_Building_Stock” feature dataset to your ArcGIS workspace to access the “*Casualties_by_tract_2pm*” feature class. This census tract layer includes casualty estimates for a day-time event, at four injury severity levels, as follows:
    a. *SUM_Level1Injury* – total number of minor injuries, i.e., injuries treated with basic first aid (Injury Severity 1) in each census tract in a day-time event
    b. *SUM_Level2Injury* - total number of non-life-threatening injuries, i.e., treat and release injuries (Injury Severity 2)
    c. *SUM_Level3Injury* - total number of life-threatening injuries. i.e., injuries requiring hospital admissions (Injury Severity 3)
    d. *SUM_Level4Injury* - total number of fatalities (Injury Severity 4)

Review the attribute data by opening the layer’s attribute table; right-click on the layer name in the table of contents and select “Open Attribute Table”.

2. To set the layer’s thematic settings, right-click on the layer name and select “Properties…”. In the Layer Properties window (**Figure 5.9**), select the “Symbology” tab. In the table of contents on the left-hand side, select “Quantities” and “Dot density”. In the Field Selection pick list, double-click on the fields *SUM_Level3Injury* and *SUM_Level4Injury* to include them in the thematic map. Double-click on the “Symbol” to the right of the field name to open the Symbol Selector; symbolize fatalities (Level 4 injuries) using red dots, and life-threatening injuries (Level 3 injuries) using orange dots. The dot size and dot value will vary from scenario to scenario. Click “OK” to accept your settings and draw the map.

Figure 5.9: Layer Properties Window for the Casualties_by_tract_2pm Feature Class



5.2.3 Direct Building Economic Loss

*This layer will be created using the file geodatabase feature class named "Economic_Losses_by_Tract", which is part of the "General_Building_Stock" file geodatabase feature dataset created by the *Hazus Export Tool*.

1. Add the "General_Building_Stock" feature dataset to your ArcGIS workspace (if it not already loaded) to access the "*Economic_Losses_by_Tract*" feature class. This census tract layer includes direct economic loss estimates resulting from damage to buildings represented by the Hazus General Building Stock inventory, as follows:
    a. *SUM_StructLoss* – total damage to structural components of buildings in each census tract ($1,000)
    b. *SUM_NonStrLosses* - total damage to non-structural components of buildings ($1,000)
    c. *SUM_BldgLosses* - total building damage, i.e., the sum of structural and non-structural damage ($1,000)
    d. *SUM_ContentLoss* - total loss associated with damage to building contents ($1,000)
    e. *SUM_InvLoss* - total loss associated with damage to commercial inventories ($1,000)
    f. *SUM_RelocLoss* - total cost associated with relocation of building occupants during building repair ($1,000)
    g. *SUM_IncLoss* - total income loss associated with building damage-related business disruption ($1,000)
    h. *SUM_RentLoss* - total value of lost rent associated with relocation of building

occupants during building repair ($1,000)

i. *SUM_WageLoss* - total wage loss associated with building damage-related business disruption ($1,000)

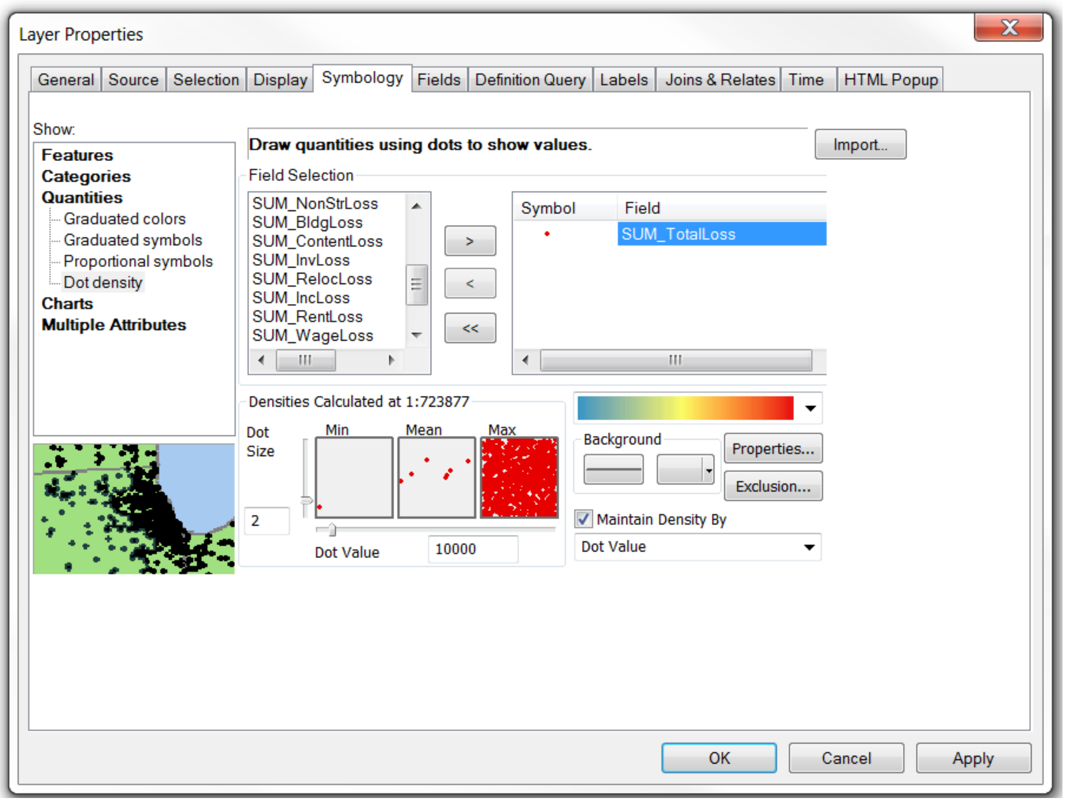
j. *SUM_OutputLoss* - total economic output loss associated with building damage-related business disruption ($1,000) ***[Note: this category of loss is estimated as input to the Hazus Indirect Economic Loss Module (IELM) but is not included in Hazus' reported Total Direct Economic Losses.]***

k. *SUM_TotalLoss* – The sum of all building damage-related direct economic losses, i.e., structural, non-structural, contents, commercial inventories, relocation, income, rent and wage losses ($1,000).

Review the attribute data by opening the layer's attribute table; right-click on the layer name in the table of contents and select "Open Attribute Table".

2. To set the layer's thematic settings, right-click on the layer name and select "Properties…". In the Layer Properties window (**Figure 5.10**), select the "Symbology" tab. In the table of contents on the left-hand side, select "Quantities" and "Dot density". In the Field Selection pick list, double-click on the field *SUM_TotalLoss* to include it in the thematic map. Double-click on the "Symbol" to the right of the field name to open the Symbol Selector; symbolize using red dots. The dot size and dot value will vary from scenario to scenario. Click "OK" to accept your settings and draw the map. Note that direct economic loss is measured in thousands of dollars so a dot value of 1,000 is equal to $1,000,000.

Figure 5.10: Layer Properties Window for the Economic_Losses_by_Tract Feature Class



5.2.4 Public Shelter Needs and Displaced Households

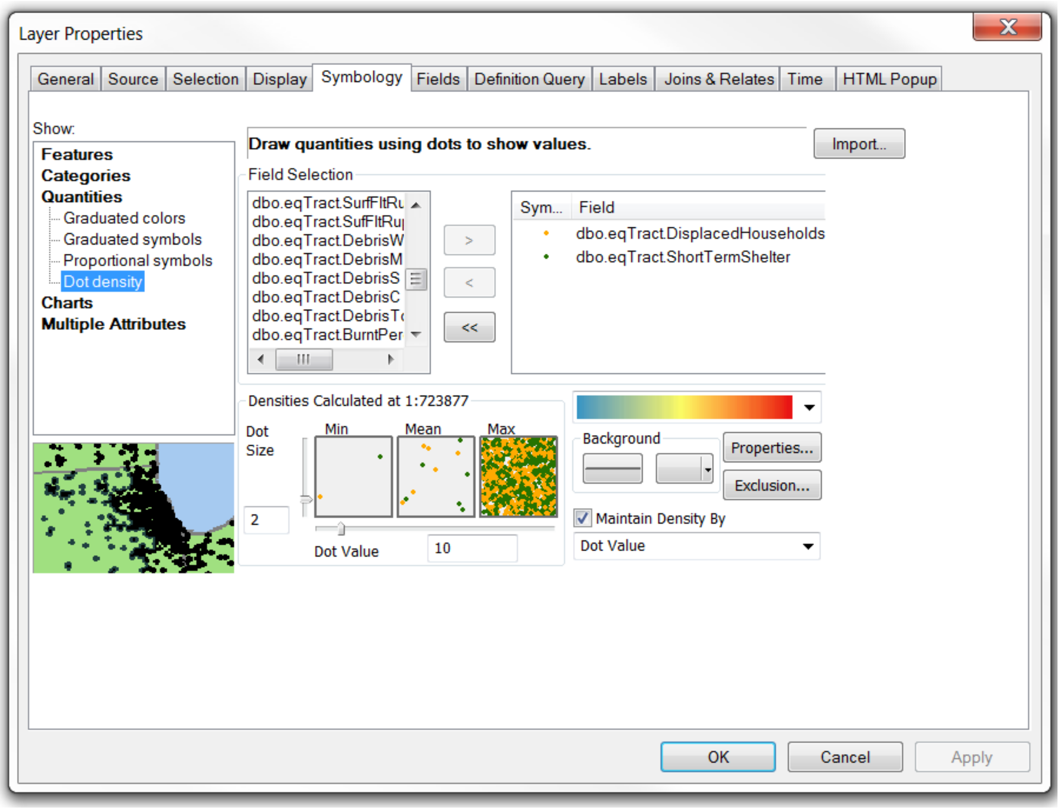
* This layer will be created using the file geodatabase feature class named "Census_Tract_Shelter_Needs_and_Debris" which is part of the "General_Building_Stock" file geodatabase feature dataset created by the *Hazus Export Tool*.

1. Add the "General_Building_Stock" feature dataset to your ArcGIS workspace (if it is not already loaded) to access the "*Census_Tract_Shelter_Needs_and_Debris*" feature class. This census tract layer includes various hazard data as well as debris and shelter estimates resulting from damage to buildings, as follows:
   a. *dbo.eqTract.DebrisW* – total estimated weight of light debris (i.e., wood and brick) in each census tract (in thousands of tons)
   b. *dbo.eqTract.DebrisM – this field is not used by Hazus, so contains "<Null"> records*
   c. *dbo.eqTract.DebrisS* - total estimated weight of heavy debris (i.e., steel and concrete) in each census tract (in thousands of tons)
   d. *dbo.eqTract.DebrisC - this field is not used by Hazus, so contains "<Null"> records*
   e. *dbo.eqTract.DebrisTotal* – total estimated weight of light and heavy debris (in thousands of tons)
   f. *dbo.eqTract.DisplacedHouseholds* - total estimated number of displaced households in each census tract
   g. *dbo.eqTract.ShortTermShelter* – total number of people expected to require publicly-provided short-term shelter

Review the attribute data by opening the layer's attribute table; right-click on the layer name in the table of contents and select "Open Attribute Table".

2. To set the layer's thematic settings, right-click on the layer name and select "Properties…". In the Layer Properties window (**Figure 5.11**), select the "Symbology" tab. In the table of contents on the left-hand side, select "Quantities" and "Dot density". In the Field Selection pick list, double-click on the fields *dbo.eqTract.DisplacedHouseholds and dbo.eqTract.ShortTermShelter* to include them in the thematic map. Double-click on the "Symbol" to the right of the field name to open the Symbol Selector; symbolize *DisplacedHouseholds* using orange dots, and *ShortTermShelter* using green dots. The dot size and dot value will vary from scenario to scenario. Click "OK" to accept your settings and draw the map.

Figure 5.11: Layer Properties Window for the *Census_Tract_Shelter_Needs_and_Debris* Feature Class



5.2.5 Estimated Total Debris

* This layer will be created using the file geodatabase feature class named “Census_Tract_Shelter_Needs_and_Debris” which is part of the “General_Building_Stock” file geodatabase feature dataset created by the *Hazus Export Tool*.

1. Add the “General_Building_Stock” feature dataset to your ArcGIS workspace (if it is not already loaded) to access the “*Census_Tract_Shelter_Needs_and_Debris*” feature class. As noted in Section 5.2.4, this census tract layer includes various hazard data as well as debris and shelter estimates resulting from damage to buildings.
   a. *dbo.eqTract.DebrisW* – total estimated weight of light debris (i.e., wood and brick) in each census tract (in thousands of tons)
   b. *dbo.eqTract.DebrisM – this field is not used by Hazus, so contains “<Null”> records*
   c. *dbo.eqTract.DebrisS* - total estimated weight of heavy debris (i.e., steel and concrete) in each census tract (in thousands of tons)
   d. *dbo.eqTract.DebrisC - this field is not used by Hazus, so contains “<Null”> records*
   e. *dbo.eqTract.DebrisTotal* – total estimated weight of light and heavy debris (in thousands of tons)
   f. *dbo.eqTract.DisplacedHouseholds* - total estimated number of displaced households in each census tract
   g. *dbo.eqTract.ShortTermShelter* – total number of people expected to require

publicly-provided short-term shelter

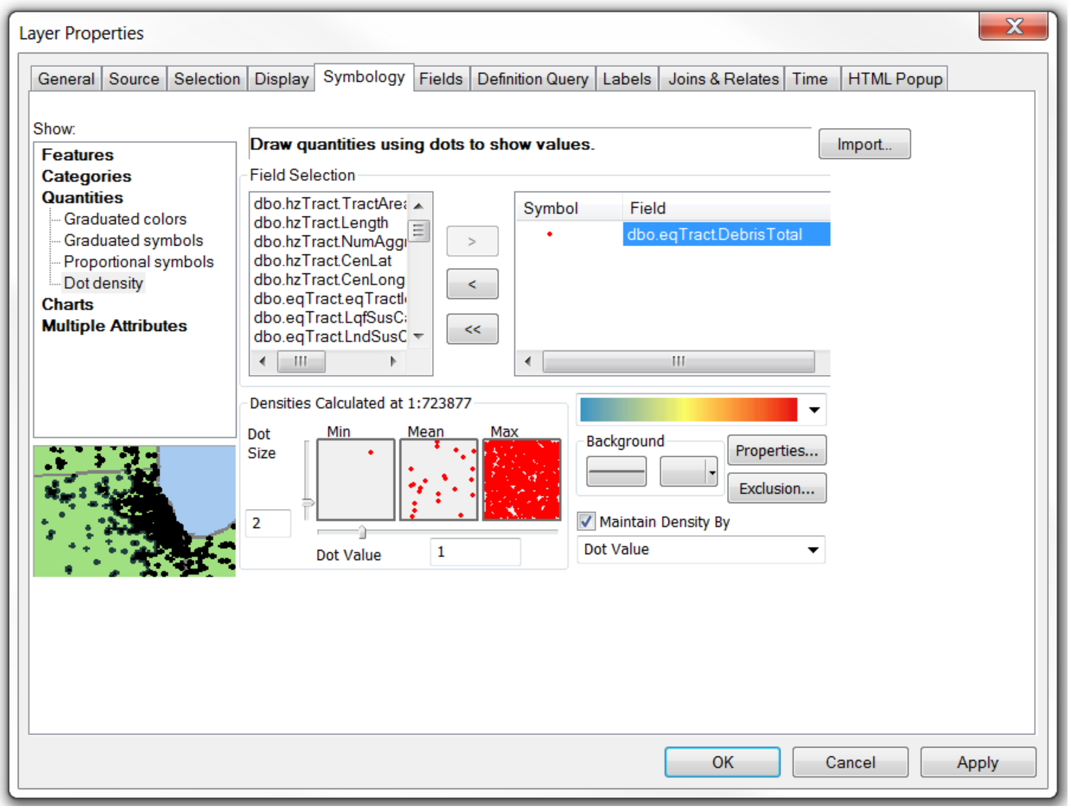
Review the attribute data by opening the layer's attribute table; right-click on the layer name in the table of contents and select "Open Attribute Table".

2. To set the layer's thematic settings, right-click on the layer name and select "Properties…". In the Layer Properties window (**Figure 5.12**), select the "Symbology" tab. In the table of contents on the left-hand side, select "Quantities" and "Dot density". In the Field Selection pick list, double-click on the field *dbo.eqTract.DebrisTotal* to include it in the thematic map. Double-click on the "Symbol" to the right of the field name to open the Symbol Selector; symbolize *dbo.eqTract.DebrisT* using red dots. The dot size and dot value will vary from scenario to scenario. Click "OK" to accept your settings and draw the map. Note that debris is measured in thousands of tons, so a dot value of 1.0 equals 1,000 tons.
3. It may also be helpful to include an estimate of the equivalent number of trucks required to haul the identified total debris amounts, for example, by County as shown for the Wasatch Fault Scenario in **Table 5.3**. Hazus uses a conversion formula of 25 tons per truckload. The "Debris Generation" section of the *Hazus Global Summary Report* (page 14 of 22) includes the total results of this conversion, while county level debris totals (in thousands of tons) are available from the *Debris Generated Report*.

Table 5.3 Estimated Debris Amounts in Tons and Truckloads, for the M7.0 Wasatch Fault Scenario Example

County	Brick and Wood (Tons)	Concrete and Steel (Tons)	Total Debris (Tons)	Total Estimated Truckloads
Davis	526,000	784,000	1,310,000	52,400
Salt Lake	11,300,000	16,544,000	27,844,000	1,113,760
Summit	1,000	1,000	2,000	80
Tooele	11,000	4,000	15,000	600
Utah	122,000	241,000	363,000	14,520
Weber	119,000	47,000	166,000	6,640
Total	**12,079,000**	**17,621,000**	**29,700,000**	**1,188,000**

Figure 5.12: Layer Properties Window for the Census_Tract_Shelter_Needs_and_Debris Feature Class



5.2.6 Highway Segment Impact

* This layer will be created using the file geodatabase feature class named "Highway_Segments" which is part of the "Transportation" file geodatabase feature dataset created by the *Hazus Export Tool*.

1. Add the "Transportation" feature dataset to your ArcGIS workspace to access the "*Highway_Segments*" feature class. This layer provides the highway segment inventory data as well as damage and functionality estimates, as follows:
    a. *dbo.eqHighwaySegment.PDsNone* – the probability that each highway segment is in the "None" damage state (values range from 0.0 to 1.0)
    b. *dbo.eqHighwaySegment.PDsSlight* – the probability that each highway segment is in the "Slight" damage state (values range from 0.0 to 1.0)
    c. *dbo.eqHighwaySegment.PDsModerate* – the probability that each highway segment is in the "Moderate" damage state (values range from 0.0 to 1.0)
    d. *dbo.eqHighwaySegment.PDsExtensive* – the probability that each highway segment is in the "Extensive" damage state (values range from 0.0 to 1.0)
    e. *dbo.eqHighwaySegment.PDsComplete* – the probability that each highway segment is in the "Complete" damage state (values range from 0.0 to 1.0)
    f. *dbo.eqHighwaySegment.PDsExceedSlight* – the probability that each highway segment has experienced "Slight" or greater damage (values range from 0.0 to

1.0)

g. *dbo.eqHighwaySegment.PDsExceedModerate* – the probability that each highway segment has experienced "Moderate" or greater damage (values range from 0.0 to 1.0)
h. *dbo.eqHighwaySegment.PDsExceedExtensive* - the probability that each highway segment has experienced "Extensive" or greater damage (values range from 0.0 to 1.0)
i. *dbo.eqHighwaySegment.FunctDay1* – highway segment functionality on Day 1 (values range from 0 – 100%)
j. *dbo.eqHighwaySegment.FunctDay3* – highway segment functionality on Day 3 (values range from 0 – 100%)
k. *dbo.eqHighwaySegment.FunctDay7* – highway segment functionality on Day 7 (values range from 0 – 100%)
l. *dbo.eqHighwaySegment.FunctDay14* – highway segment functionality on Day 14 (values range from 0 – 100%)
m. *dbo.eqHighwaySegment.FunctDay30* – highway segment functionality on Day 30 (values range from 0 – 100%)
n. *dbo.eqHighwaySegment.FunctDay90* – highway segment functionality on Day 90 (values range from 0 – 100%)

Review the attribute data by opening the layer's attribute table; right-click on the layer name in the table of contents and select "Open Attribute Table".

2. To set the layer's thematic settings, right-click on the layer name and select "Properties…". In the Layer Properties window, select the "Symbology" tab. In the table of contents on the left-hand side, select "Quantities" and "Graduated Colors". In the Fields Value dropdown menu, select *dbo.eqHighwaySegment.PDsExceedModerate.* Under "Classification" on the right-hand side, click "Classify…" to bring up the Classification window (**Figure 5.13**). From the "Classification – Classes" pulldown menu, pick 3 classes, then from the "Classification - Method:" pulldown menu, select "Manual". Edit the Break Values on the right to: 0.25, 0.75, and 1.0. Click "OK" to return to the Layer Properties window (**Figure 5.14**). Double-click on the "Symbol" to the right of each value range to access the Symbol Selector; symbolize *0 – 0.25* using a green line, *0.25 – 0.75* using a yellow line and *0.75 – 1.0* using a red line. Click "OK" to accept your settings and draw the map. Note that highway segments will only be damaged if ground failure has occurred, and in many cases this damage will be modest (as shown in **Figure 5.13**); for scenarios that do not include liquefaction or landslide hazard data (i.e., "shaking only"), these elements will not be damaged.

Figure 5.13: Classification Window for the Highway_Segments Feature Class

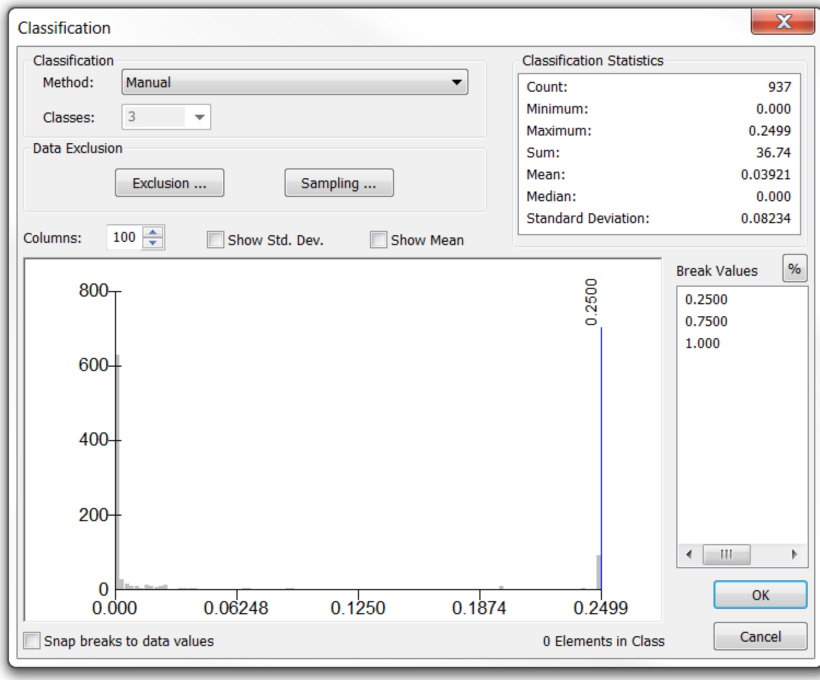
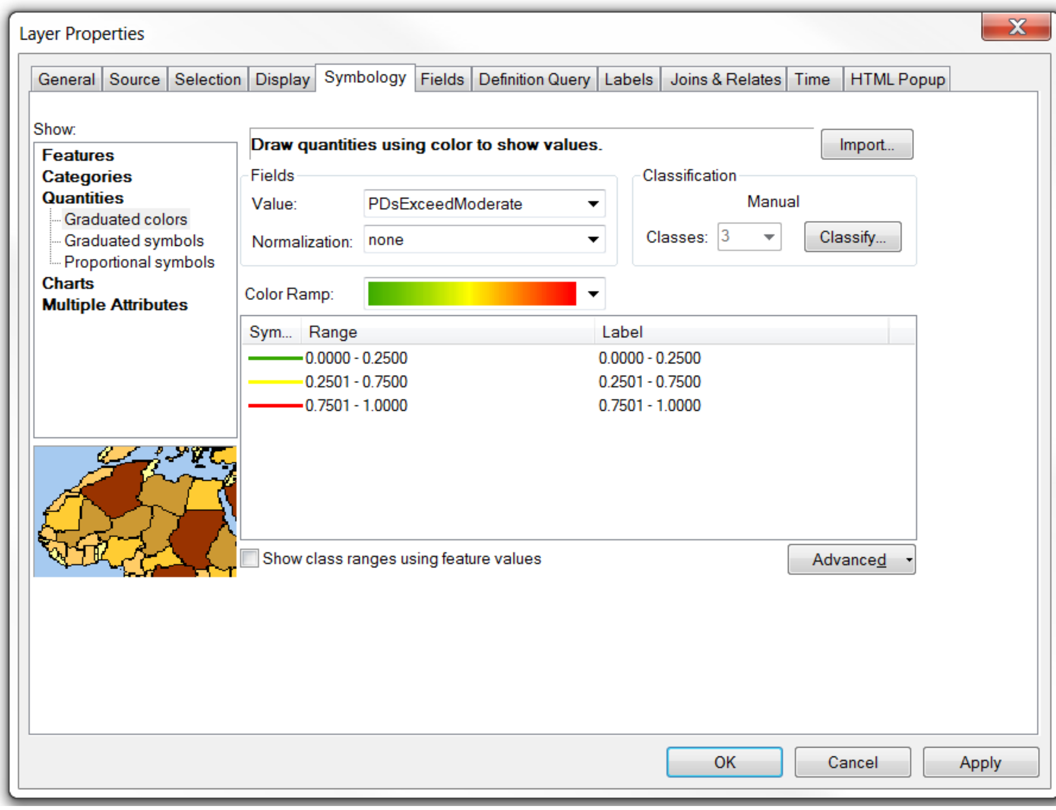


Figure 5.14: Layer Properties Window for the Highway_Segments Feature Class



5.2.7 Major Roadway Bridge Impact

* This layer will be created using the file geodatabase feature class named "Highway_Bridges" which is part of the "Transportation" file geodatabase feature dataset created by the *Hazus Export Tool*.

1. Add the "*Transportation*" feature dataset to your ArcGIS workspace (if it is not already loaded) to access the "*Highway_Bridges*" feature class. This layer provides the highway bridge inventory data as well as damage and functionality estimates, as follows:
    a. *dbo.eqHighwayBridge.PDsNone* – the probability that each highway bridge is in the "None" damage state (values range from 0.0 to 1.0)
    b. *dbo.eqHighwayBridge.PDsSlight* – the probability that each highway bridge is in the "Slight" damage state (values range from 0.0 to 1.0)
    c. *dbo.eqHighwayBridge.PDsModerate* – the probability that each highway bridge is in the "Moderate" damage state (values range from 0.0 to 1.0)
    d. *dbo.eqHighwayBridge.PDsExtensive* – the probability that each highway bridge is in the "Extensive" damage state (values range from 0.0 to 1.0)
    e. *dbo.eqHighwayBridge.PDsComplete* – the probability that each highway bridge is in the "Complete" damage state (values range from 0.0 to 1.0)
    f. *dbo.eqHighwayBridge.PDsExceedSlight* – the probability that each highway bridge has experienced "Slight" or greater damage (values range from 0.0 to 1.0)
    g. *dbo.eqHighwayBridge.PDsExceedModerate* – the probability that each highway bridge has experienced "Moderate" or greater damage (values range from 0.0 to 1.0)
    h. *dbo.eqHighwayBridge.PDsExceedExtensive* - the probability that each highway bridge has experienced "Extensive" or greater damage (values range from 0.0 to 1.0)
    i. *dbo.eqHighwayBridge.FunctDay1* – highway bridge functionality on Day 1 (values range from 0 – 100%)
    j. *dbo.eqHighwayBridge.FunctDay3* – highway bridge functionality on Day 3 (values range from 0 – 100%)
    k. *dbo.eqHighwayBridge.FunctDay7* – highway bridge functionality on Day 7 (values range from 0 – 100%)
    l. *dbo.eqHighwayBridge.FunctDay14* – highway bridge functionality on Day 14 (values range from 0 – 100%)
    m. *dbo.eqHighwayBridge.FunctDay30* – highway bridge functionality on Day 30 (values range from 0 – 100%)
    n. *dbo.eqHighwayBridge.FunctDay90* – highway bridge functionality on Day 90 (values range from 0 – 100%)

Review the attribute data by opening the layer's attribute table; right-click on the layer name in the table of contents and select "Open Attribute Table".

2. To set the layer's thematic settings, right-click on the layer name and select "Properties…". In the Layer Properties window, select the "Symbology" tab. In the table of contents on the left-hand side, select "Quantities" and "Graduated Colors". In the Fields Value dropdown menu, select *dbo.eqHighwayBridge.PDsExceedModerate.* Under "Classification" on the right-hand side, click "Classify…" to bring up the Classification window (**Figure 5.15**). From the "Classification – Classes" pulldown menu, pick 3 classes, then from the "Classification - Method:" pulldown menu, select "Manual". Edit the Break Values on the right to: 0.25, 0.75, and 1.0. Click "OK" to

return to the Layer Properties window (**Figure 5.16**). Double-click on the "Symbol" to the right of each value range to access the Symbol Selector, and symbolize *0 – 0.25* using green dots, *0.25 – 0.75* using yellow dots and *0.75 – 1.0* using red dots. Click "OK" to accept your settings and draw the map.

3. It may also be helpful to include an estimate of the required number of bridge inspectors, as shown for the Wasatch Fault Scenario in **Table 5.4**. While the actual rate of inspection will vary based on a number of conditions, including access to damaged areas, complexity of the damage distribution and inspector availability, approximate "rules of thumb" were developed with input from experienced inspectors to support FEMA's Wasatch Fault Scenario, as follows. The estimated number of bridge inspectors is estimated for priority inspections only (i.e., for bridges with at least moderate damage), assuming that two engineers can inspect five bridges a day, for three days; the total number of required inspectors is calculated as the number of priority bridges divided by 7.5. These estimates do not account for potential re-inspections required as a result of significant aftershocks.

Figure 5.15: Classification Window for the Highway_Bridges Feature Class

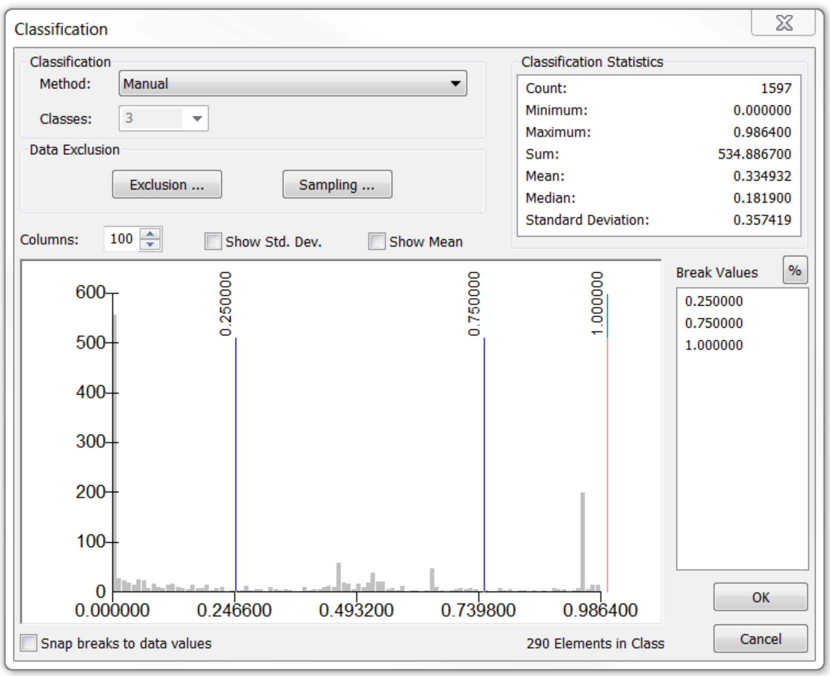


Figure 5.16: Layer Properties Window for the Highway_Bridges Feature Class

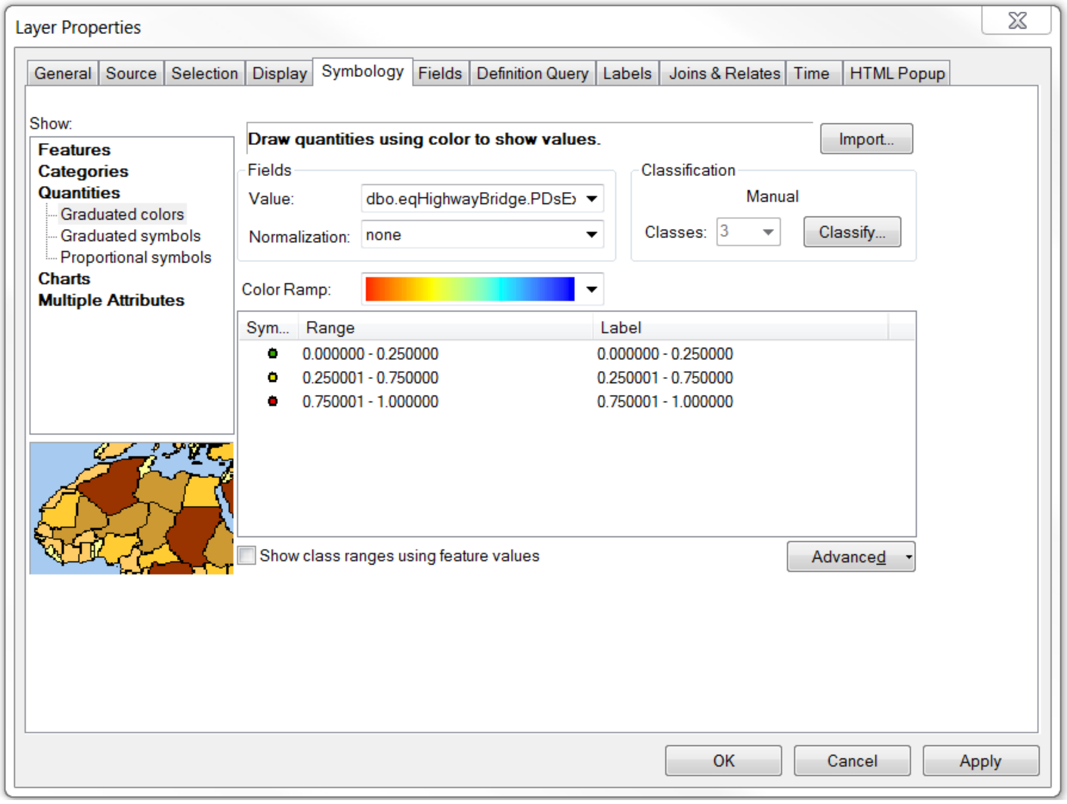


Table 5.4 Estimated Number of Bridge Inspectors Required for a M7.0 Wasatch Fault Scenario

County	Total # of Bridges	# of Bridges Needing Inspection (Bridges with at least Moderate Damage)	# of Bridge Inspectors Needed
Salt Lake	608	365	49
Juab	80	0	0
Weber	141	10	1
Tooele	54	2	1
Cache	62	0	0
Rich	23	0	0
Morgan	80	0	0
Summit	156	0	0
Wasatch	24	0	0
Box Elder	230	0	0
Utah	314	53	7
Davis	130	27	4
Total	**1,902**	**458**	**62**

5.2.8 Hospital Functionality (Day 1)

* This layer will be created using the file geodatabase feature class named "Medical_Care_Facilities", which is part of the "Essential_Facilties" file geodatabase feature dataset created by the *Hazus Export Tool.*

1. Add the "*Essential_Facilities*" feature dataset to your ArcGIS workspace to access the "*Medical_Care_Facilities*" feature class. This layer provides the medical care facilities/hospital inventory data as well as damage and functionality estimates, as follows:
    a. *dbo.eqCareFlty.PDsNone* – the probability that each hospital is in the "None" damage state (values range from 0.0 to 1.0)
    b. *dbo.eqCareFlty.PDsSlight* – the probability that each hospital is in the "Slight" damage state (values range from 0.0 to 1.0)
    c. *dbo.eqCareFlty.PDsModerate* – the probability that each hospital is in the "Moderate" damage state (values range from 0.0 to 1.0)
    d. *dbo.eqCareFlty.PDsExtensive* – the probability that each hospital is in the "Extensive" damage state (values range from 0.0 to 1.0)
    e. *dbo.eqCareFlty.PDsComplete* – the probability that each hospital is in the "Complete" damage state (values range from 0.0 to 1.0)
    f. *dbo.eqCareFlty.PDsExceedSlight* – the probability that each hospital has experienced "Slight" or greater damage (values range from 0.0 to 1.0)
    g. *dbo.eqCareFlty.PDsExceedModerate* – the probability that each hospital has experienced "Moderate" or greater damage (values range from 0.0 to 1.0)
    h. *dbo.eqCareFlty.PDsExceedExtensive* - the probability that each hospital has experienced "Extensive" or greater damage (values range from 0.0 to 1.0)
    i. *dbo.eqCareFlty.FunctDay1* – hospital functionality on Day 1 (values range from 0 – 100%)
    j. *dbo.eqCareFlty.FunctDay3* – hospital functionality on Day 3 (values range from 0 – 100%)
    k. *dbo.eqCareFlty.FunctDay7* – hospital functionality on Day 7 (values range from 0 – 100%)
    l. *dbo.eqCareFlty.FunctDay14* – hospital functionality on Day 14 (values range from 0 – 100%)
    m. *dbo.eqCareFlty.FunctDay30* – hospital functionality on Day 30 (values range from 0 – 100%)
    n. *dbo.eqCareFlty.FunctDay90* – hospital functionality on Day 90 (values range from 0 – 100%)

Review the attribute data by opening the layer's attribute table; right-click on the layer name in the table of contents and select "Open Attribute Table".

2. To set the layer's thematic settings, right-click on the layer name and select "Properties…". In the Layer Properties window, select the "Symbology" tab. In the table of contents on the left-hand side, select "Quantities" and "Graduated Colors". In the Fields Value dropdown menu, select *dbo.eqCareFlty.FunctDay1.* Under "Classification" on the right-hand side, click "Classify…" to bring up the Classification window (**Figure 5.17**). From the "Classification – Classes" pulldown menu, pick 3

classes, then from the “Classification - Method:” pulldown menu, select “Manual”. Edit the Break Values on the right to: 25, 75, and 100. Click “OK” to return to the Layer Properties window (**Figure 5.18**). Double-click on the “Symbol” to the right of each value range to access the Symbol Selector; symbolize *0 –25* using red hospital symbols (i.e., the ESRI symbol named “Hospital 2”), *25 – 75* using yellow hospital symbols and *75 – 100* using green hospital symbols. Click “OK” to accept your settings and draw the map. A similar approach may be implemented for mapping of other essential facilities included in the “Essential_Facilties” file geodatabase feature dataset created by the *Hazus Export Tool*; Emergency Operations Centers (EOCs), Fire Stations, Police Stations and Schools.

Figure 5.17: Classification Window for the Medical_Care_Facilities Feature Class

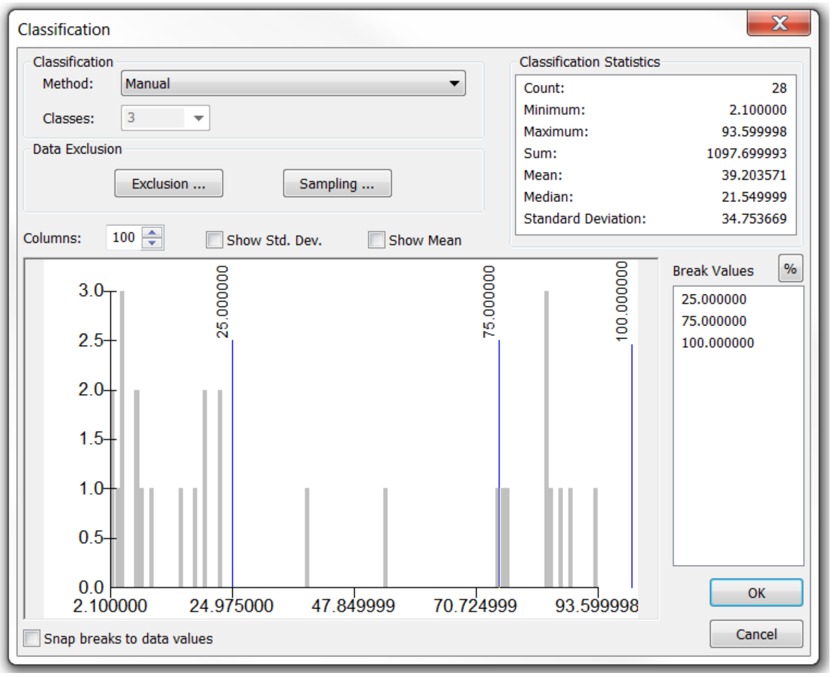
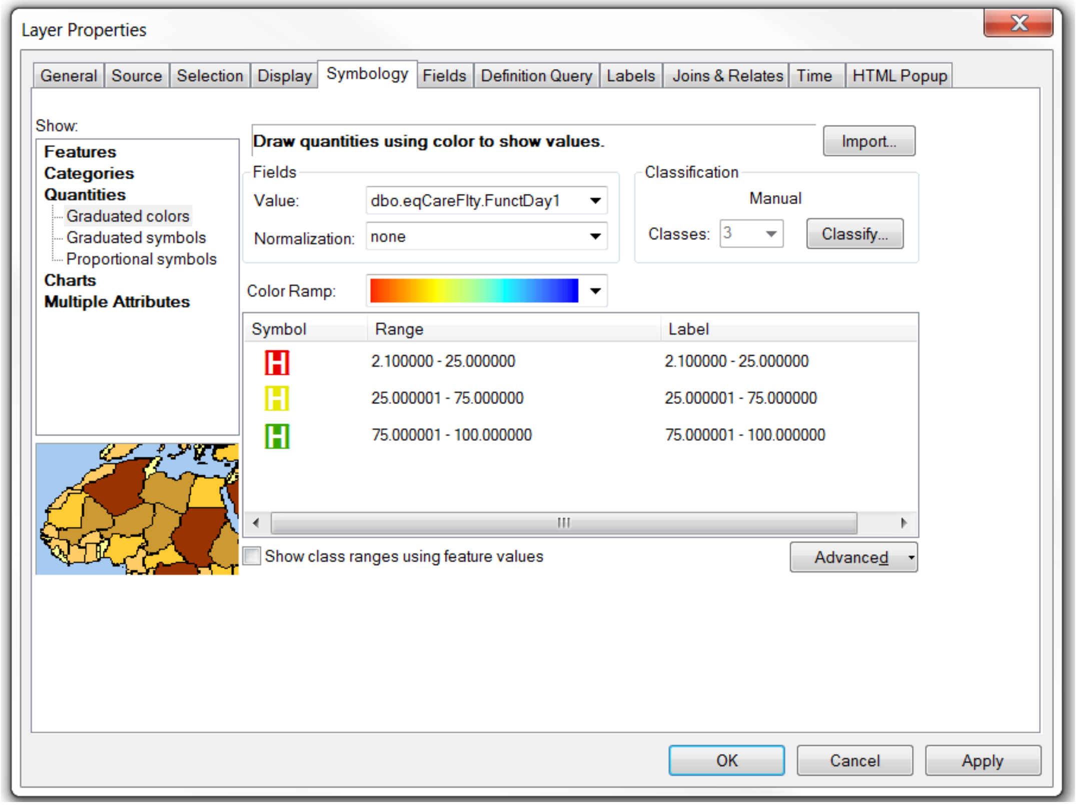


Figure 5.18: Layer Properties Window for the Medical_Care_Facilities Feature Class



5.2.9 Electrical Power Facility Impact

*This layer will be created using the file geodatabase feature class named "Electrical_Power_Facilities", which is part of the "Utilities" file geodatabase feature dataset as exported by the *Hazus Export Tool*.

1. Add the "*Utilities*" feature dataset to your ArcGIS workspace to access the "*Electrical_Power_Facilities*" feature class. This layer provides the power facilities inventory data as well as damage and functionality estimates, as follows:
    a. *dbo.eqElectricPowerFlty.PDsNone* – the probability that each electric power facility is in the "None" damage state (values range from 0.0 to 1.0)
    b. *dbo.eqElectricPowerFlty.PDsSlight* – the probability that each electric power facility is in the "Slight" damage state (values range from 0.0 to 1.0)
    c. *dbo.eqElectricPowerFlty.PDsModerate* – the probability that each electric power facility is in the "Moderate" damage state (values range from 0.0 to 1.0)
    d. *dbo.eqElectricPowerFlty.PDsExtensive* – the probability that each electric power facility is in the "Extensive" damage state (values range from 0.0 to 1.0)
    e. *dbo.eqElectricPowerFlty.PDsComplete* – the probability that each electric power facility is in the "Complete" damage state (values range from 0.0 to 1.0)
    f. *dbo.eqElectricPowerFlty.PDsExceedSlight* – the probability that each electric power facility has experienced "Slight" or greater damage (values range from 0.0 to 1.0)

g. *dbo.eqElectricPowerFlty.PDsExceedModerate* – the probability that each electric power facility has experienced “Moderate” or greater damage (values range from 0.0 to 1.0)
h. *dbo.eqElectricPowerFlty.PDsExceedExtensive* - the probability that each electric power facility has experienced “Extensive” or greater damage (values range from 0.0 to 1.0)
i. *dbo.eqElectricPowerFlty.FunctDay1* – electric power facility functionality on Day 1 (values range from 0 – 100%)
j. *dbo.eqElectricPowerFlty.FunctDay3* – electric power facility functionality on Day 3 (values range from 0 – 100%)
k. *dbo.eqElectricPowerFlty.FunctDay7* – electric power facility functionality on Day 7 (values range from 0 – 100%)
l. *dbo.eqElectricPowerFlty.FunctDay14* – electric power facility functionality on Day 14 (values range from 0 – 100%)
m. *dbo.eqElectricPowerFlty.FunctDay30* – electric power facility functionality on Day 30 (values range from 0 – 100%)
n. *dbo.eqElectricPowerFlty.FunctDay90* – electric power facility functionality on Day 90 (values range from 0 – 100%)

Review the attribute data by opening the layer’s attribute table; right-click on the layer name in the table of contents and select “Open Attribute Table”.

2. To set the layer’s thematic settings, right-click on the layer name and select “Properties…”. In the Layer Properties window, select the “Symbology” tab. In the table of contents on the left-hand side, select “Quantities” and “Graduated Colors”. In the Fields Value dropdown menu, select *dbo.eqElectricPowerFlty.PDsExceedModerate.* Under “Classification” on the right-hand side, click “Classify…” to bring up the Classification window (**Figure 5.19**). From the “Classification – Classes” pulldown menu, pick 3 classes, then from the “Classification - Method:” pulldown menu, select “Manual”. Edit the Break Values on the right to: 0.25, 0.75, and 1.0. Click “OK” to return to the Layer Properties window (**Figure 5.20**). Double-click on the “Symbol” to the right of each value range to access the Symbol Selector; symbolize *0 – 0.25* using a green circle with an “X” through it (i.e., the ESRI symbol named “Circle 13”, Font: ESRI Default Marker, Subset: Basic Latin), *0.25 – 0.75* using yellow symbols and *0.75 – 1.0* using red symbols. Click “OK” to accept your settings and draw the map. A similar approach may be implemented for mapping of other utility facilities included in the “Utilities” file geodatabase feature dataset created by the *Hazus Export Tool*; communications facilities, oil facilities (see Section 5.2.10) natural gas facilities (see Section 5.2.11), potable water facilities (see Section 5.2.12), and wastewater facilities.

Figure 5.19: Classification Window for the Electrical_Power_Facilities Feature Class

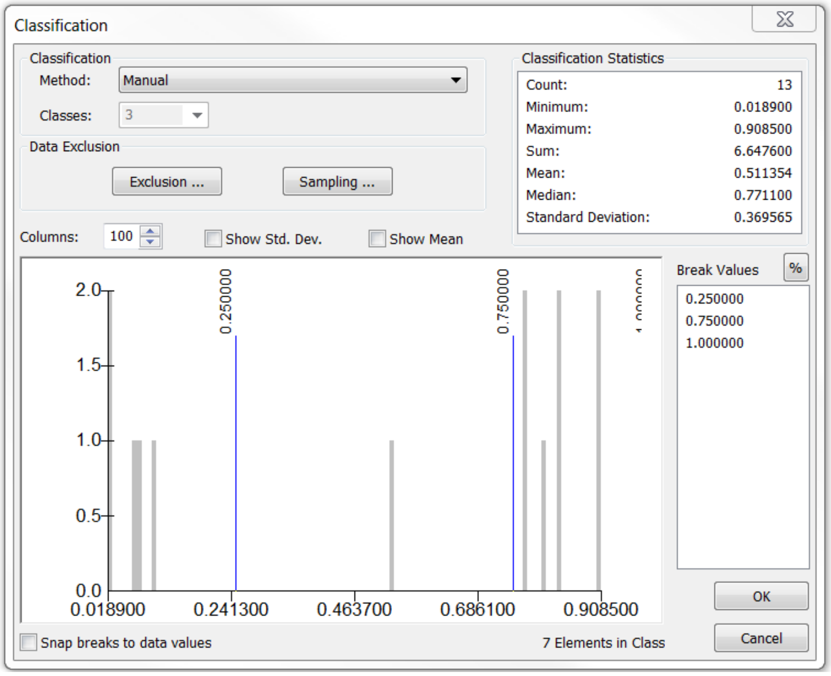
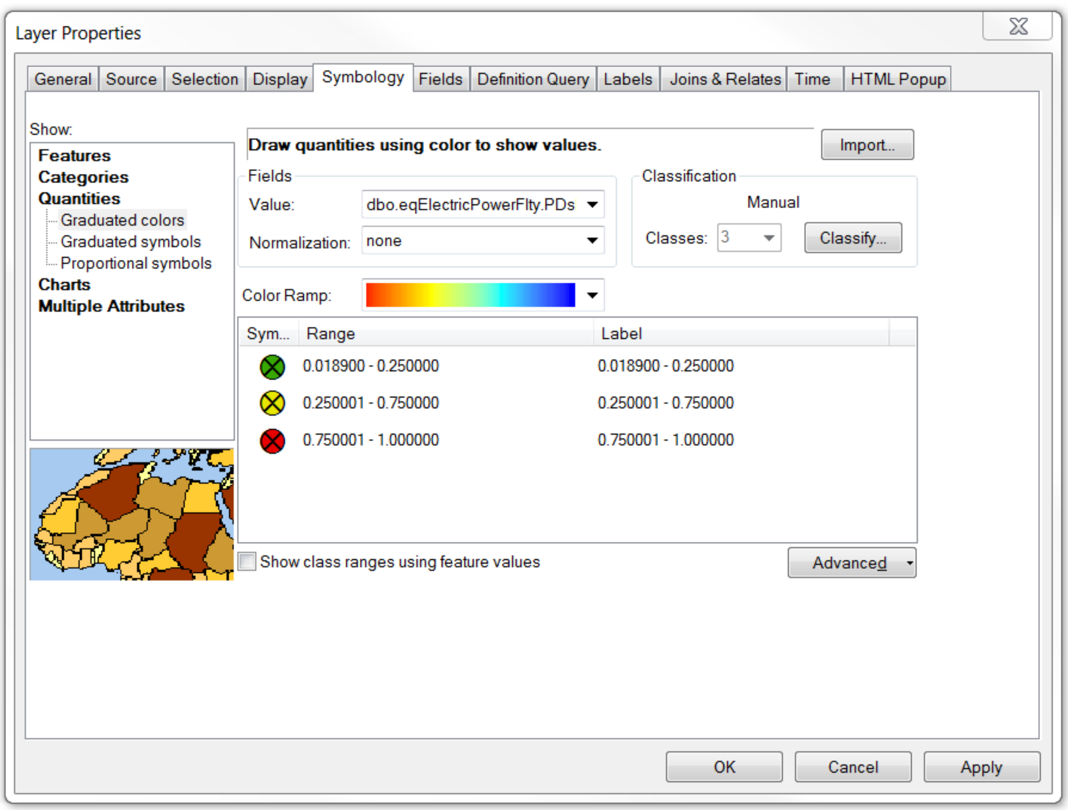


Figure 5.20: Layer Properties Window for the Electrical_Power_Facilities Feature Class



5.2.10 Oil Facility Impact

*This feature class will be created using the file geodatabase feature class named "Oil_Facilities", which is part of the "Utilities" file geodatabase feature dataset as exported by the *Hazus Export Tool*.

1. Add the layer "*Utilities*" feature dataset to your ArcGIS workspace (if it is not already loaded) to access the "*Oil_Facilities*" feature class. This layer provides the oil facilities inventory data as well as damage and functionality estimates, as follows:
    a. *dbo.eqOilFlty.PDsNone* – the probability that each oil facility is in the "None" damage state (values range from 0.0 to 1.0)
    b. *dbo.eqOilFlty.PDsSlight* – the probability that each oil facility is in the "Slight" damage state (values range from 0.0 to 1.0)
    c. *dbo.eqOilFlty.PDsModerate* – the probability that each oil facility is in the "Moderate" damage state (values range from 0.0 to 1.0)
    d. *dbo.eqOilFlty.PDsExtensive* – the probability that each oil facility is in the "Extensive" damage state (values range from 0.0 to 1.0)
    e. *dbo.eqOilFlty.PDsComplete* – the probability that each oil facility is in the "Complete" damage state (values range from 0.0 to 1.0)
    f. *dbo.eqOilFlty.PDsExceedSlight* – the probability that each oil facility has experienced "Slight" or greater damage (values range from 0.0 to 1.0)
    g. *dbo.eqOilFlty.PDsExceedModerate* – the probability that each oil facility has experienced "Moderate" or greater damage (values range from 0.0 to 1.0)
    h. *dbo.eqOilFlty.PDsExceedExtensive* - the probability that each oil facility has experienced "Extensive" or greater damage (values range from 0.0 to 1.0)
    i. *dbo.eqOilFlty.FunctDay1* – oil facility functionality on Day 1 (values range from 0 – 100%)
    j. *dbo.eqOilFlty.FunctDay3* – oil facility functionality on Day 3 (values range from 0 – 100%)
    k. *dbo.eqOilFlty.FunctDay7* – oil facility functionality on Day 7 (values range from 0 – 100%)
    l. *dbo.eqOilFlty.FunctDay14* – oil facility functionality on Day 14 (values range from 0 – 100%)
    m. *dbo.eqOilFlty.FunctDay30* – oil facility functionality on Day 30 (values range from 0 – 100%)
    n. *dbo.eqOilFlty.FunctDay90* – oil facility functionality on Day 90 (values range from 0 – 100%)

Review the attribute data by opening the layer's attribute table; right-click on the layer name in the table of contents and select "Open Attribute Table".

2. To set the layer's thematic settings, right-click on the layer name and select "Properties…". In the Layer Properties window, select the "Symbology" tab. In the table of contents on the left-hand side, select "Quantities" and "Graduated Colors". In the Fields Value dropdown menu, select *dbo.eqOilFlty.PDsExceedModerate.* Under "Classification" on the right-hand side, click "Classify…" to bring up the Classification window (**Figure 5.21**). From the "Classification – Classes" pulldown menu, pick 3 classes, then from the "Classification - Method:" pulldown menu, select "Manual".

Edit the Break Values on the right to: 0.25, 0.75, and 1.0. Click "OK" to return to the Layer Properties window (**Figure 5.22**). Double-click on the "Symbol" to the right of each value range to access the Symbol Selector; symbolize *0 – 0.25* using a green Petroleum Facilities symbol (e.g., use the ERS Homeland Security symbol named "L4 Petroleum Facilities", which can be found by typing "Petroleum Facilities" into the search box at the top of the Symbol Selector window as shown in **Figure 5.23**), *0.25 – 0.75* using yellow symbols and *0.75 – 1.0* using red symbols. Click "OK" to accept your settings and draw the map.

Figure 5.21: Classification Window for the Oil_Facilities Feature Class

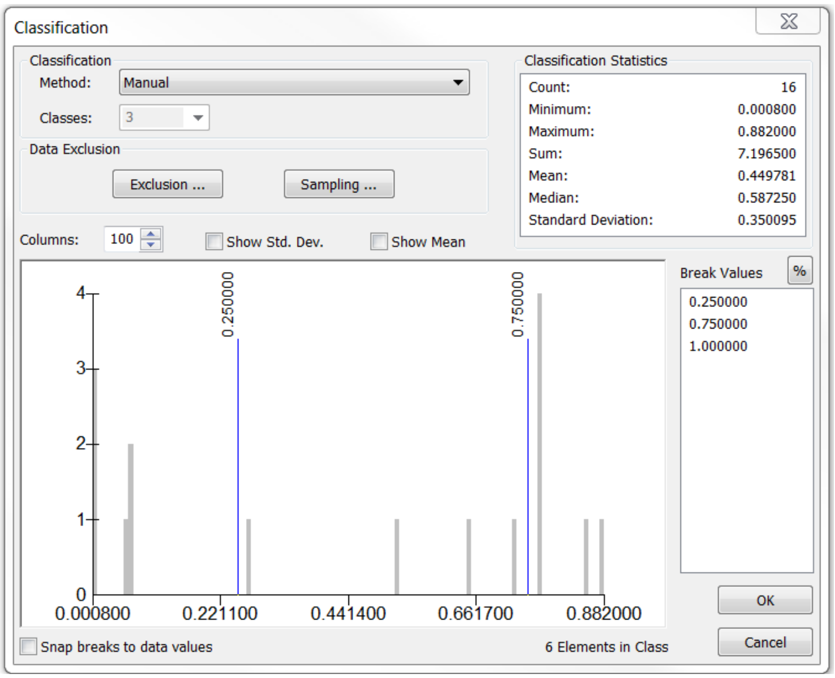


Figure 5.22: Layer Properties Window for the Oil_Facilities Feature Class

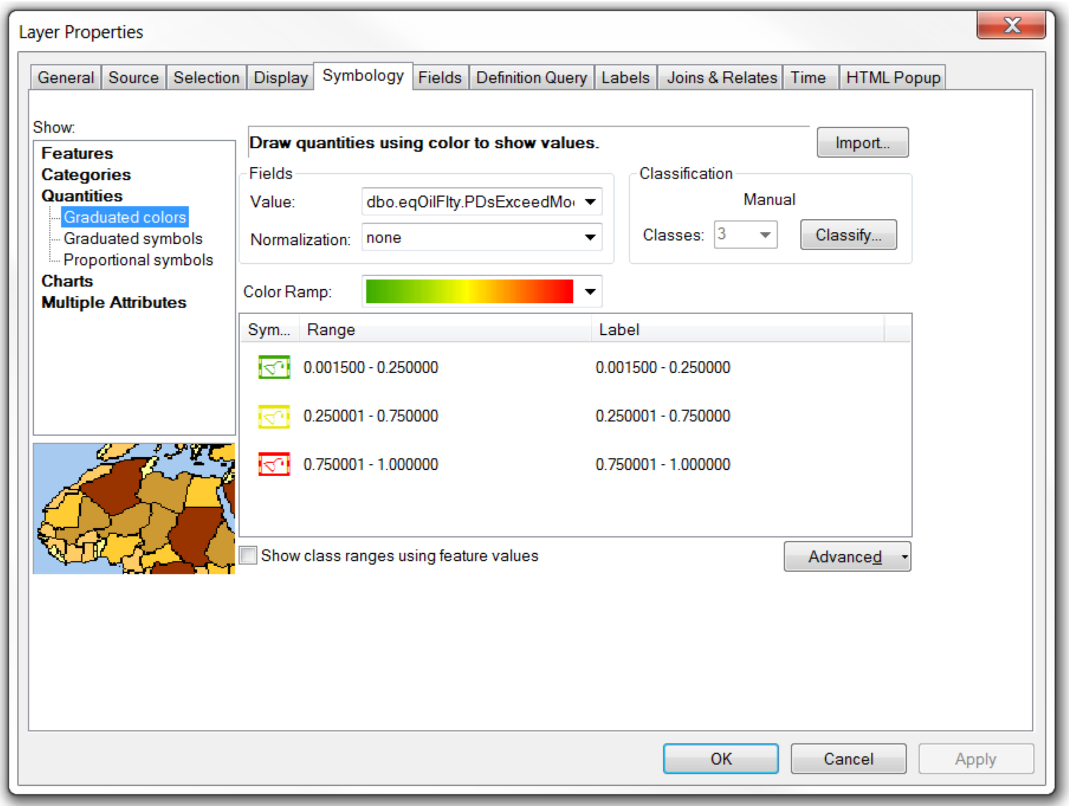
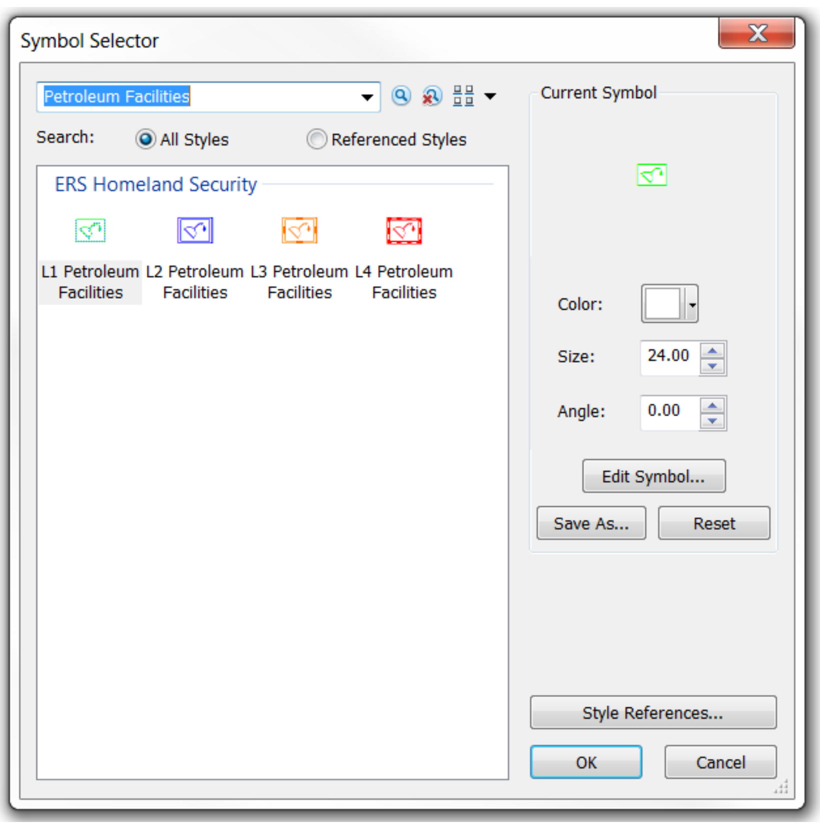


Figure 5.23: Symbol Selector Window for the Oil_Facilities Feature Class



5.2.11 Natural Gas Facility Impact

*This layer will be created using the file geodatabase feature class named "Natural_Gas_Facilities", which is part of the "Utilities" file geodatabase feature dataset as exported by the *Hazus Export Tool*.

1. Add the "*Utilities*" feature dataset to your ArcGIS workspace (if it is not already loaded) to access the "*Natural_Gas_Facilities*" feature class. This layer provides the natural gas facilities inventory data as well as damage and functionality estimates, as follows:
    a. *dbo.eqNaturalGasFlty.PDsNone* – the probability that each natural gas facility is in the "None" damage state (values range from 0.0 to 1.0)
    b. *dbo.eqNaturalGasFlty.PDsSlight* – the probability that each natural gas facility is in the "Slight" damage state (values range from 0.0 to 1.0)
    c. *dbo.eqNaturalGasFlty.PDsModerate* – the probability that each natural gas facility is in the "Moderate" damage state (values range from 0.0 to 1.0)
    d. *dbo.eqNaturalGasFlty.PDsExtensive* – the probability that each natural gas facility is in the "Extensive" damage state (values range from 0.0 to 1.0)
    e. *dbo.eqNaturalGasFlty.PDsComplete* – the probability that each natural gas facility is in the "Complete" damage state (values range from 0.0 to 1.0)
    f. *dbo.eqNaturalGasFlty.PDsExceedSlight* – the probability that each natural gas facility has experienced "Slight" or greater damage (values range from 0.0 to 1.0)
    g. *dbo.eqNaturalGasFlty.PDsExceedModerate* – the probability that each natural gas facility has experienced "Moderate" or greater damage (values range from 0.0 to 1.0)
    h. *dbo.eqNaturalGasFlty.PDsExceedExtensive* - the probability that each natural gas facility has experienced "Extensive" or greater damage (values range from 0.0 to 1.0)
    i. *dbo.eqNaturalGasFlty.FunctDay1* – natural gas facility functionality on Day 1 (values range from 0 – 100%)
    j. *dbo.eqNaturalGasFlty.FunctDay3* – natural gas facility functionality on Day 3 (values range from 0 – 100%)
    k. *dbo.eqNaturalGasFlty.FunctDay7* – natural gas facility functionality on Day 7 (values range from 0 – 100%)
    l. *dbo.eqNaturalGasFlty.FunctDay14* – natural gas facility functionality on Day 14 (values range from 0 – 100%)
    m. *dbo.eqNaturalGasFlty.FunctDay30* – natural gas facility functionality on Day 30 (values range from 0 – 100%)
    n. *dbo.eqNaturalGasFlty.FunctDay90* – natural gas facility functionality on Day 90 (values range from 0 – 100%)

Review the attribute data by opening the layer's attribute table; right-click on the layer name in the table of contents and select "Open Attribute Table".

2. To set the layer's thematic settings, right-click on the layer name and select "Properties…". In the Layer Properties window, select the "Symbology" tab. In the table of contents on the left-hand side, select "Quantities" and "Graduated Colors". In

the Fields Value dropdown menu, select *dbo.eqNaturalGasFlty.PDsExceedModerate.* Under “Classification” on the right-hand side, click “Classify…” to bring up the Classification window (**Figure 5.24**). From the “Classification – Classes” pulldown menu, pick 3 classes, then from the “Classification - Method:” pulldown menu, select “Manual”. Edit the Break Values on the right to: 0.25, 0.75, and 1.0. Click “OK” to return to the Layer Properties window (**Figure 5.25**). Double-click on the “Symbol” to the right of each value range to access the Symbol Selector; symbolize *0 – 0.25* using a green Natural Gas Facilities symbol (e.g., use the ERS Homeland Security symbol named “L4 Natural Gas Facilities” which can be found by typing “Natural Gas Facilities” into the search box at the top of the Symbol Selector window as shown in **Figure 5.26**). Symbolize *0 – 0.25* using a green symbol, *0.25 – 0.75* using yellow symbols and *0.75 – 1.0* using red symbols. Click “OK” to accept your settings and draw the map.

Figure 5.24: Classification Window for the Natural_Gas_Facilities Feature Class

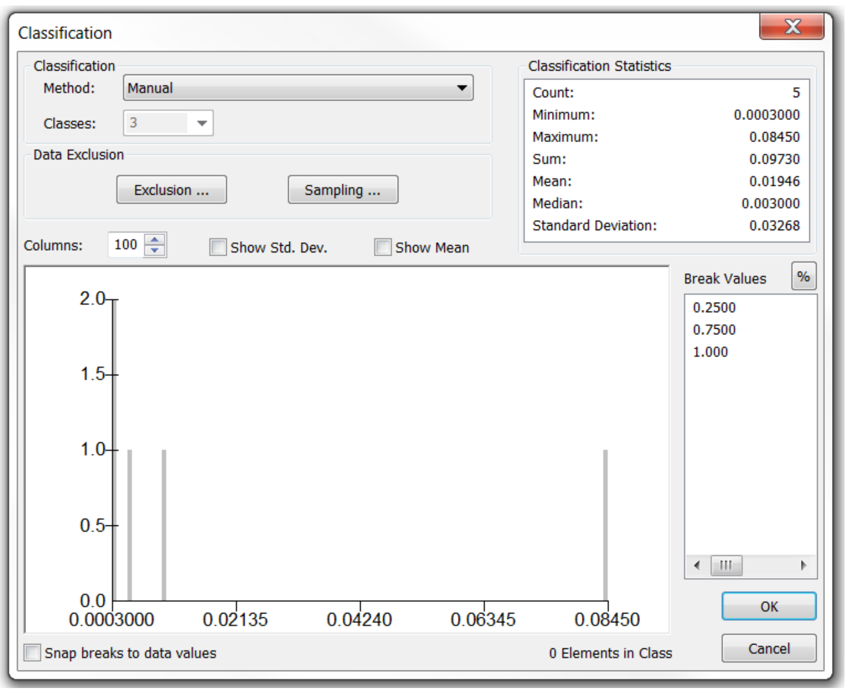


Figure 5.25: Layer Properties Window for the Natural_Gas_Facilities Feature Class

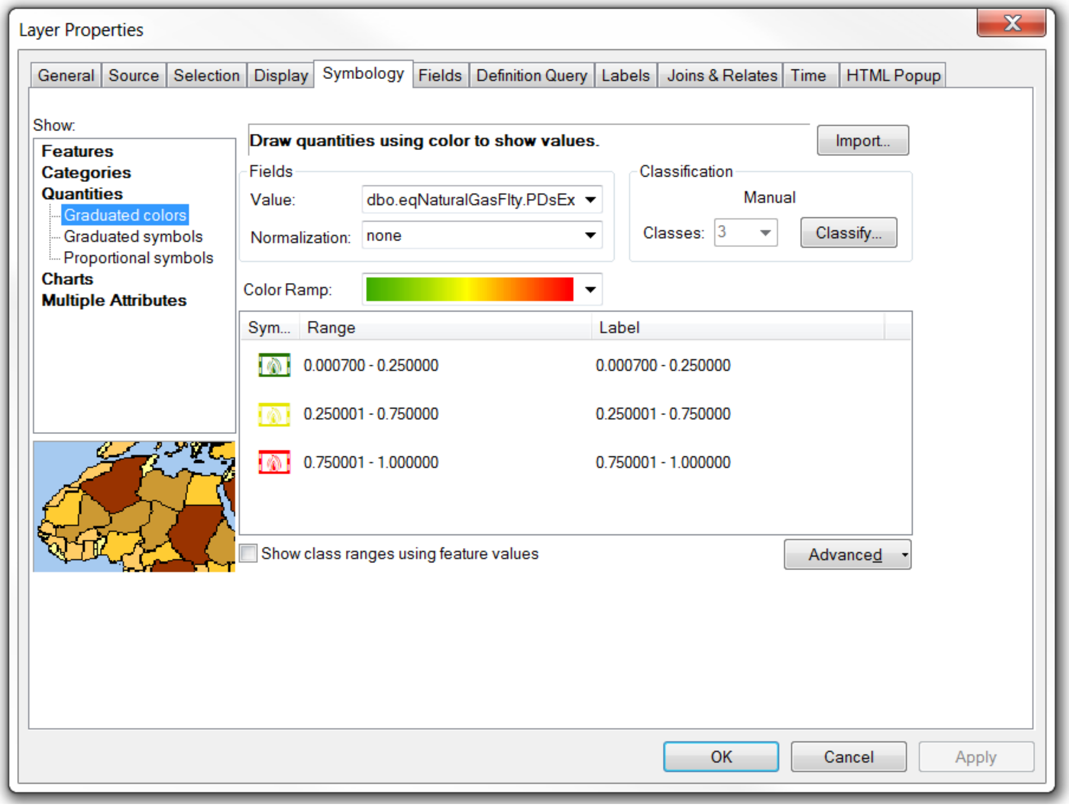
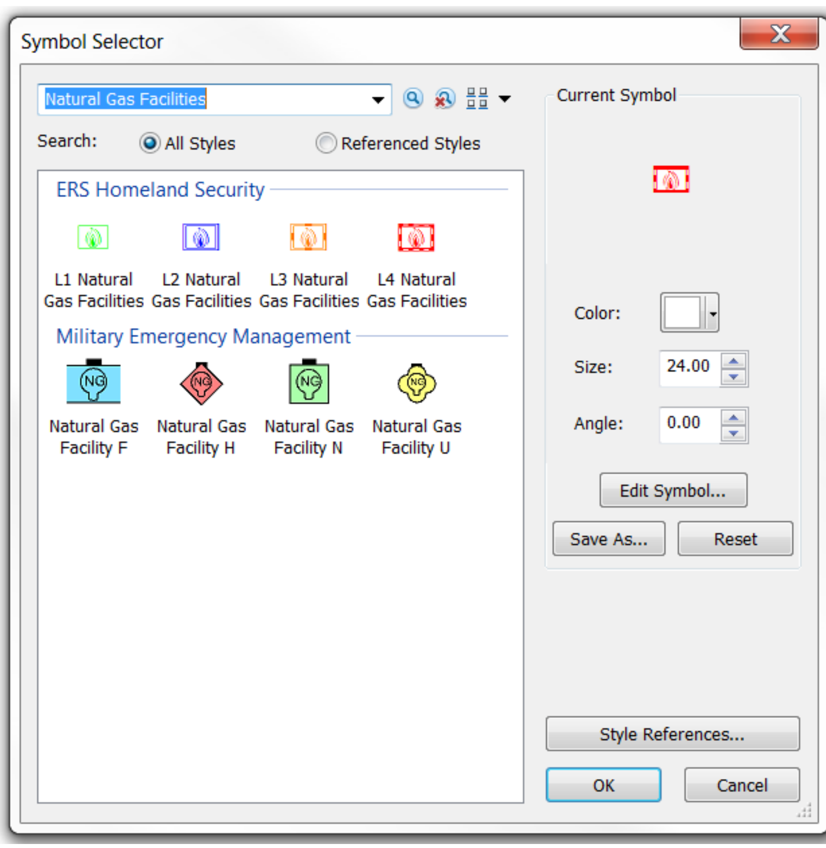


Figure 5.26: Symbol Selector Window for the Natural_Gas_Facilities Feature Class



5.2.12 Potable Water Facility Impact

*This layer will be created using the file geodatabase feature class named "Potable Water Facilities", which is part of the "Utilities" file geodatabase feature dataset as exported by the *Hazus Export Tool.*

1. Add the "*Utilities*" feature dataset to your ArcGIS workspace (if it is not already loaded) to access the "*Potable_Water_Facilities*" feature class. This layer provides the potable water facilities inventory data as well as damage and functionality estimates, as follows:
    a. *dbo.eqPotableWaterFlty.PDsNone* – the probability that each potable water facility is in the "None" damage state (values range from 0.0 to 1.0)
    b. *dbo.eqPotableWaterFlty.PDsSlight* – the probability that each potable water facility is in the "Slight" damage state (values range from 0.0 to 1.0)
    c. *dbo.eqPotableWaterFlty.PDsModerate* – the probability that each potable water facility is in the "Moderate" damage state (values range from 0.0 to 1.0)
    d. *dbo.eqPotableWaterFlty.PDsExtensive* – the probability that each potable water facility is in the "Extensive" damage state (values range from 0.0 to 1.0)
    e. *dbo.eqPotableWaterFlty.PDsComplete* – the probability that each potable water facility is in the "Complete" damage state (values range from 0.0 to 1.0)
    f. *dbo.eqPotableWaterFlty.PDsExceedSlight* – the probability that each potable water facility has experienced "Slight" or greater damage (values range from 0.0 to 1.0)
    g. *dbo.eqPotableWaterFlty.PDsExceedModerate* – the probability that each potable water facility has experienced "Moderate" or greater damage (values range from 0.0 to 1.0)
    h. *dbo.eqPotableWaterFlty.PDsExceedExtensive* - the probability that each potable water facility has experienced "Extensive" or greater damage (values range from 0.0 to 1.0)
    i. *dbo.eqPotableWaterFlty.FunctDay1* – potable water facility functionality on Day 1 (values range from 0 – 100%)
    j. *dbo.eqPotableWaterFlty.FunctDay3* – potable water facility functionality on Day 3 (values range from 0 – 100%)
    k. *dbo.eqPotableWaterFlty.FunctDay7* – potable water facility functionality on Day 7 (values range from 0 – 100%)
    l. *dbo.eqPotableWaterFlty.FunctDay14* – potable water facility functionality on Day 14 (values range from 0 – 100%)
    m. *dbo.eqPotableWaterFlty.FunctDay30* – potable water facility functionality on Day 30 (values range from 0 – 100%)
    n. *dbo.eqPotableWaterFlty.FunctDay90* – potable water facility functionality on Day 90 (values range from 0 – 100%)

Review the attribute data by opening the layer's attribute table; right-click on the layer name in the table of contents and select "Open Attribute Table".

2. To set the layer's thematic settings, right-click on the layer name and select "Properties…". In the Layer Properties window, select the "Symbology" tab. In the table of contents on the left-hand side, select "Quantities" and "Graduated Colors". In

the Fields Value dropdown menu, select *dbo.eqPotableWaterFlty.PDsExceedModerate.* Under "Classification" on the right-hand side, click "Classify…" to bring up the Classification window (**Figure 5.27**). From the "Classification – Classes" pulldown menu, pick 3 classes, then from the "Classification - Method:" pulldown menu, select "Manual". Edit the Break Values on the right to: 0.25, 0.75, and 1.0. Click "OK" to return to the Layer Properties window (**Figure 5.28**). Double-click on the "Symbol" to the right of each value range to access the Symbol Selector; symbolize *0 – 0.25* using a green Water Facilities symbol (e.g., use the ERS Homeland Security symbol named "L4 Water Supply Infrastructure" which can be found by typing "ERS Water" into the search box at the top of the Symbol Selector window as shown in **Figure 5.29**). Symbolize *0 – 0.25* using a green symbol, *0.25 – 0.75* using yellow symbols and *0.75 – 1.0* using red symbols. Click "OK" to accept your settings and draw the map.

3. It may also be helpful to include an estimate of the number of households without potable water at Day 1, their daily water needs (gallons per day) and the equivalent number of water trucks required to supply this need. The *Hazus Global Summary* Report tabulates the total number of households without water in Table 9 (page 13 of 22), while the *Potable Water System Performance Report* includes the household estimates by County. To estimate the daily water needs per person, the following calculations are required
    a. Convert households without water to the number of people without water by multiplying by a typical number of people per households (3.0 on average, or a more precise number can be computed for each county from Hazus' demographic data on households and populations).
    b. Assume the average person requires 1 gallon (~3.79 liters) of water per day, based on U.S. Army Corps of Engineers planning guidance.
    c. Assume one water truck can carry 4,755 gallons (~18,000 liters) of water (per U.S. Army Corps of Engineers planning guidance) to derive the total number of truckloads required each day.

    An example, by County, for the Wasatch Fault Scenario is provided in **Table 5.5**.

Table 5.5 Estimated Water Impacts and Resource Needs, by County for the Wasatch Fault Scenario Example

County	# Households without Potable Water (at Day 1)	Daily Potable Water Needs Per Person (Gallons/day)	Number of Truckloads needed Daily
Davis	22,017	66,051	14
Salt Lake	284,640	853,920	180
Utah	55	165	1

Figure 5.27: Classification Window for the Potable_Water_Facilities Feature Class

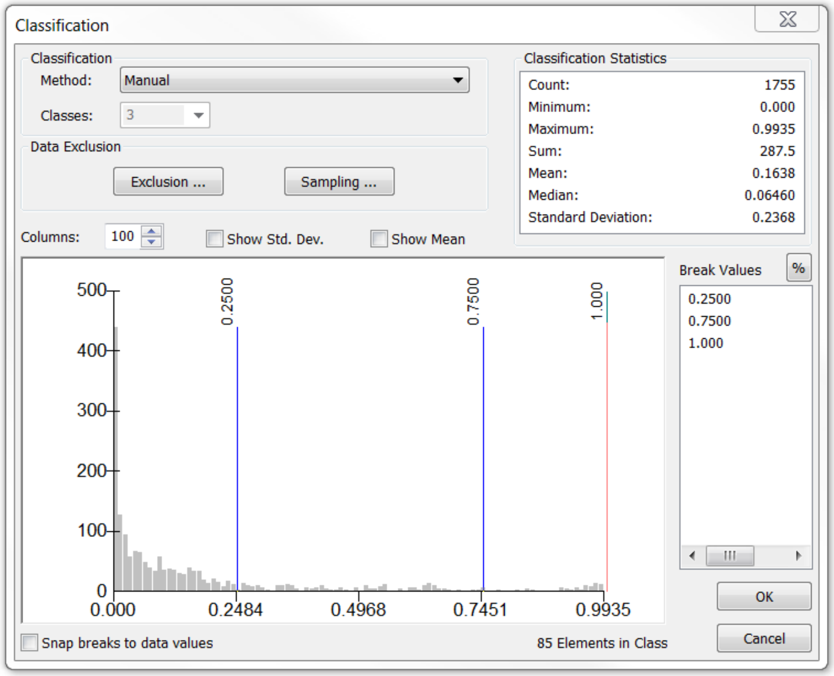


Figure 5.28: Layer Properties Window for the Potable_Water_Facilities Feature Class

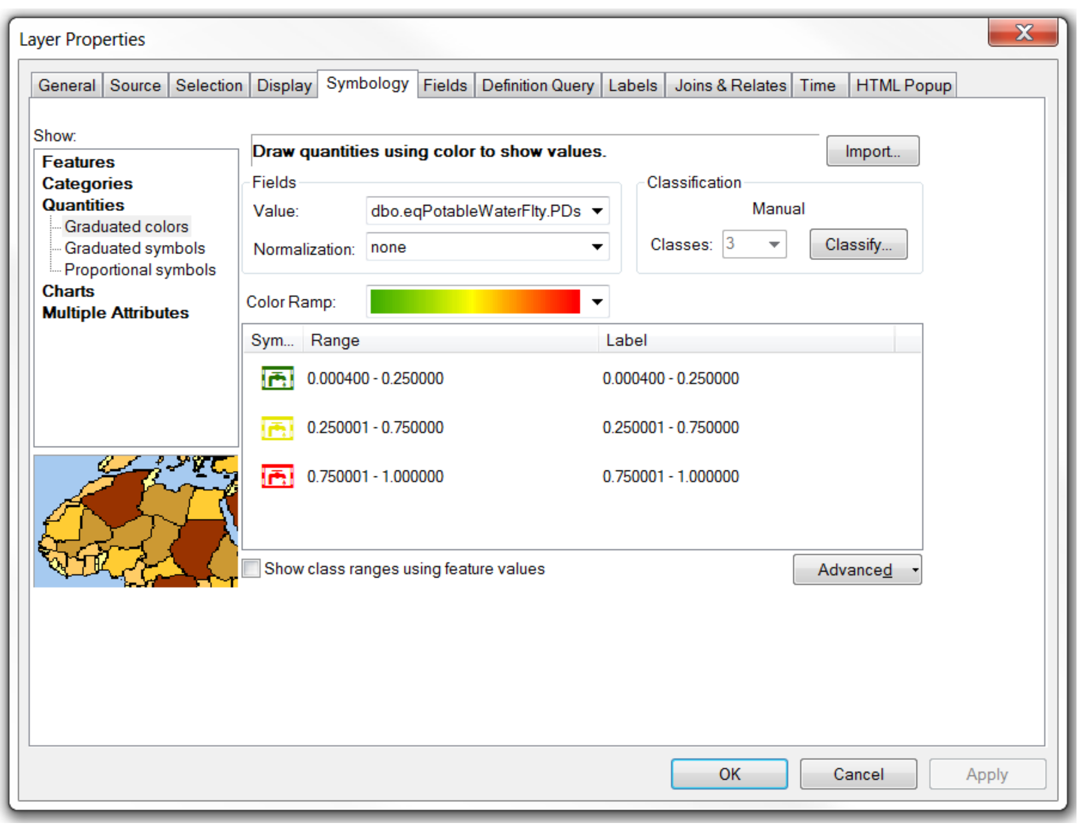
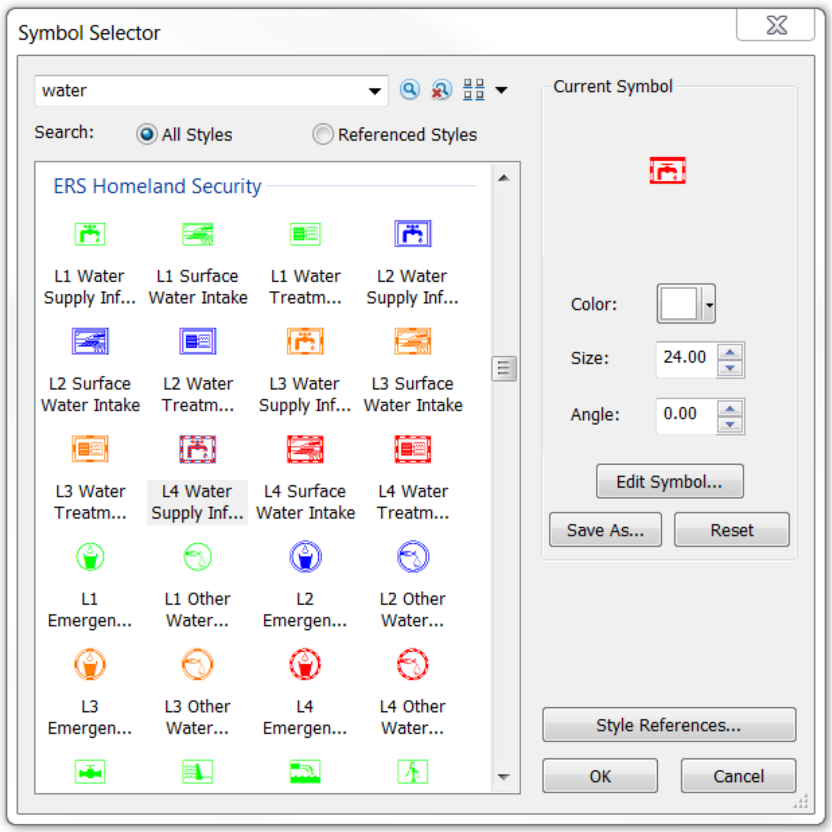


Figure 5.29: Symbol Selector Window for the Potable_Water_Facilities Feature Class



5.2.13 Strong Ground Shaking - PGA (Peak Ground Acceleration)

* This layer will be created using the file geodatabase feature class named "Census_Tract_Shelter_Needs_and_Debris" which is part of the "General_Building_Stock" file geodatabase feature dataset created by the *Hazus Export Tool*, and the USGS' PGA layer thematic settings, available in the pga.lyr file associated with each ShakeMap.

1. Add the "General_Building_Stock" feature dataset to your ArcGIS workspace (if it is not already loaded) to access the "*Census_Tract_Shelter_Needs_and_Debris*" feature class. As noted in Section 5.2.4, this census tract layer includes various ground shaking and ground failure hazards data by census tract, as well as debris and shelter estimates resulting from damage to buildings. Hazard data includes:
    a. *dbo.eqTract.PGA* – peak ground acceleration in each census tract (in units of g)
    b. *dbo.eqTract.PGV* – peak ground velocity in each census tract (in units of in/sec)
    c. *dbo.eqTract.Sa03* – spectral acceleration at 0.3 second period in each census tract (in units of g)
    d. *dbo.eqTract.Sa10* – spectral acceleration at 1.0 second period in each census tract, (in units of g)

Review the attribute data by opening the layer's attribute table; right-click on the layer name in the table of contents and select "Open Attribute Table".

2. To set the layer's thematic settings, right-click on the layer name and select "Properties…". In the Layer Properties window, select the "Symbology" tab. In the table of contents on the left-hand side, select "Quantities" and "Graduated colors". In the Field Selection pick list, select the field *dbo.eqTract.PGA* (**Figure 5.30**). Click "Import…" to access the "Import Symbology" window (**Figure 5.31**). Click on the folder symbol to navigate to the storage location of the USGS ShakeMap "pga.lyr" file, downloaded as part of the SHAPE.ZIP (**Figure 5.32**). Select the "pga.lyr" file and click "Add" to return to the "Import Symbology" window. Select "Complete symbology definition" and click "OK" to continue. This brings up the "Import Symbology Matching Dialog" (**Figure 5.33**); select *dbo.eqTractPGA* from the pick list and click "OK" to continue. This should result in assignment of USGS standard PGA ranges and colors as shown in **Figure 5.34**.

Figure 5.30: Layer Properties Window for the *Census_Tract_Shelter_Needs_and_Debris* Feature Class

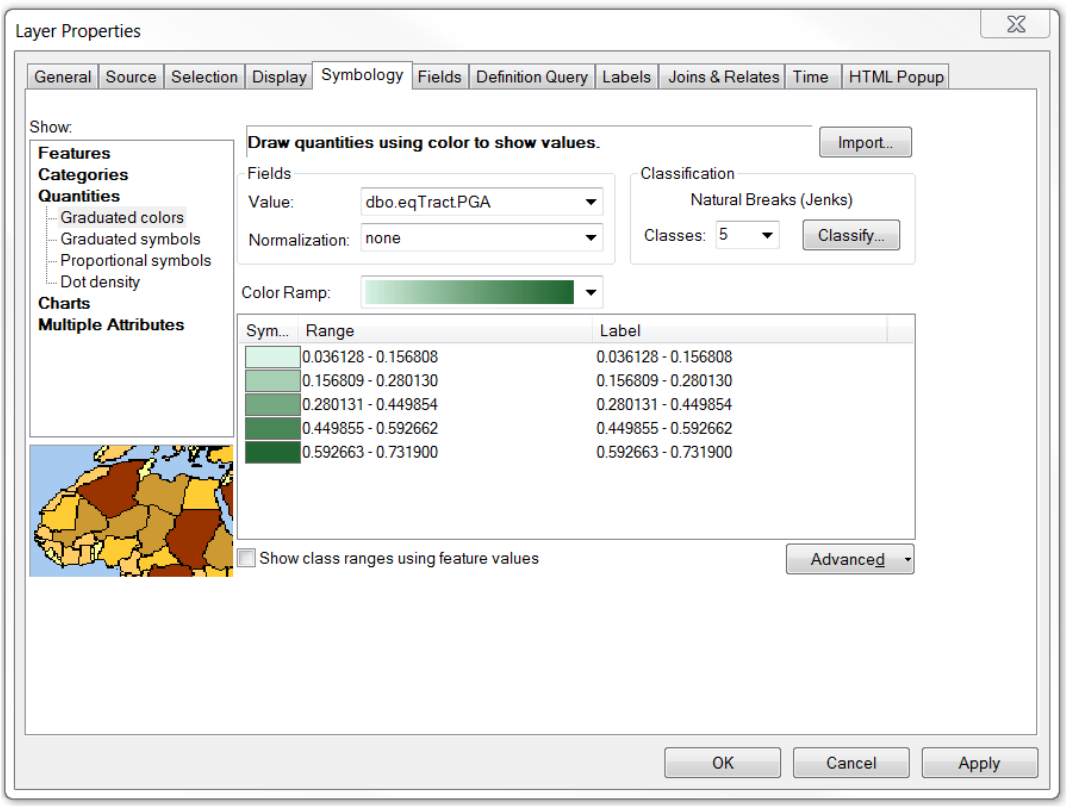


Figure 5.31: Import Symbology Window for the PGA layer

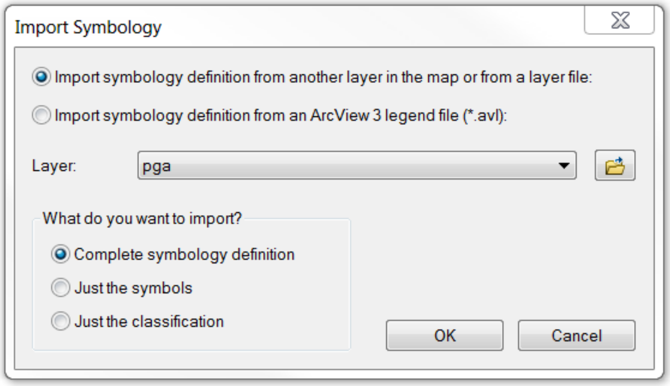


Figure 5.32: Import Symbology from Layer Window for the PGA layer

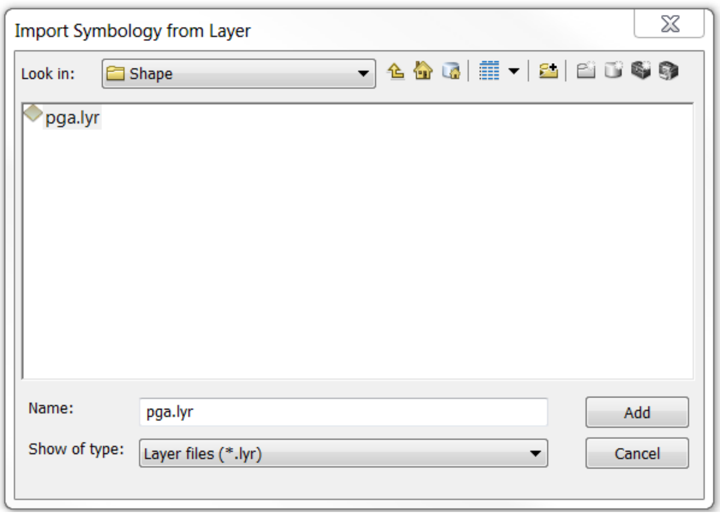


Figure 5.33: Import Symbology Matching Dialog Window for the PGA layer

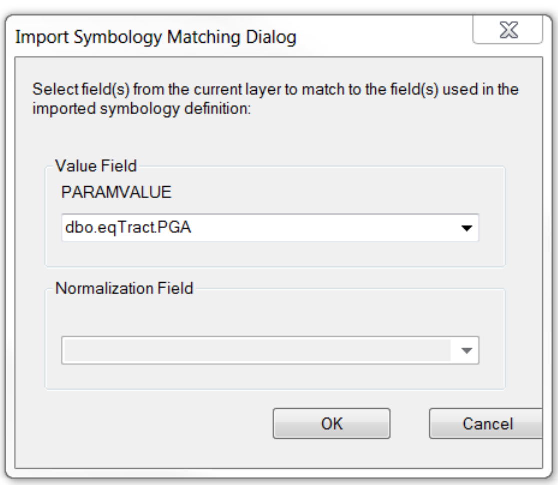
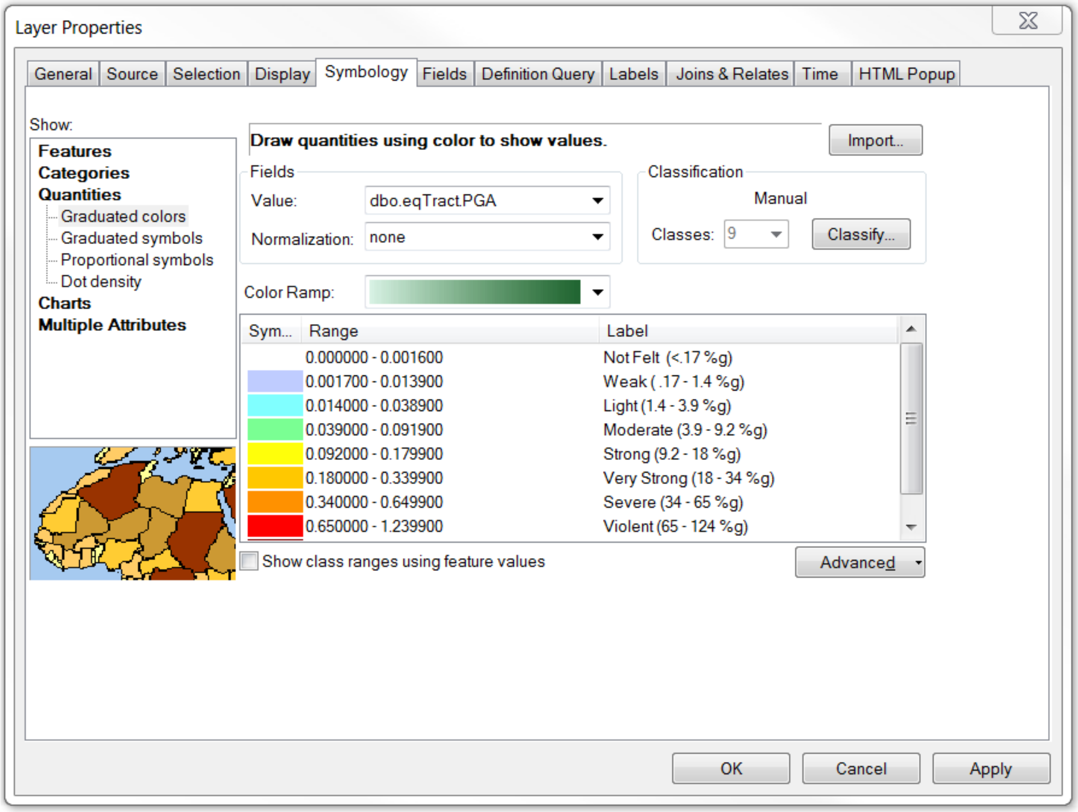


Figure 5.34: Layer Properties Window for the PGA layer



5.2.14 Search and Rescue Needs

FEMA has developed a methodology that estimates potential urban search and rescue (USAR) team requirements for earthquakes using Hazus building damage estimates; the required number of USAR teams and personnel is proportional to the estimated number of collapsed buildings.

As an example, the number of red-tagged and collapsed buildings resulting from a Magnitude 7.0 scenario earthquake on the Wasatch fault underlying Salt Lake City are given in **Table 5.6**. The number of red tagged buildings is equal to the number of buildings in the Complete damage state, and can be determined as described in Section 5.2.1. Collapse rates for buildings in the Complete data State as given in the table are mathematical average values (rounded up) taken from the more detailed collapse rate table in the Hazus Technical Manual, reproduced here as **Table 5.7**.

Table 5.6 Red-Tagged and Collapsed Buildings by Structure Type for a M7.0 Wasatch Fault Scenario Earthquake

Structure Type	Red (Complete)	Collapse Rates for Complete Damage	Total Collapse	USAR Building Types
Wood	1,663	3%	50	Type IV
Steel	870	6%	52	Type I
Concrete	797	10%	80	Type I
Precast Concrete	198	13%	26	Type II
Reinforced Masonry	7,515	10%	752	Type II
Unreinforced Masonry	52,250	15%	7,838	Type III
Manufactured Housing	259	3%	8	Type IV
Total	**63,552**		**8,806**	

Table 5.7 Hazus Collapse Rates by Model Building Type for Complete Structural Damage

Model Building Type	Probability of Collapse Given a Complete Damage State
W1	3%
W2	3%
S1L	8%
S1M	5%
S1H	3%
S2L	8%
S2M	5%
S2H	3%
S3	3%
S4L	8%
S4M	5%
S4H	3%
S5L	8%
S5M	5%
S5H	3%
C1L	13%
C1M	10%
C1H	5%
C2L	13%
C2M	10%
C2H	5%
C3L	15%
C3M	13%
C3H	10%
PC1	15%
PC2L	15%
PC2M	13%
PC2H	10%
RM1L	13%
RM1M	10%
RM2L	13%

Model Building Type	Probability of Collapse Given a Complete Damage State
RM2M	10%
RM2H	5%
URML	15%
URMM	15%
MH	3%

The number of collapsed buildings, by USAR building type, can be combined with the USAR resource assumptions given in **Table 5.8** to estimate the number of each type of USAR team needed. The assumptions provided in **Table 5.8** were developed by FEMA, with expert assistance, for application to significant earthquake events. Nevertheless, all assumptions should be reviewed for relevance to the user's specific scenario.

Table 5.8 Urban Search and Rescue Resource Assumptions

	Type I	Type II	Type III	Type IV
Personnel per Team	**70**	**32**	**22**	**6**
Hours Allowed for Mission Accomplishment	72	72	72	72
Hours Deployment Time	24	24	6	6
Hours Available for Mission Accomplishment	48	48	66	66
Days Available for Mission Accomplishment	**2**	**2**	**2.75**	**2.75**
Structures per Team per Operational Period	4	8	16	30
Hours Per Day	12	12	12	12
Structures per Team per Day	4	8	16	30
Structures per Team per Mission	**8**	**16**	**44**	**83**

To estimate the number of USAR teams required, the number of collapsed buildings of each USAR building type is divided by the number of *Structures per Team per Mission* from **Table 5.8**. Similarly, the number of trained personnel is estimated as the number of required Teams multiplied by *Personnel per Team*.

The results for the Wasatch Fault scenario are given in **Table 5.9**. As shown in the table, this event produces significant numbers of collapsed unreinforced masonry (URM) buildings, which require a substantial number of USAR Type III teams for response.

Table 5.9 Urban Search & Rescue Team Needs Estimated for a M7.0 Wasatch Fault Scenario Earthquake

URBAN SEARCH & RESCUE GAP ANALYSIS-Mw 7.0 WASATCH FAULT, SALT LAKE SEGMENT		
Resource	**Metric**	**Required**
Total number of **US&R Type I Task Forces** required? (Approximately 70 members, trained & equipped for light frame, heavy wall, heavy floor and concrete-steel construction **(heavy reinforced concrete))**.	# Buildings	132
	Task Forces	17
	Trained Personnel	1,190
Total number of **US&R Type II Task Forces** required? (Approximately 32 members, trained & equipped for light frame, heavy wall, heavy floor and concrete-steel construction.)	# Buildings	778
	Task Forces	49
	Trained Personnel	1,568
Total number of **Collapse S&R Type III Teams** required? (Approximately 22 members, trained & equipped for light frame construction.)	# Buildings	7,838
	Teams	179
	Trained Personnel	3,938
Total number of **Collapse S&R Type IV Teams** required? (Approximately 6 members, trained & equipped for light frame construction.)	# Buildings	58
	Teams	1
	Trained Personnel	6

6. References

FEMA, 2019, Hazus Earthquake Model User Guidance; Hazus Version 4.2.2.

FEMA, 2012, *Multi-Hazard Loss Estimation Methodology Earthquake Model: Hazus-MH 2.1Technical Manual*, Federal Emergency Management Agency, Washington, D.C., https://www.fema.gov/media-library-data/20130726-1820-25045-6286/hzmh2_1_eq_tm.pdf

FEMA, 2009, ShakeMap-Based HAZUS-MH Loss Estimation Maps: Intermountain Seismic Belt, Utah: http://www.fema.gov/library/viewRecord.do?id=3660

Kircher, C.A., Whitman, R.V., and Holmes, W.T., 2006, HAZUS Earthquake Loss Estimation Methods: ***Natural Hazards Rev.***, Volume 7, Issue 2, pp. 45-59, Issue Date: May 2006

NEHRP, 2009, NEHRP's ShakeMap-HAZUS Demonstration Projects: SeismicWaves, How the National Earthquake Hazards Reduction Program Is Advancing Earthquake Safety, September 2009, http://www.nehrp.gov/pdf/SeismicWavesSep09.pdf

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Wald, D.J., Lin, K.W., Porter, K., Turner, L., 2008, ShakeCast: Automating and Improving the Use of ShakeMap for Post-Earthquake Decision-Making and Response, ***Earthquake Spectra*** Volume 24, Issue 2, pp. 533-553 (May 2008)