Chapter 9. Running HAZUS with User Supplied Data

Chapter 9 provides you with a step-by-step discussion of how to perform an analysis if you wish to modify default parameters and data. Before attempting an analysis that will incorporate user-supplied data, follow the steps in Chapter 3 for running an analysis using only the default data.

9.1 Defining the Study Region

The first step in any analysis is defining a study region. Defining a study region was discussed in Section 3.1.

9.2 Defining the Potential Earth Science Hazards

Section 3.2 gave a brief overview of how to define a scenario earthquake. **HAZUS** has a number of options for defining the potential earth science hazards (PESH). It also allows you to estimate losses based on one of three characterizations of hazard. These are:

- Scenario earthquake (deterministic hazard),
- Probabilistic seismic hazard analysis
- User-supplied map of ground motion

The **deterministic hazard** can be a historical epicenter event, a source event, or an arbitrary event:

- Historical Epicenter Event: The historical epicenter event definition consists of selecting the desired event from the **HAZUS** database of 3,500 historical events. The database includes a magnitude and depth, both of which can be overridden. The desired event can be picked either through a list box or graphically from a map.
- Source Event: For the Western United States, the source event definition consists of selecting the desired fault source from the **HAZUS** database of faults. The user can override the width, type, magnitude, and rupture length of the selected source event. The user graphically defines the epicenter of the event (on the fault).
- Arbitrary Event: An arbitrary earthquake event is defined by the location of its epicenter and by its magnitude. Its location is specified either by entry of latitude and longitude or graphically on a map. The user also specifies the magnitude, depth, type, rupture orientation and length (for the Western U.S.) .

The **probabilistic hazard** option allows the user to generate estimates of damage and loss based on probabilistic seismic hazard for three return periods. No other parameters are required for input. A new option in HAZUS 99 that is defined through the probabilistic hazard, is the **Annualized Loss**. Annualized loss is defined as the expected value of loss in any one year, and is developed by aggregating the losses and their exceedance probabilities. Refer to Chapter 15 of the *Technical Manual* for more details.

The **user-supplied hazard** option requires the user to supply digitized peak ground acceleration (PGA) and spectral acceleration (SA) contour maps. Spectral accelerations at 0.3 second and 0.1 second (SA@0.3 and SA@1.0) are needed to define the hazard. The damage and losses are computed based on the user-supplied maps.

9.2.1 Defining Earthquake Hazard

Figure 9.1 shows the hazard definition menu. Again note that the hazard cannot be defined until the study region has been created (see Section 3.1). Clicking on the **Scenario** option allows you to define the earthquake hazard using the window shown in Figure 9.2.

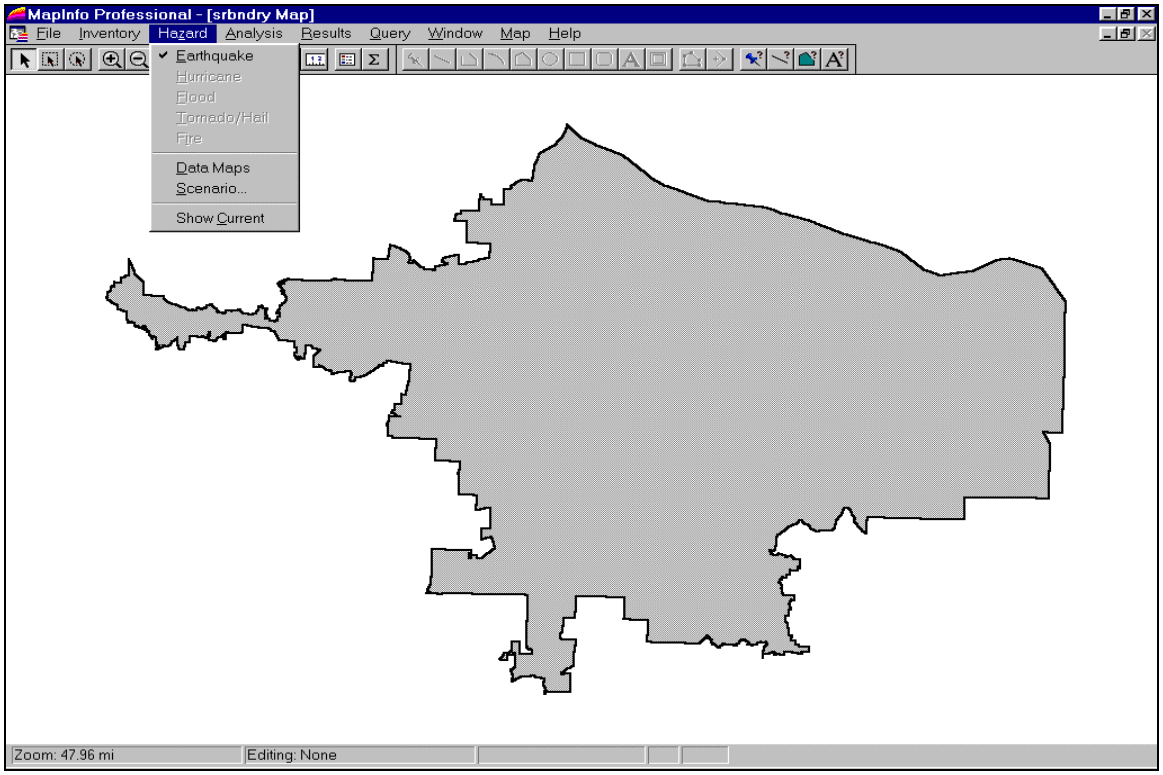


Figure 9.1 Hazard definition menu in HAZUS

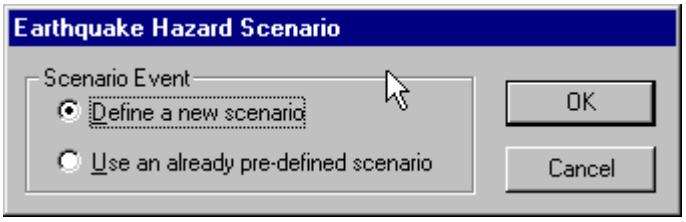


Figure 9.2 Earthquake Hazard Scenario window in HAZUS

To define earthquake hazard, choose **Define new scenario event** or **Open predefined scenario event** (see Figure 9.2). If the study region is new and you haven't defined a scenario previously, then choose the **Define new scenario event** option. When you click on **Define new scenario event** the window shown in Figure 9.3 will appear.

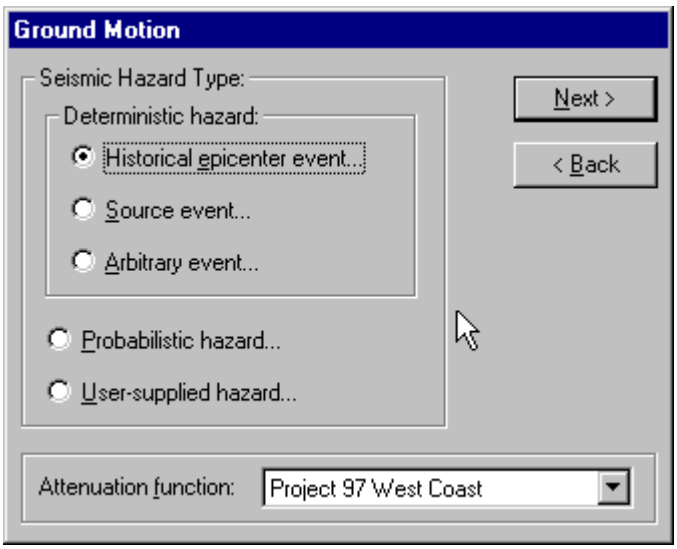


Figure 9.3 Ground Motion definition window in HAZUS

If you have previously run a scenario for a study region and you want to recall this scenario event for analysis on another study region, you can choose a predefined scenario event from Figure 9.2. When you select **Open predefined scenario event**, you will be prompted with the window shown in Figure 9.4. Use the drop down menu to choose any of the scenarios that have been previously defined.

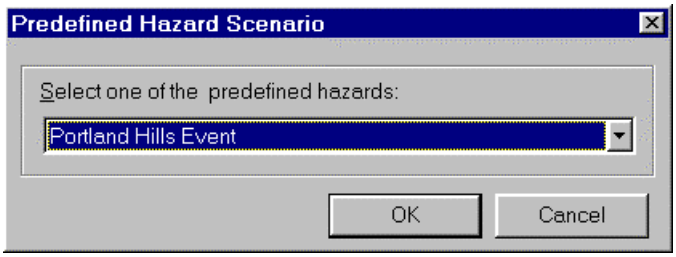


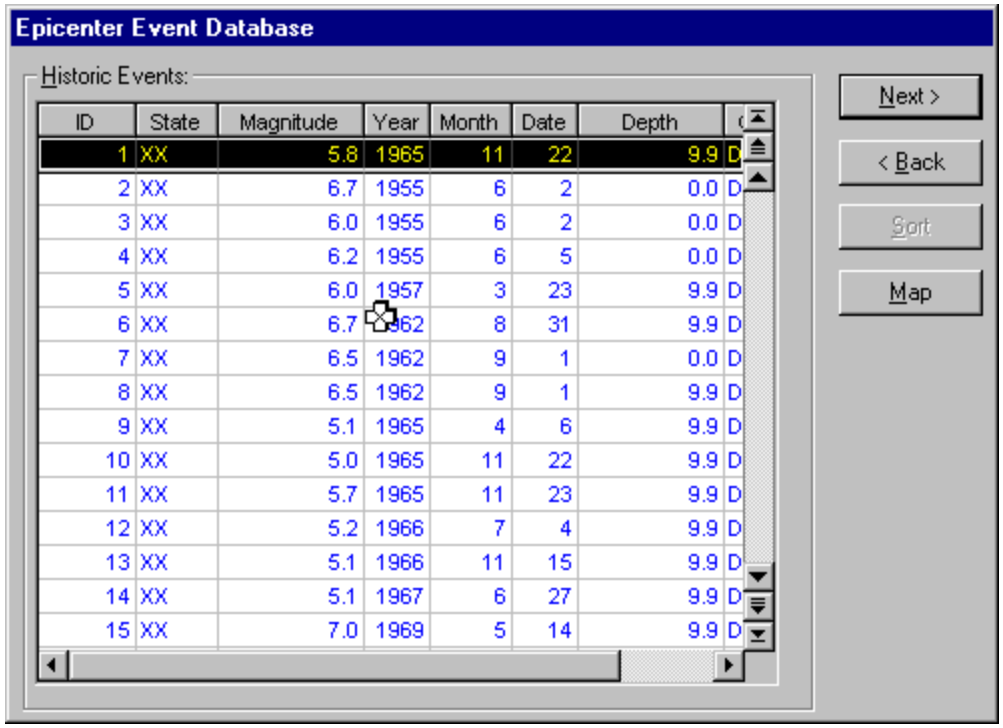
Figure 9.4 Predefined Hazard Scenario window in HAZUS

9.2.2 Defining a Deterministic Scenario

The three methods of defining a deterministic scenario are discussed in the following sections.

9.2.2.1 Historical Epicenter

Select the option **Historical epicenter event** from Figure 9.3 and click the **OK** button. A window (see Figure 9.5), which displays the earthquake epicenter database, will appear. Choose the historical event from the database or alternatively select the epicenter graphically from a map (Figure 9.6) by clicking on the **Map** button. To select an epicenter using the map option, click on the epicenter of choice. To obtain information about the epicenter as shown in the lower left of Figure 9.6, select the "i" tool from the tool bar and click on the epicenter location. Once you have finished gathering information and are ready to select an epicenter, click on the selection button (diagonal arrow) located on the tool bar, and then select the epicenter for the analysis.



ID	State	Magnitude	Year	Month	Date	Depth
1	XX	5.8	1965	11	22	9.9
2	XX	6.7	1955	6	2	0.0
3	XX	6.0	1955	6	2	0.0
4	XX	6.2	1955	6	5	0.0
5	XX	6.0	1957	3	23	9.9
6	XX	6.7	1962	8	31	9.9
7	XX	6.5	1962	9	1	0.0
8	XX	6.5	1962	9	1	9.9
9	XX	5.1	1965	4	6	9.9
10	XX	5.0	1965	11	22	9.9
11	XX	5.7	1965	11	23	9.9
12	XX	5.2	1966	7	4	9.9
13	XX	5.1	1966	11	15	9.9
14	XX	5.1	1967	6	27	9.9
15	XX	7.0	1969	5	14	9.9

Figure 9.5 Database of historic earthquakes supplied with HAZUS

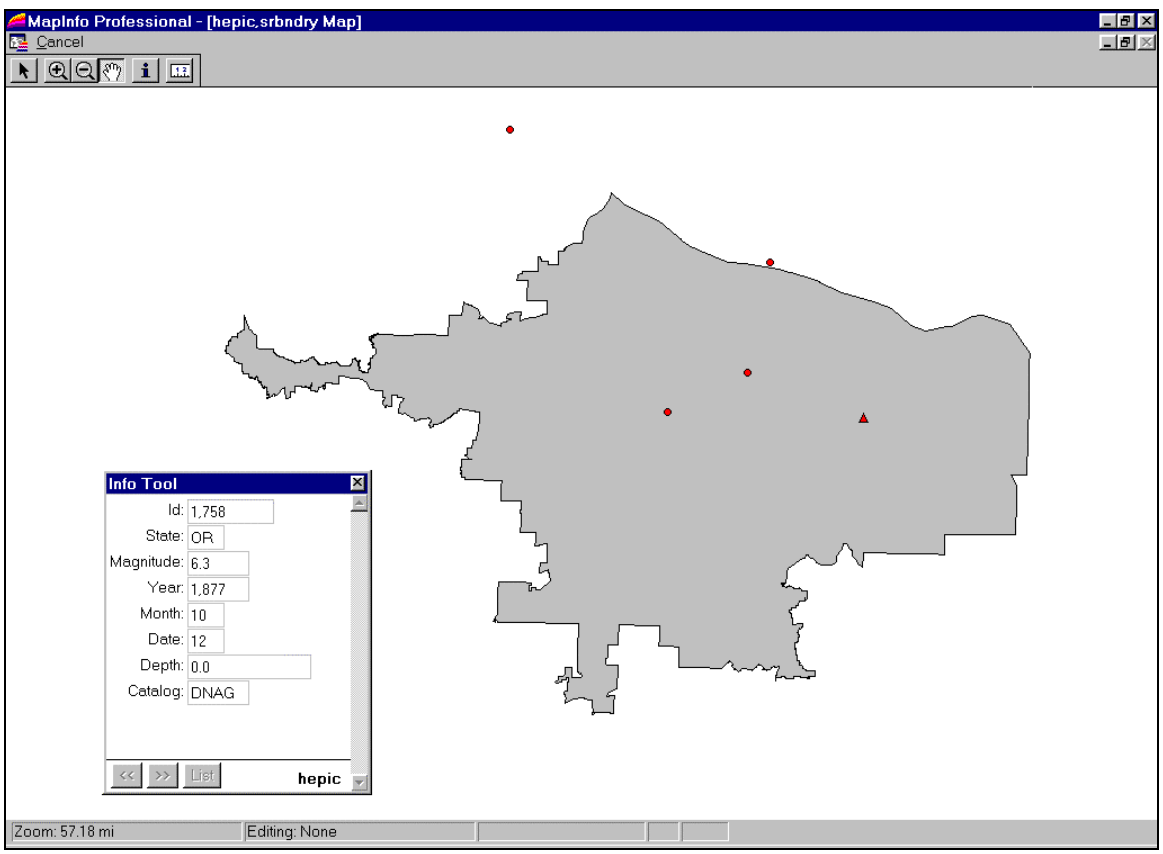


Figure 9.6 Map of historic earthquakes in or near the study region

Once you have selected an epicenter, you can modify the parameters of the historical event through the window shown in Figure 9.7. Rupture orientation is measured in degrees (0 to 360) clockwise from North. Rupture length is based on the default magnitude versus rupture length relationship (Wells and Coppersmith, 1994) unless you choose to override it. If you change the magnitude of the historical earthquake, click on the **Override** button to allow **HAZUS** to compute a new rupture length to correspond to the new magnitude.

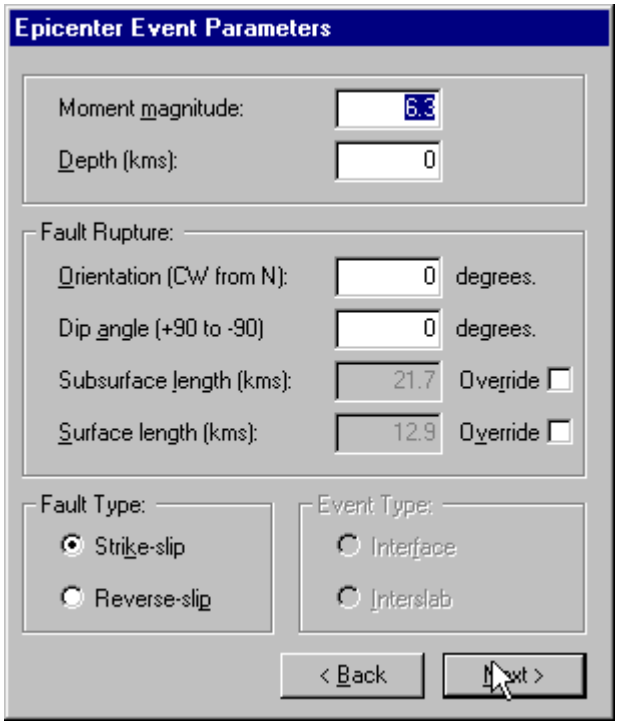


Figure 9.7 Window to modify parameters of a selected historical event

9.2.2.2 Fault Source Event

A database of faults used by the USGS in "Project 97" is supplied with **HAZUS**. The earthquake source database is shown in Figure 9.8. . Clicking on **Source event** in Figure 9.3, followed by **OK**, will cause Figure 9.8 to appear. You can use this window to select a fault, or using the **Map** option, you can select the fault graphically from a map. The scenario earthquake can then be located anywhere along the selected fault. Each source is given a source number and the database is presented so that sources are in numerical order. If you wish to sort the database in some other order, highlight the desired column by clicking on the title at the top of the column and then click on the **Sort** button. For example to sort the database in alphabetical order, highlight the fault name column and sort.

Once a source has been selected from the source database shown in Figure 9.8, the dialog box in Figure 9.9 will appear. To define the location of the epicenter, click on the **Define** button. You will then be presented with a map of sources. The scenario event epicenter is defined by clicking on a location on the map. Magnitude and rupture length are then defined the same as they were in Figure 9.7.

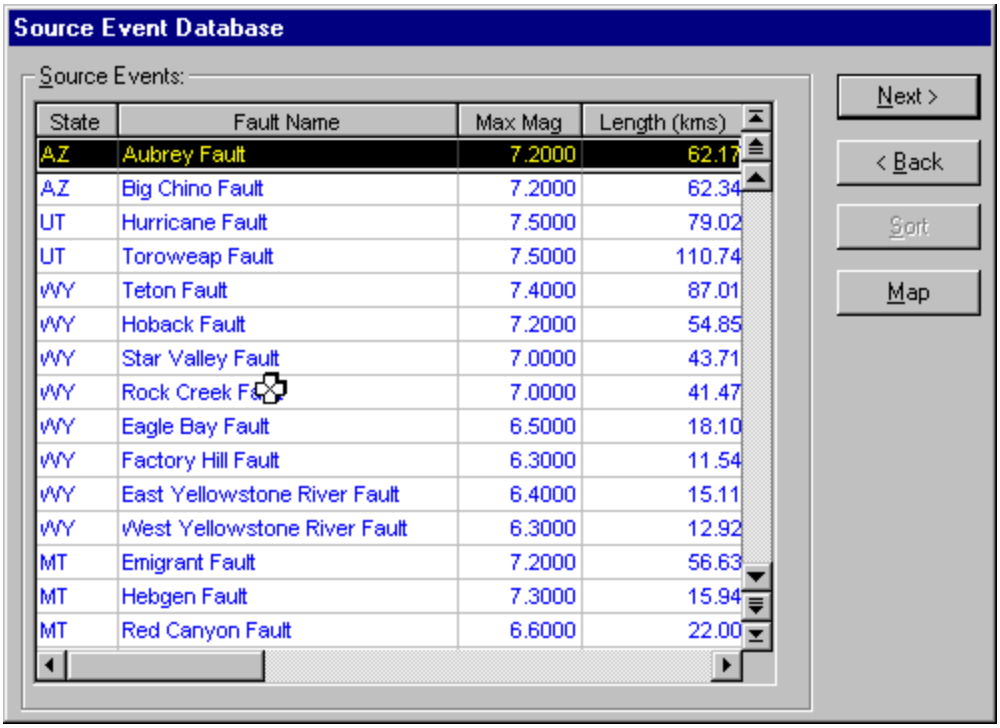


Figure 9.8 Selecting the fault from the HAZUS source database

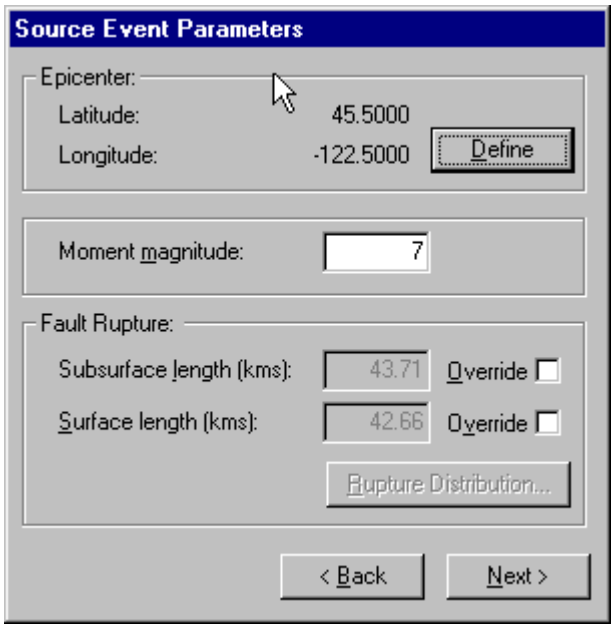


Figure 9.9 Window to modify parameters for the selected source

9.2.2.3 Arbitrary Event

If you have chosen the Arbitrary event option (see Figure 9.3), you will use the dialog box shown in Figure 9.10 to define the location, magnitude, epicenter depth, rupture orientation and rupture length. The epicenter is defined by either viewing the region map and clicking on a location (use Map button) or by typing in latitude and longitude.

Rupture orientation is measured in degrees (0 to 360) clockwise from North. Rupture length is based on the default magnitude versus rupture length relationship (Wells and Coppersmith, 1994) unless you choose to override it. If you change the magnitude of the earthquake, click on the Override button to allow **HAZUS** to compute a new the rupture length to correspond to the new magnitude.

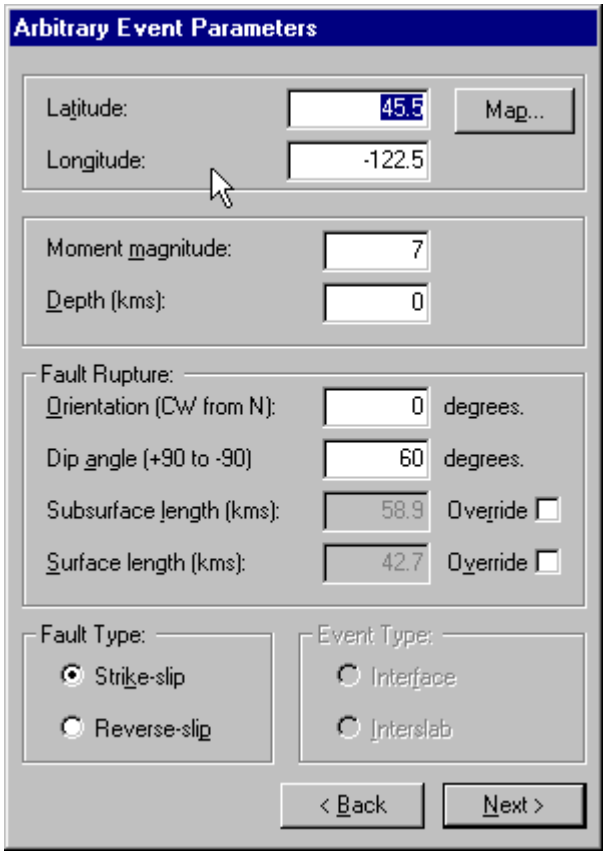


Figure 9.10 Window to define parameters for an arbitrary event

9.2.3 Defining Probabilistic Hazard

The user can select a scenario based on ground shaking data derived from the USGS probabilistic seismic hazard curves. The probabilistic analysis option is available for eight return periods[7] of ground shaking. The user specifies the desired return period through the drop down menu in Figure 9.11. The user can also select the **Annualized Loss** option (see Figure 9.11) that will estimate average annualized losses for the general building stock and casualties. In addition, the user must specify the representative magnitude for the scenario (i.e. data required for the liquefaction calculation). The default assumption is an **M**=7.0 earthquake. If the user has concerns with the appropriate of the default magnitude assumption, consult a local earth science expert or call the technical support line for **HAZUS** at 1-800-955-9442.

[7] The eight return periods are: 100- year, 250- year, 500- year, 750- year, 1000- year, 1500- year, 2000- year, and 2500-year.

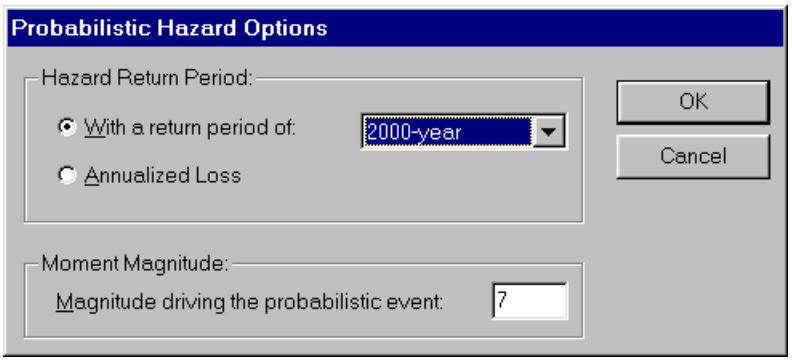


Figure 9.11 Probabilistic hazard options window

9.2.4 User-defined Hazard

You can supply maps of ground shaking intensity for estimating damage and loss. In order to utilize this option, you must obtain ground-shaking maps in a compatible format for input into **HAZUS** (see Chapter 6). The location of the maps is specified in the **User-defined Hazard Data** dialog as shown in Figure 9.12.

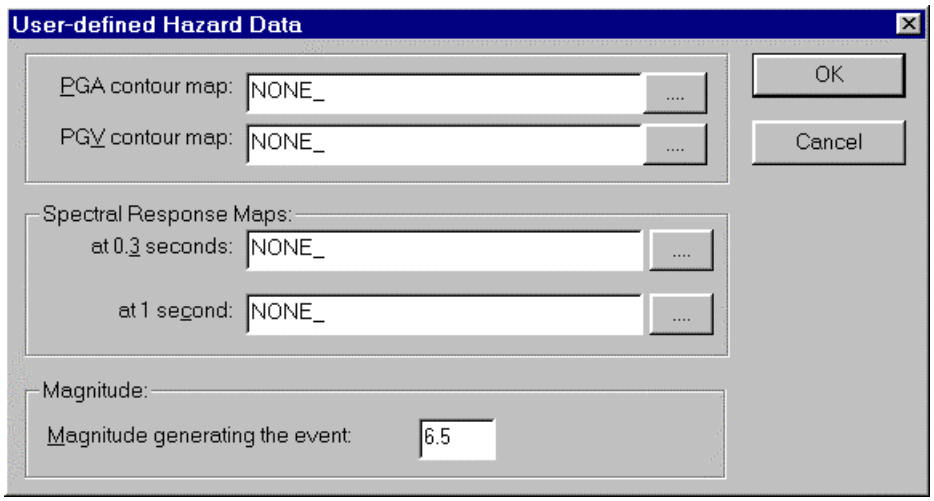


Figure 9.12 Dialog for specifying the location of user-supplied shaking maps

9.2.5 Choosing an Attenuation Function

HAZUS contains default attenuation relationships, which define how ground motion decreases as a function of distance from the source. For the Western United States, five attenuation functions are available. For the Eastern United States, three attenuation relationships are available. The default **HAZUS** attenuation functions were chosen to be consistent with the Project97 work conducted by the USGS. You can modify the attenuation relationship used in the analysis through the **Ground Motion** dialog box shown in Figure 9.3. A detailed description of the supplied attenuation relationships is provided in the *Technical Manual*.

9.2.5.1 Selecting An Earthquake Scenario

A scenario earthquake is defined by its size and location and in cases where a fault is well defined, a rupture length. Earthquake size is measured in **HAZUS** by moment magnitude (**M**). Location is defined by latitude and longitude. It is important to note that the scenario event does not have to occur within the defined study region. The user can define the rupture length, measured in kilometers. However, **HAZUS** does have a default relationship between rupture length and magnitude (Wells and Coppersmith, 1994) as described in the *Technical Manual*.

Basis for Selecting a Scenario Earthquake

- Largest historical earthquake
- Largest Possible Earthquake
- Maximum Possible Earthquake + Smaller More Frequent Event
- Earthquake Scenario from Previous Study

There are several approaches to selecting a scenario earthquake.

9.2.5.2 Largest Historical Earthquake

One approach is to base the scenario earthquake on the largest earthquake known to have occurred in or near the region. This assumes that if such an earthquake has occurred before, it can occur again. **HAZUS** includes a database of historic earthquakes (see Figure 9.5) based on the Global Hypocenter Database available from the National Earthquake Information Center (NEIC, 1992). The NEIC database contains reported earthquakes from 300 BC to 1990. You can access this database by clicking on **Historical epicenter event** in Figure 9.3 and then selecting an historic earthquake for the scenario event (follow the steps in Section 9.2.1). If several active faults exist in the region, it is appropriate to select maximum historical events from each fault and to perform a loss study for each of these scenarios.

Once an event based on an historical epicenter has been chosen, you can run the analysis with that event or modify the earthquake using the window shown in Figure 9.6. You have the option to change the magnitude, the earthquake depth, the rupture length and the orientation of the rupture. The location of the event cannot be changed if an historical epicenter has been chosen. If you wish to use a different location you must select a different historical event or use the "Arbitrary Event" option.

9.2.5.3 Largest Possible Earthquake

Another approach to selecting a scenario earthquake is to use the largest event that could possibly occur in the study region. This earthquake would be at least as large, and may in fact be larger than the largest historical event. In this case the size of the event would depend on geologic factors such as the type, length and depth of the source. Except in cases where the maximum possible event is well documented in published literature, a seismologist would be required to define this earthquake.

9.2.5.4 Maximum Possible + Smaller Event

In some of the past studies, two levels of earthquakes have been used: an historical maximum earthquake or a maximum possible earthquake, and a smaller earthquake

chosen by judgment. The smaller earthquake has often been defined to have a magnitude one unit less than the historical maximum earthquake. Recommendations in the 1989 National Research Panel Report (FEMA, 1989) are that the scenario event should be relatively probable, yet damaging. The Panel found that the use of a very large but very infrequent earthquake could cause rejection of loss estimates. Use of a frequent but small event provides little useful information. The user may wish to select a scenario earthquake that has a probability of occurrence associated with it. An example would be an earthquake that has X% probability of occurrence in the next Y years. This probability can then be used to express the likelihood that the estimated losses will occur.

9.2.5.5 Earthquake Scenario from Previous Study

Another approach is for the user to base loss estimates on an earthquake that was used in a previous loss study. Problems that can occur with this approach are that some previous studies are based upon using **Modified Mercalli Intensity** (MMI) to define the scenario earthquake. Modified Mercalli Intensity is a system for measuring the size of an earthquake (from I to XII) based upon the damage that occurs. For example an MMI of VI indicates that some cracks appear in chimneys, some windows break, small objects fall off shelves and a variety of other things occur. MMI is not based on instrumental recordings of earthquake motions and does not easily correlate with engineering parameters, thus MMI is not used in **HAZUS**. A seismologist would be required to convert maps or other MMI based data to moment magnitude or spectral response for it to be used in **HAZUS**.

9.2.6 Viewing the Current Defined Hazard

At any time during data entry, analysis or viewing of results, you can view the parameters that define the selected hazard by clicking on the **Hazard|Show Current** option on the **HAZUS** menu bar. An example of the displayed summary is found in Figure 9.13.

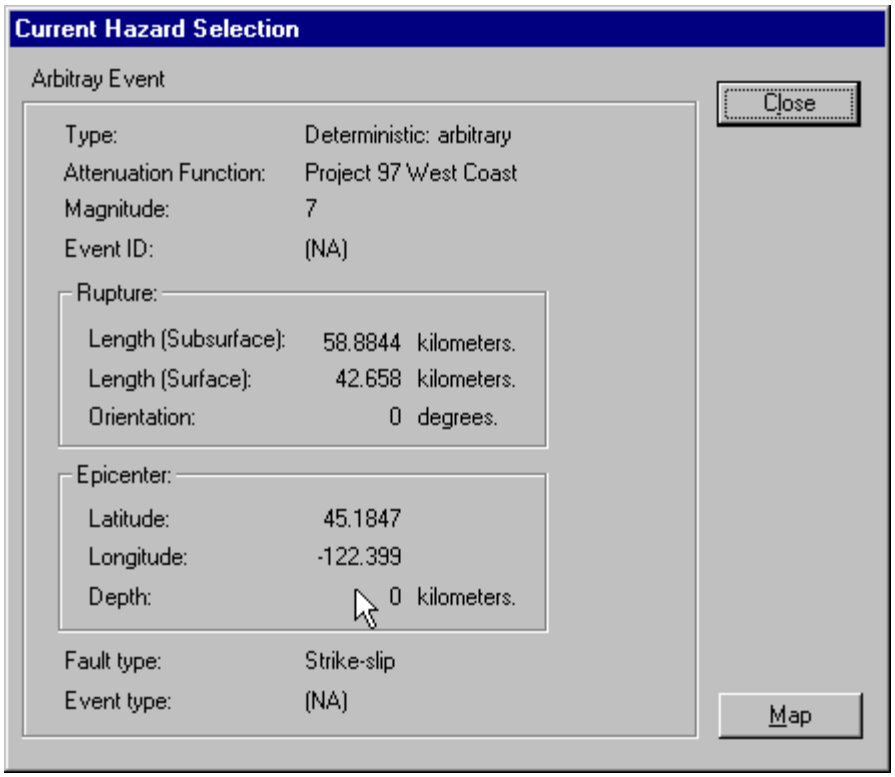


Figure 9.13 Viewing the parameters of the current hazard definition

9.2.7 Including Site Effects

The type of soil in the study region can affect the amplitude of the ground motion. Soft soils tend to amplify certain frequencies within the ground shaking, resulting in greater damage. To include the effects of soils, the user must supply a soil map. If a soil map is not supplied, **HAZUS** bases ground motions on a default soil type. A digitized soil map can be entered into **HAZUS** using the steps outlined in Sections 6.1 and 6.8 of this manual.

There are a variety of schemes for classifying soils, but only one standardized classification scheme is used in **HAZUS**. The site classes are summarized in Table A.1 of Appendix A. The default soil class for **HAZUS** is soil Class D. Many available soil maps do not use the classification scheme shown in Table A.1. In this case, a geotechnical engineer or geologist will be required to convert the classification scheme of the available soil map to that shown in Table A.1.

9.2.8 Including Ground Failure

Three types of ground failure are considered in **HAZUS**: liquefaction, landsliding and surface fault rupture. Each of these types of ground failure are quantified by **permanent ground displacement** (PGD) measured in inches.

Liquefaction is a soil behavior phenomenon in which a saturated soil looses a substantial amount of strength causing the soil to behave somewhat like a liquid. As a result soil may boil up through cracks in the ground and may lose most of its strength and stiffness. This can cause uneven settlement of the soil, or spreading of the soil. The result is that

structures founded on soils that have liquefied tend to have more damage than those on other types of soils. This can be particularly significant in the case of lifelines, where roads become bumpy, cracked and unusable or underground pipes break because of liquefaction. Silty and clayey soils tend to be less susceptible than sandy soils to liquefaction-type behaviors.

Permanent ground displacements due to lateral spreads or flow slides and differential settlement are commonly considered significant potential hazards associated with liquefaction. Lateral spreads are ground failure phenomena that occur near abrupt topographic features (i.e., free-faces) and on gently sloping ground underlain by liquefied soil. Lateral spreading movements may be on the order of inches to several feet or more and are typically accompanied by surface fissures and slumping. Flow slides generally occur in liquefied materials found on steeper slopes and may involve ground movements of hundreds of feet. As a result, flow slides can be the most catastrophic of the liquefaction-related ground-failure phenomena. Fortunately, flow slides are much less common occurrences than lateral spreads.

Settlement is a result of particles moving closer together into a denser state. This may occur in both liquefied and non-liquefied zones with significantly larger contributions to settlement expected to result from liquefied soil. Since soil characteristics vary over even relatively small areas, settlements may occur differentially. This differential settlement can cause severe damage to structures and pipelines, as it tends to tear them apart.

9.2.8.1 Liquefaction

To include liquefaction in the analysis, you may specify a liquefaction susceptibility map using the steps outlined in Section 6.8 of this manual or you may specify susceptibility on a census tract by census tract basis through the technique described in Section 6.8 (by changing LqfSusCat). In addition to the liquefaction susceptibility map you must select the **Liquefaction** option under **PESH** when the analysis is run.

There are three steps involved in the evaluation of liquefaction hazard:

1. Characterize liquefaction susceptibility (very low to very high)
2. Assign probability of liquefaction
3. Assign expected permanent ground deformations

A liquefaction susceptibility map, showing the susceptibility for each census tract, is a result of the first step. An experienced geotechnical engineer, familiar with both the region and with liquefaction, should be consulted in developing this map. The relative liquefaction susceptibility of the soil/geologic conditions of a region or sub-region is characterized by using geologic map information and the classification system presented in Table 9.1. High resolution (1:24,000 or greater) or lower resolution (1:250,000) geologic maps are generally available for many areas from geologists or regional US Geological Survey offices, state geological agencies, or local government agencies. The geologic maps typically identify the age, the environment of the deposit, and material type for a particular mapped geologic unit. Based on these characteristics, a relative liquefaction susceptibility rating (very low to very high) can be assigned from Table 9.1 to each soil type.

Based on the liquefaction susceptibility and the peak ground acceleration, a probability of liquefaction is assigned during the analysis (see Section 4.2 of the *Technical Manual*). Areas of geologic materials characterized as rock or rock-like are considered for the analysis to present no liquefaction hazard.

Finally, in order to evaluate the potential losses due to liquefaction, an expected permanent ground displacement (PGD) in the form of ground settlement or lateral spreading is assigned. The PGD is based on peak ground acceleration and liquefaction susceptibility. **HAZUS** assigns PGD using a procedure derived from experience as discussed in the *Technical Manual*.

Table 9.1 Liquefaction Susceptibility of Sedimentary Deposits (from Youd and Perkins, 1978)

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
Esturine	Locally variable	High	Moderate	Low	Very Low
Beach					
High Wave Energy	Widespread	Moderate	Low	Very Low	Very Low
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	---	---	---

9.2.8.2 Landslide

As with liquefaction, to include landslide in the analysis you must specify a landslide susceptibility map using the steps outlined in Section 6.8 of this manual or you may specify susceptibility on a census tract by census tract basis through the technique described in Section 6.8 (by changing LndSusCat). In addition to the landslide susceptibility map, you must select the **Landslide** option under **PESH** when the analysis is run.

There are three steps involved in the evaluation of landslide hazard:

1. Characterize landslide susceptibility (I to X))
2. Assign probability of landslide

3. Assign expected permanent ground deformations

A landslide susceptibility map, showing the susceptibility for each census tract, is a result of the first step. An experienced geotechnical engineer, familiar with both the region and with earthquake-caused landsliding, should be consulted in developing this map. Landslide susceptibility can be characterized by the geologic group, ground water level, slope angle and the critical acceleration (a_c). Using information about geologic group, ground water level, slope, and a corresponding default critical acceleration; the methodology provides rules for assigning landslide susceptibility. Landslide susceptibility is measured on a scale of I to X, with X being the most susceptible. The geologic groups and associated susceptibilities are summarized in Table 9.2.

Once landslide susceptibility has been determined, **HAZUS** provides default values for probability of landsliding and expected PGD as a function of ground acceleration. The *Technical Manual* describes the procedure in detail.

Table 9.2 Landslide Susceptibility of Geologic Groups

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, c' =300 psf, ϕ' = 35°)**	None	None	I	II	IV	VI
B	**Weakly Cemented Rocks and Soils (sandy soils and poorly cemented sandstone, c' =0, ϕ' = 35°)**	None	III	IV	V	VI	VII
C	**Argillaceous Rocks (shales, clayey soil, existing landslides, poorly compacted fills, c' =0 ϕ' = 20°)**	V	VI	VII	IX	IX	IX
(b) WET (groundwater level at ground surface)							
A	**Strongly Cemented Rocks (crystalline rocks and well-cemented sandstone, c' =300 psf, ϕ' = 35°)**	None	III	VI	VII	VIII	VIII
B	**Weakly Cemented Rocks and Soils (sandy soils and poorly cemented sandstone, c' =0, ϕ' = 35°)**	V	VIII	IX	IX	IX	X
C	**Argillaceous Rocks (shales, clayey soil, existing landslides, poorly compacted fills, c' =0 ϕ' = 20°)**	VII	IX	X	X	X	X

9.2.8.3 Surface Fault Rupture

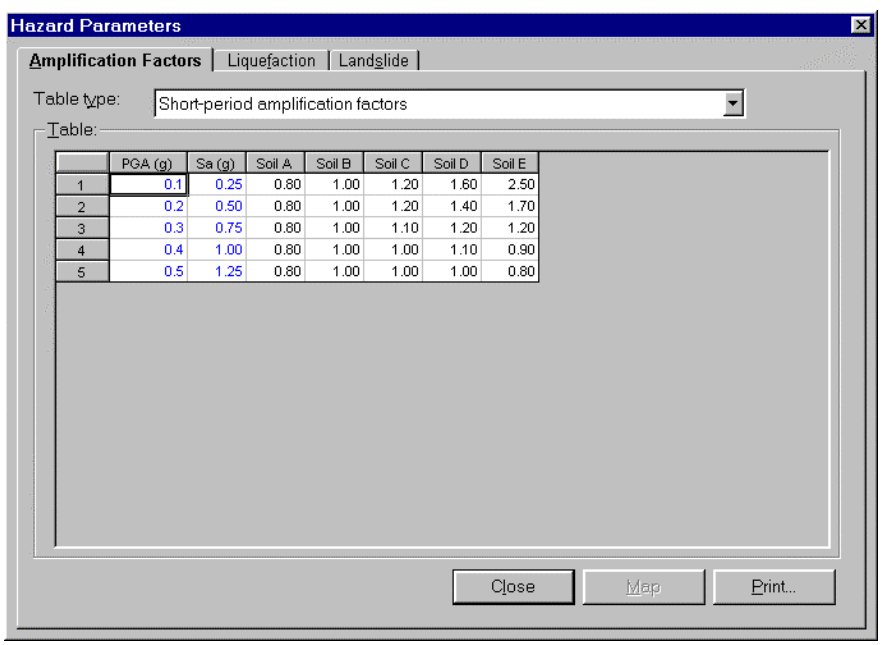
When an earthquake occurs, it is possible that the fault rupture can extend from its initiation at some depth all the way to the ground surface. Many earthquakes do not exhibit evidence of rupture at the ground surface, particularly in the Eastern United States. Generally, surface fault rupture is observed only in the Western United States and Alaska. When it occurs, displacements due to surface fault rupture can be on the order of several meters and can be a significant contributor to damage if a structure crosses or is built on top of the fault rupture. Pipelines, roadways, bridges and railways that cross faults are vulnerable to surface fault rupture.

Selecting the surface fault option under **PESH** will include the surface fault rupture hazard in the analysis. **HAZUS** provides a default relationship between moment magnitude (**M**) and the displacement in meters that can result from surface fault rupture (see the *Technical Manual* for more information). For any location along the fault rupture, fault displacement can occur, however, the amount of fault displacement is described by a probability distribution. Surface fault rupture is presented to the user in the form of PGD contour maps.

9.2.8.4 Modifying PESH Parameters

Default parameters relating to site effects and ground failure can be modified using the windows shown in Figures 9.14 and 9.15. It should be noted, however, that these parameters should not be modified unless you have expertise in seismology and geotechnical engineering. These windows can be accessed through the **Analysis|Parameters|Hazard** option in the **HAZUS** menu bar.

The window shown in Figure 9.14 is used to modify soil amplification factors. These factors are discussed in the *Technical Manual*. As discussed in the *Technical Manual*, soil does not behave uniformly and in an area with very high susceptibility to liquefaction it is unlikely that the entire area will actually liquefy. In fact, liquefaction may appear in pockets with a large portion of the area remaining unaffected. A parameter is used to define the proportion of a geologic map unit that is likely to liquefaction given its relative susceptibility. The window in Figure 9.15 is used to modify the parameter defaults. Similarly, a window like Figure 9.15 is used to modify the proportion of a map unit that is susceptible to landslide given its relative landslide susceptibility. These factors are found in the *Technical Manual*.



	PGA (g)	Sa (g)	Soil A	Soil B	Soil C	Soil D	Soil E
1	0.1	0.25	0.80	1.00	1.20	1.60	2.50
2	0.2	0.50	0.80	1.00	1.20	1.40	1.70
3	0.3	0.75	0.80	1.00	1.10	1.20	1.20
4	0.4	1.00	0.80	1.00	1.00	1.10	0.90
5	0.5	1.25	0.80	1.00	1.00	1.00	0.80

Figure 9.14 Window for modifying soil amplification factors

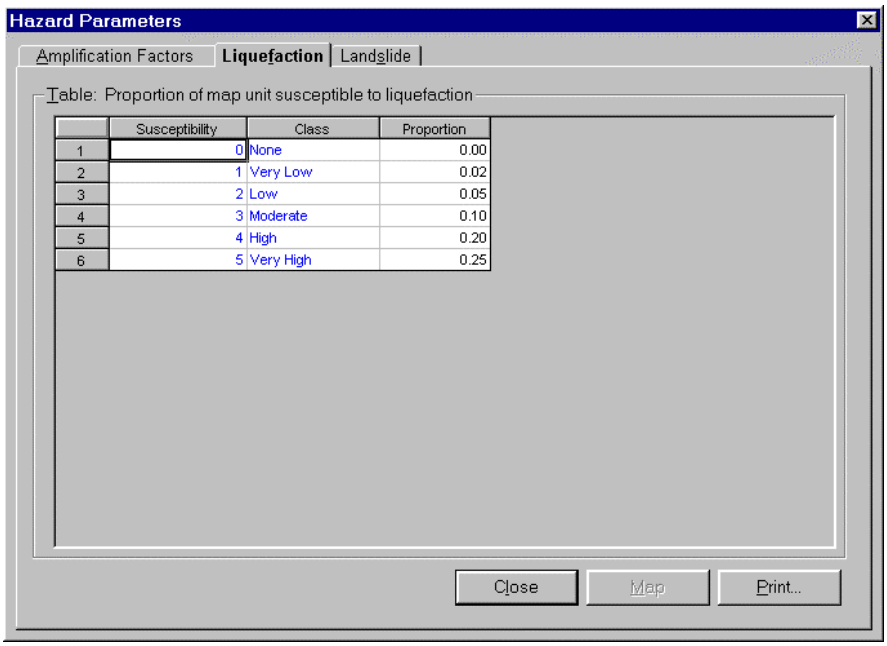


Figure 9.15 Window for modifying the proportion of map area that is susceptible to liquefaction

9.3 Running the PESH Option

As discussed in Section 3.3, the first step in running the analysis is to run the **PESH**. All loss estimation analyses must run the **PESH** option at least once since the PESH module defines the ground motion that is used to estimate damage and loss.

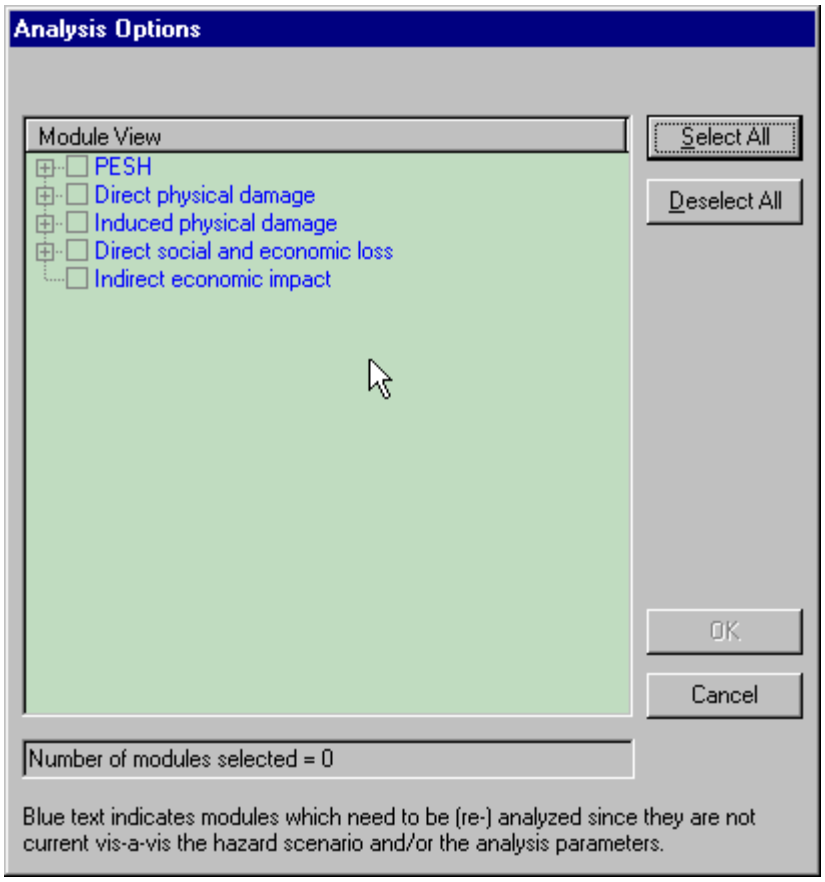


Figure 9.16 Analysis Options in HAZUS

Figure 9.16 shows the Analysis Options menu for **HAZUS**. Clicking on the + sign next to **PESH**, displays the PESH Analysis Options. Partial display of all the PESH options is shown in Figure 9.17. These menus are discussed in Section 3.3.

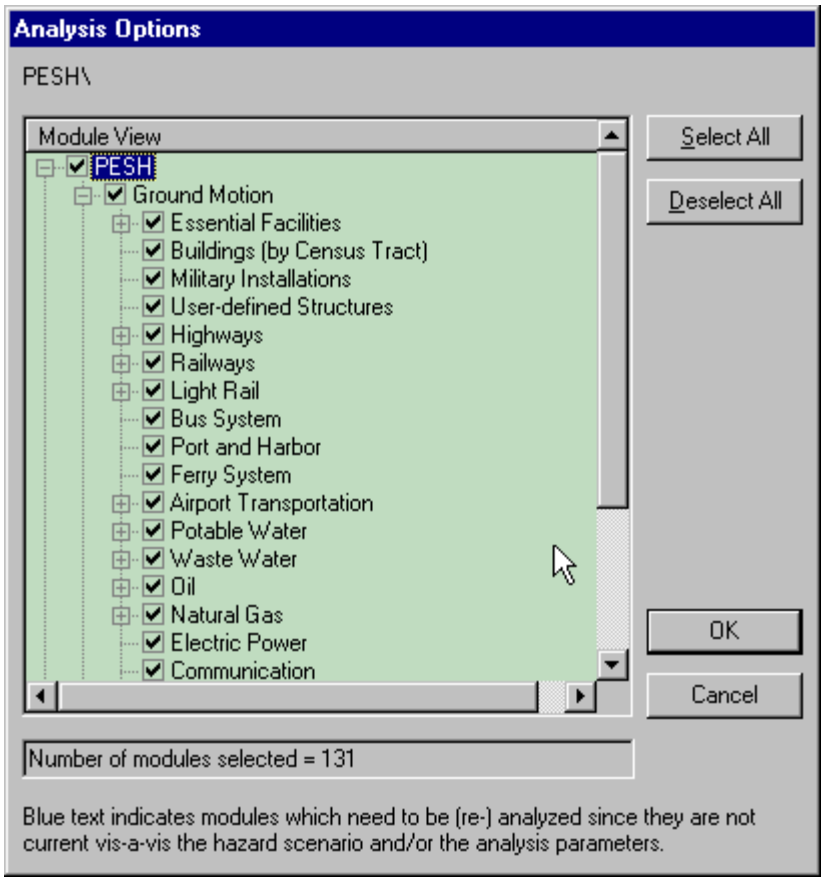


Figure 9.17 PESH analysis options in HAZUS.

9.4 Running the Direct Physical Damage Option

The **Direct physical damage** analysis option is used to estimate damage to buildings and lifelines. Clicking the + sign box next to **Direct physical damage** option in the window shown in Figure 9.16 will prompt you the options available for **Direct physical damage.** A partial display of the option is shown below.

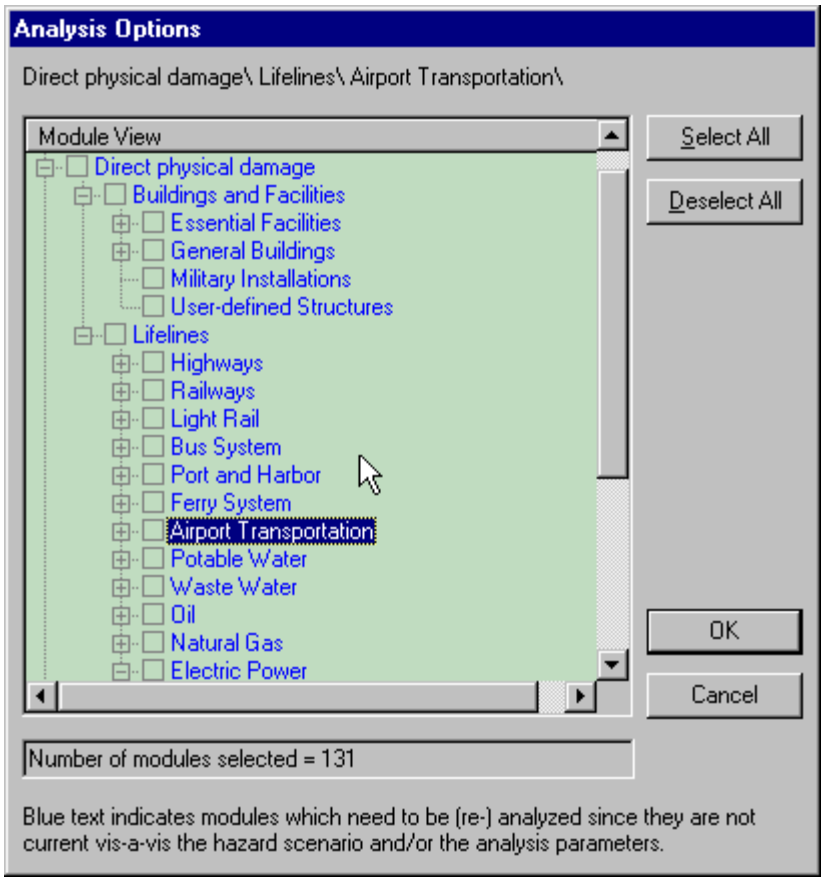


Figure 9.18 Direct Physical Damage analysis options

This menu allows you to select which types of facilities and lifelines you want to have analyzed. If you want to run the analysis with default inventory and data, simply select the types of facilities to be analyzed by checking the empty box next to that particular facility. If you want to modify the default inventory before running your analysis, follow the instructions for modifying databases in Chapters 6 and 7 of this manual.

9.4.1 Structural Versus Non-structural Damage

HAZUS estimates damage to structural and non-structural building components separately. Structural components are the walls, columns, beams and floor systems that are responsible for holding up the building. In other words, the structural components are the gravity and lateral load resisting systems. Non-structural building components include building mechanical/electrical systems and architectural components such as partition walls, ceilings, windows and exterior cladding that are not designed as part of the building load carrying system. Equipment that is not an integral part of the building, such as computers, is considered **building contents**.

Damage to structural components affects casualties, building disruption, cost of repair and other losses differently than damage to non-structural components. For example, if the ceiling tiles fall down in a building, business operations can probably resume once the debris is removed. On the other hand, if a column in a building is damaged, there is a life safety hazard until the column is repaired or temporarily shored, possibly resulting in a

long-term disruption. It should also be noted that the types of non-structural components in a given building depend on the building occupancy. For example, single-family residences would not have exterior wall panels, suspended ceilings, or elevators, while these items would be found in an office building. Hence, the relative values of non-structural components in relation to overall building replacement value vary with type of occupancy. In the direct economic loss module, estimates of repair and replacement cost are broken down by occupancy to account for differences in types of non-structural components.

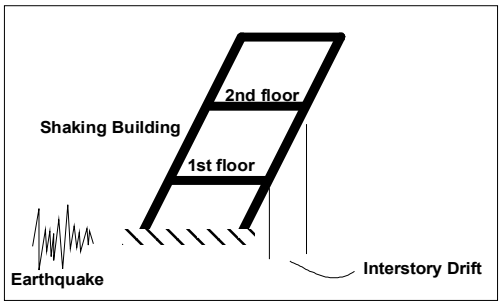


Figure 9.19 Interstory drift in a shaking building

Some non-structural components (partition walls and windows) tend to crack and tear apart when the floors of the building move past each other during the earthquake. As can be seen in Figure 9.19 the wall that extends from the first floor to the second floor is pulled out of shape due to the interstory drift, causing it to crack and tear. In the methodology this is called **drift-sensitive non-structural damage**. Other non-structural components such as mechanical equipment tend to get damaged by falling over or being torn from their supports due to the acceleration of the building. This is similar to being knocked off your feet if someone tries to pull a rug out from under you. In the methodology this is called **acceleration-sensitive non-structural damage**. Of course many non-structural components are affected by both acceleration and drift, but for simplification, components are identified with one or the other as summarized in Table 9.3.

Table 9.3 Building Component Non-structural Damage

Type of Non-structural Damage	
Drift Sensitive	Acceleration Sensitive
• Wall partitions • Exterior wall panels and cladding • Glass • Ornamentation	• Suspended ceilings • Mechanical and electrical equipment • Piping and ducts • Elevators

9.4.2 Definitions of Damage States - Buildings

Damage estimates are used in **HAZUS** to estimate life-safety consequences of building damage, expected monetary losses due to building damage, expected monetary losses which may result as a consequence of business interruption, expected social impacts, and other economic and social impacts. The building damage predictions may also be used to

study expected damage patterns in a given region for different scenario earthquakes, for example, to identify the most vulnerable building types, or the areas with the worst expected damage to buildings.

To serve these purposes, damage predictions must be descriptive. The user must be able to glean the nature and extent of the physical damage to a building type from the damage prediction output so that life-safety, societal and monetary losses that result from the damage can be estimated. Building damage can best be described in terms of the nature and extent of damage exhibited by its components (beams, columns, walls, ceilings, piping, HVAC equipment, etc.). For example, such component damage descriptions as "shear walls are cracked", "ceiling tiles fell", "diagonal bracing buckled", or "wall panels fell out", used together with such terms as "some" and "most" would be sufficient to describe the nature and extent of overall building damage.

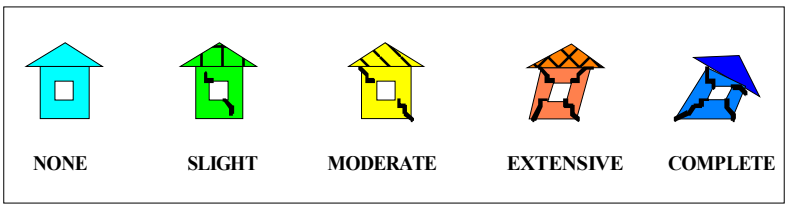


Figure 9.20 The five damage states.

Using the criteria described above, damage is described by five **damage states**: none, slight, moderate, extensive or complete. General descriptions for the structural damage states of 16 common building types are found in the *Technical Manual*. Table 9.4 provides an example of the definitions of damage states for light wood frame buildings. It should be understood that a single damage state could refer to a wide range of damage. For example the **slight** damage state for light wood frame structures may vary from a few very small cracks at one or two windows, to small cracks at all the window and door openings.

Table 9.4 Examples of Structural Damage State Definitions

Wood, Light Frame
Slight: Small plaster or gypsum board cracks at corners of door and window openings and wall-ceiling intersections; small cracks in masonry chimneys and masonry veneer.
Moderate: Large plaster or gypsum-board cracks at corners of door and window openings; small diagonal cracks across shear wall panels exhibited by small cracks in stucco and gypsum wall panels; large cracks in brick chimneys; toppling of tall masonry chimneys.
Extensive: Large diagonal cracks across shear wall panels or large cracks at plywood joints; permanent lateral movement of floors and roof; toppling of most brick chimneys; cracks in foundations; splitting of wood sill plates and/or slippage of structure over foundations; partial collapse of room-over-garage or other soft-story configurations; small foundations cracks.
Complete: Structure may have large permanent lateral displacement, may collapse, or be in imminent danger of collapse due to cripple wall failure or the failure of the lateral load resisting system; some structures may slip and fall off the foundations; large foundation cracks.

Damage to non-structural components is considered to be independent of building type. This is because partitions, ceilings, cladding, etc., are assumed to incur the same damage

when subjected to the same interstory drift or floor acceleration whether they are in a steel frame building or in a concrete shear wall building. Therefore as shown in the example in Table 9.5, descriptions of non-structural damage states are developed for common non-structural systems, rather than as a function of building type.

Table 9.5 Examples of Non-structural Damage State Definitions

Suspended Ceilings
Slight: A few Ceiling tiles may have moved or fallen down.
Moderate: Falling of tiles is more extensive; in addition the ceiling support framing (t-bars) may disconnect and/or buckle at a few locations; lenses may fall off a few light fixtures.
Extensive: The ceiling system may exhibit extensive buckling, disconnected t-bars and falling ceiling tiles; ceiling may have partial collapse at a few locations and a few light fixtures may fall.
Complete: The ceiling system is buckled throughout and/or has fallen down and requires complete replacement.

9.4.3 Definitions of Damage States - Lifelines

As with buildings, five damage states are defined: none, slight, moderate, extensive and complete. For each component of each lifeline a description of the damage is provided for each damage state. These descriptions are found in Sections 7.1 through 8.6 of the *Technical Manual*. An example of the damage state descriptions for electrical power system distribution circuits is found in Table 9.6

Table 9.6 Damage State Descriptions for Electrical Power System Distribution Circuits

Damage State	Damage Description
Slight	Failure of 4% of all circuits
Moderate	Failure of 12% of all circuits
Extensive	Failure of 50% of all circuits
Complete	Failure of 80% of all circuits

Damage states can be defined in numerical terms as is the case for distribution circuits or they can be more descriptive as shown in Table 9.7.

Table 9.7 Damage State Descriptions for Electrical Power System Generation Plants

Damage State	Damage Description
Slight	Turbine tripping, or light damage to diesel generator, or the building is in the slight damage state.
Moderate	Chattering of instrument panels and racks, or considerable damage to boilers and pressure vessels, or the building is in the moderate damage state.
Extensive	Considerable damage to motor driven pumps, or considerable damage to large vertical pumps, or the building is in the extensive damage state.
Complete	Extensive damage to large horizontal vessels beyond repair, or extensive damage to large motor operated valves, or the building is in the complete damage state.

9.4.4 Fragility Curves - Buildings

Based on the damage state descriptions described in the previous section and using a series of engineering calculations that can be found in the *Technical Manual*, **fragility curves** were developed for each building type. A fragility curve describes the probability

of being in a specific damage state as a function of the size of earthquake input. For structural damage the fragility curves express damage as a function of building displacement. The fragility curves express non-structural damage as a function of building displacement or acceleration, depending upon whether they refer to drift-sensitive or acceleration-sensitive damage.

Default fragility curves are supplied with the methodology. It is highly recommended that default curves be used in the loss studies. Modification of these fragility curves requires the input of a structural engineer experienced in the area of seismic design.

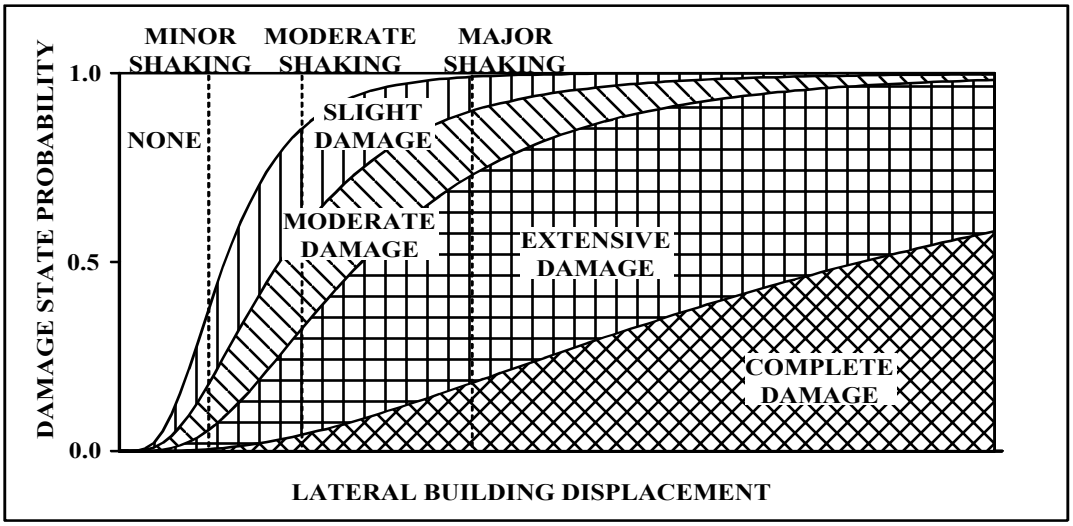


Figure 9.21 Sample building fragility curve

9.4.5 Fragility Curves - Lifelines

As with buildings, default damage functions (fragility curves) have been developed for all components of all lifeline systems. Typical damage functions are shown in Figures 9.21 and 9.22. The damage functions are provided in terms of PGA (Figure 9.22) and PGD (Figure 9.23). The top curve in Figure 9.22 gives the probability that the damage state is at least slight given that the bridge has been subjected to a specified PGA. For example, if the bridge experiences a PGA of 0.4g, there is a 0.7 probability that the damage will be slight or worse. Figure 9.23 is similar, except it is in terms of PGD. Thus if a bridge experiences a permanent ground deformation of 12 inches, there is a 100 percent chance that it will have at least slight damage and a 70% chance it will have moderate damage or worse.

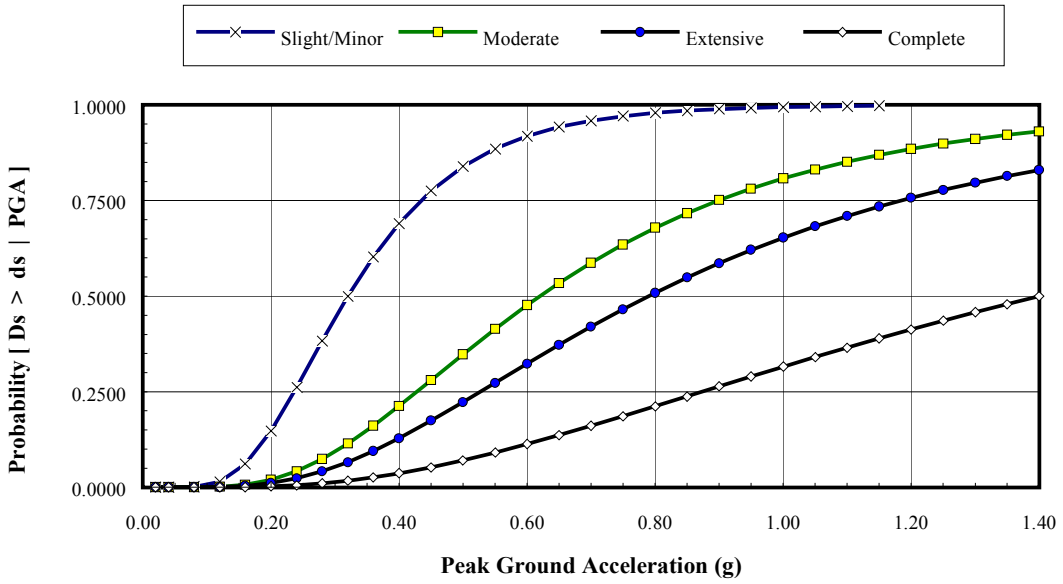


Figure 9.22 Fragility Curves at Various Damage States for Seismically Designed Railway Bridges Subject to Peak Ground Acceleration

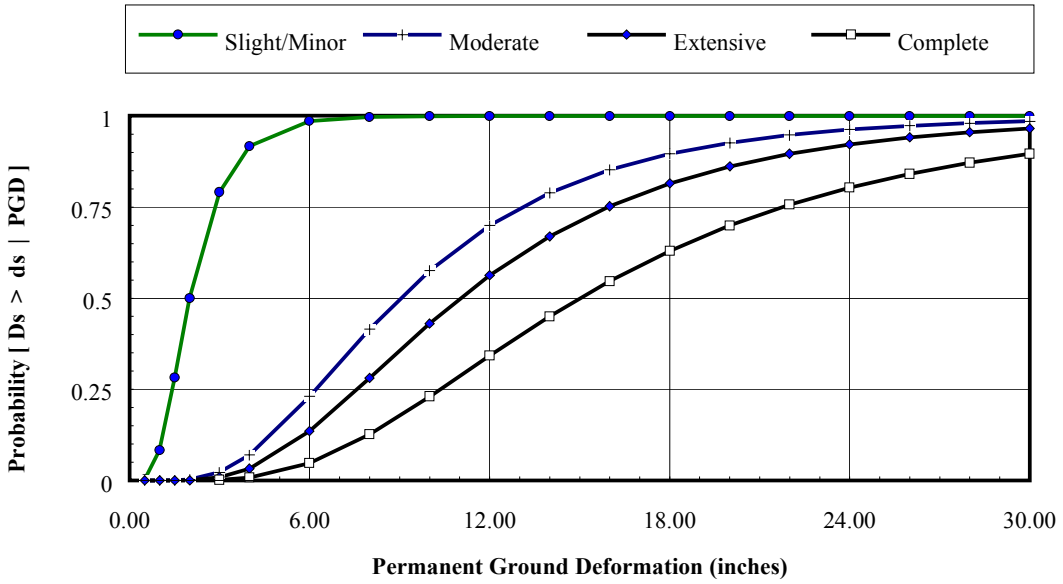
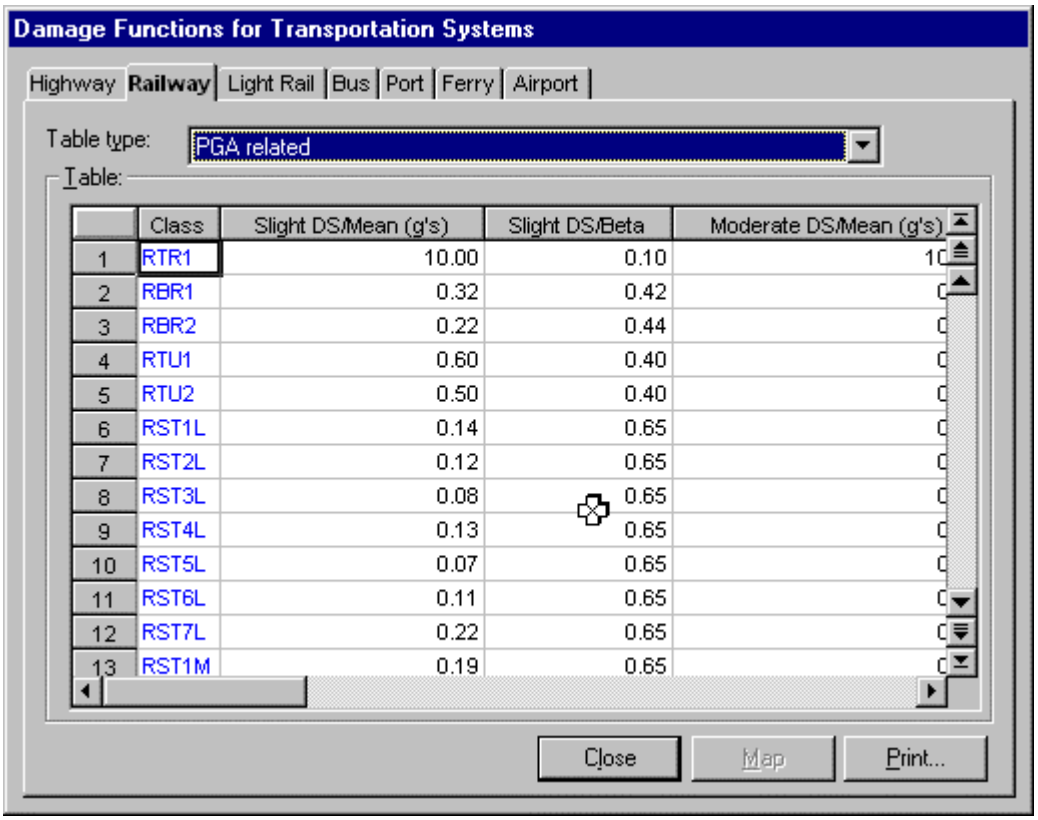


Figure 9.23 Fragility Curves at Various Damage States for Seismically Designed Railway Bridges Subject to Permanent Ground Deformation

The default damage functions are lognormal with parameters (medians and betas) as defined in the *Technical Manual*. These parameters can also be viewed and modified using **HAZUS**. The window for viewing parameters of fragility curves for bus system components is shown in Figure 9.24. In this example, parameters of damage functions for PGA induced damage are displayed. The user can also view parameters for PGD induced damage. The column "Slight DS/Median (g's)" contains the median PGA for the

slight damage state. The median is defined as the value at which the probability is 0.5. Compare the slight damage fragility curve in Figure 9.22 with the parameters for the component RBR1 in Figure 9.24. Note that slight damage curve passes through the probability 0.5 at a PGA of 0.32g and the moderate damage curve passes through 0.5 at a PGA of 0.62g. The column "Slight DS/Beta" contains the parameter Beta, which is an indicator the dispersion of the distribution. The larger the Beta the more spread out the fragility curve. The Beta for slight damage to RBR1 is 0.42, while the Beta for moderate damage is 0.55. In comparing the fragility curves for slight and moderate damage in Figure 9.22 it can be seen that the slope of the slight damage curve is reflecting its smaller Beta. While these parameters can be modified, default values should be used unless an expert structural engineer experienced in seismic design is consulted.



	Class	Slight DS/Mean (g's)	Slight DS/Beta	Moderate DS/Mean (g's)
1	RTR1	10.00	0.10	10
2	RBR1	0.32	0.42	0
3	RBR2	0.22	0.44	0
4	RTU1	0.60	0.40	0
5	RTU2	0.50	0.40	0
6	RST1L	0.14	0.65	0
7	RST2L	0.12	0.65	0
8	RST3L	0.08	0.65	0
9	RST4L	0.13	0.65	0
10	RST5L	0.07	0.65	0
11	RST6L	0.11	0.65	0
12	RST7L	0.22	0.65	0
13	RST1M	0.19	0.65	0

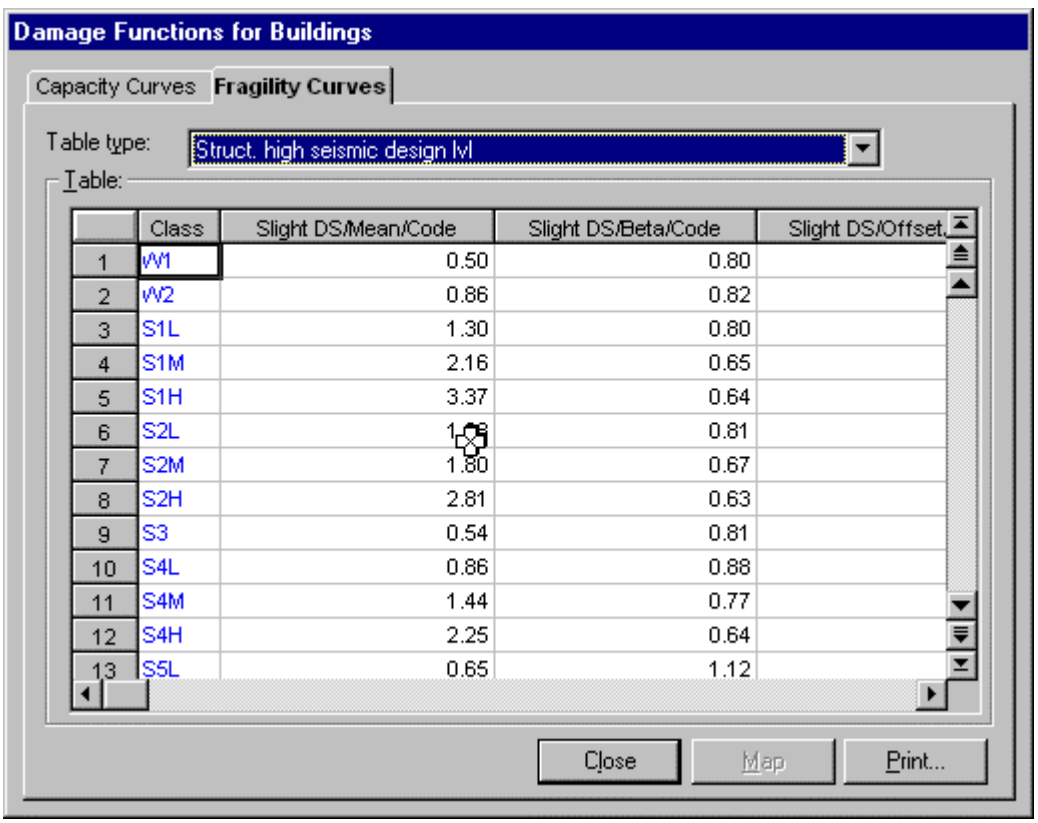
Figure 9.24 Parameters of lognormal damage functions, as viewed in HAZUS, for PGA induced damage to railway system components

9.4.6 Modifying Fragility Curves

The fragility curves described in the previous section are each characterized by a median and a lognormal standard deviation (β). There are two types of curves: those for which spectral displacement is the parameter describing earthquake demand and those for which spectral acceleration is the parameter. The first type of curve is used for estimating structural damage and drift-sensitive non-structural damage. The second type is for estimating acceleration sensitive non-structural damage.

Default fragility curves are provided for all model building types, essential facility model building types and for all lifeline components. Figure 9.25 shows an example of the parameters of fragility curves for model buildings with a high seismic design level. This window is accessed through the **Analysis|Damage Functions|General Building Stock** menu. Fragility curves are available for three seismic design levels and three construction standards for both structural and non-structural damage. (Note: Design levels and construction standards are discussed in the *Technical Manual*.) Fragility curves for lifelines are accessed through the **Analysis|Damage Functions| Transportation Systems** menu or the **Analysis| Damage Functions|Utility Systems** menu. Fragility curves are available for both PGA and PGD related damage.

Should you desire to modify the fragility curves, change the mean and beta in this window and then click on the **Close** button. You will be asked to confirm that you want to save your changes. Development of fragility curves is complex and is discussed in detail in the *Technical Manual*. It is strongly recommended that you use the default parameters provided unless you have expertise in the development of fragility curves.



	Class	Slight DS/Mean/Code	Slight DS/Beta/Code	Slight DS/Offset
1	W1	0.50	0.80	
2	W2	0.86	0.82	
3	S1L	1.30	0.80	
4	S1M	2.16	0.65	
5	S1H	3.37	0.64	
6	S2L	1.08	0.81	
7	S2M	1.80	0.67	
8	S2H	2.81	0.63	
9	S3	0.54	0.81	
10	S4L	0.86	0.88	
11	S4M	1.44	0.77	
12	S4H	2.25	0.64	
13	S5L	0.65	1.12	

Figure 9.25 Parameters of Building Fragility Curves

9.4.7 Steps For Calculating Damage State Probabilities

There are several steps that are needed to calculate damage state probabilities:

- Calculate the spectral accelerations and spectral displacements at the site in question. This is in the form of a response spectrum.
- Modify the response spectrum to account for the increased damping that occurs at higher levels of building response (non-linear behavior).
- Create a capacity curve for the model building type which shows how the building responds as a function of the laterally applied earthquake load.
- Overlay the building capacity curve with the modified response spectrum (demand curve). The building displacement is estimated from the intersection of the building capacity curve and the response spectrum
- The estimated building displacement is used to interrogate the fragility curves.

Figure 9.26 illustrates the intersection of the building capacity curve and a response spectrum that has been adjusted for higher levels of damping.

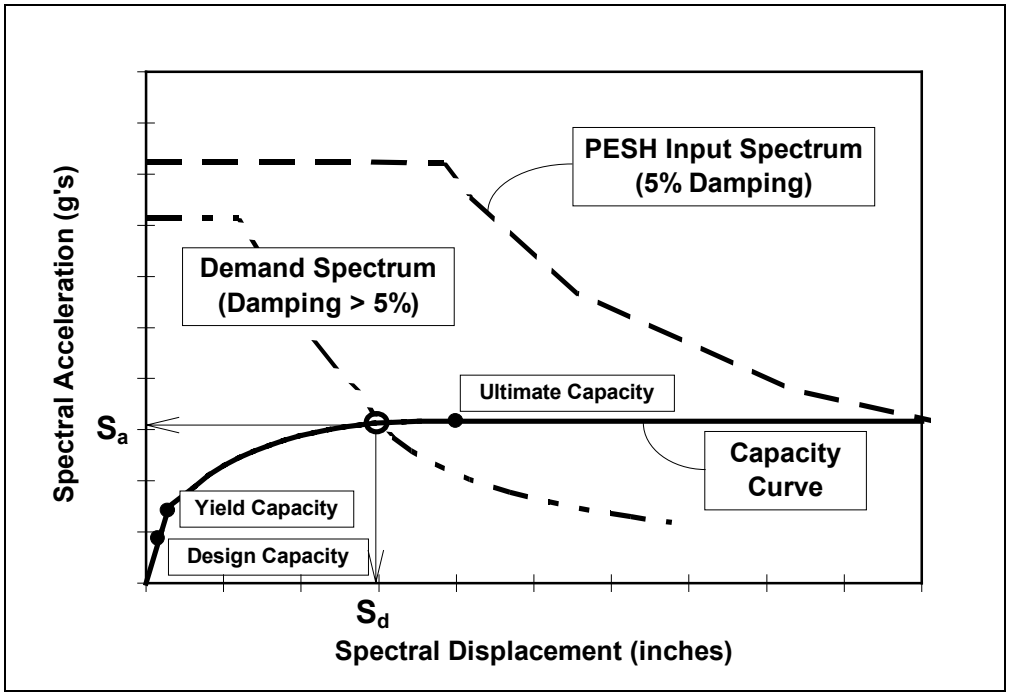


Figure 9.26 Example Capacity Curve and Spectral Demand

9.4.8 Modifying Capacity Curves

Two points define capacity curves as shown in Figure 9.26: the yield capacity and the ultimate capacity. For general building stock, these parameters can be viewed, as shown in Figure 9.27, by clicking on the **Analysis|Damage Functions|General Building Stock** menu. Capacity curves are available for three levels of seismic design and three construction standards. Capacity curves are discussed in detail in *the Technical Manual*. To modify the capacity curves, modify the yield capacity and ultimate capacity spectral accelerations and displacements and then click on the **Close** button. You will be asked to confirm that you want to save your changes. It is strongly recommended that you use the default parameters unless you have expertise in the development of capacity curves.

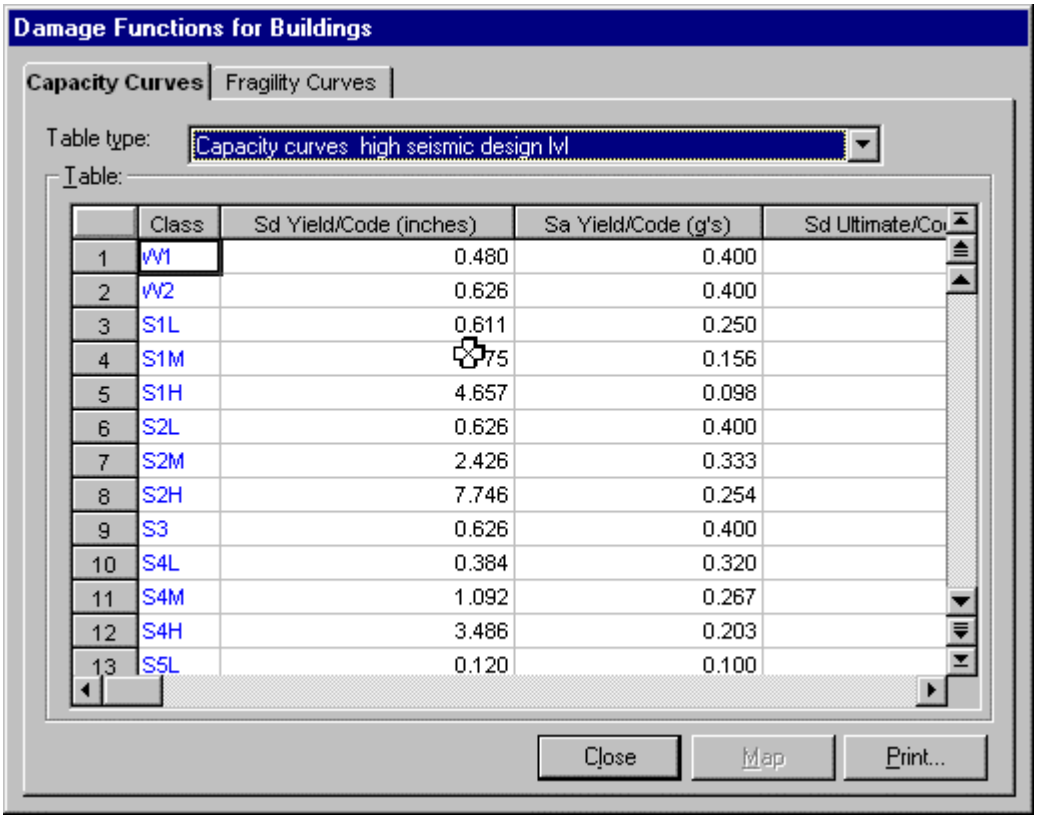


Figure 9.27 Parameters of capacity curves for model building types with a high seismic design level

9.4.9 Restoration Time

The damage state descriptions discussed in Section 9.4.2 provide a basis for establishing loss of function and repair time of facilities. A distinction should be made between loss of function and repair time. In this methodology, loss of function is defined as the time that a facility is not capable of conducting business. This, in general, will be shorter than repair time because businesses will rent alternative space while repairs and construction are being completed. Loss of function (restoration time) is estimated in the methodology only for essential facilities, transportation lifelines and utility lifelines.

Default restoration functions are provided with the methodology for essential facilities, transportation lifelines and utility lifelines. An example of a set of restoration functions is found in Figure 9.28. Restoration curves describe the fraction of facilities (or components in the case of lifelines) that are expected to be open or operational as a function of time following the earthquake. For example, looking at the curves shown in Figure 9.28, 10 days after the earthquake, about 20% of the facilities that were in the extensive damage state immediately after the earthquake and about 60% of the facilities that were in the moderate damage state immediately after the earthquake, are expected to be functional. Each curve is based on a Normal distribution with a mean and standard deviation. The parameters of the restoration functions are accessed through the **Analysis|Restoration Functions** menu and can be viewed and modified in a window such as the one shown in Figure 9.29.

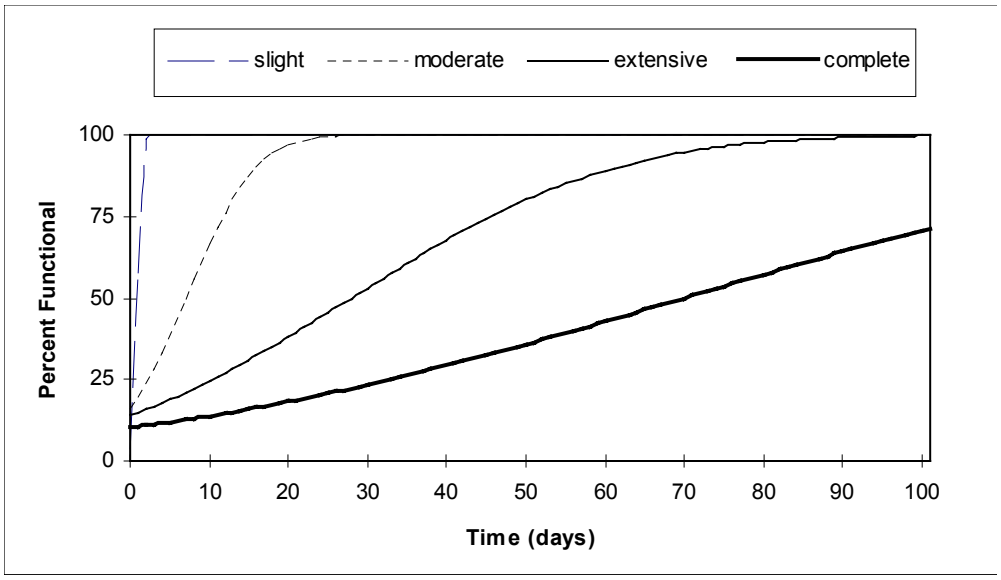


Figure 9.28 Restoration functions for a sample facility type

Typing in a new value and then clicking on the Close button can modify parameters for restoration curves. You will be asked to confirm that you want to save your changes. Restoration curves are based on data published in ATC-13. It is strongly recommended that you use the default parameters unless you have expertise in the development of restoration functions.

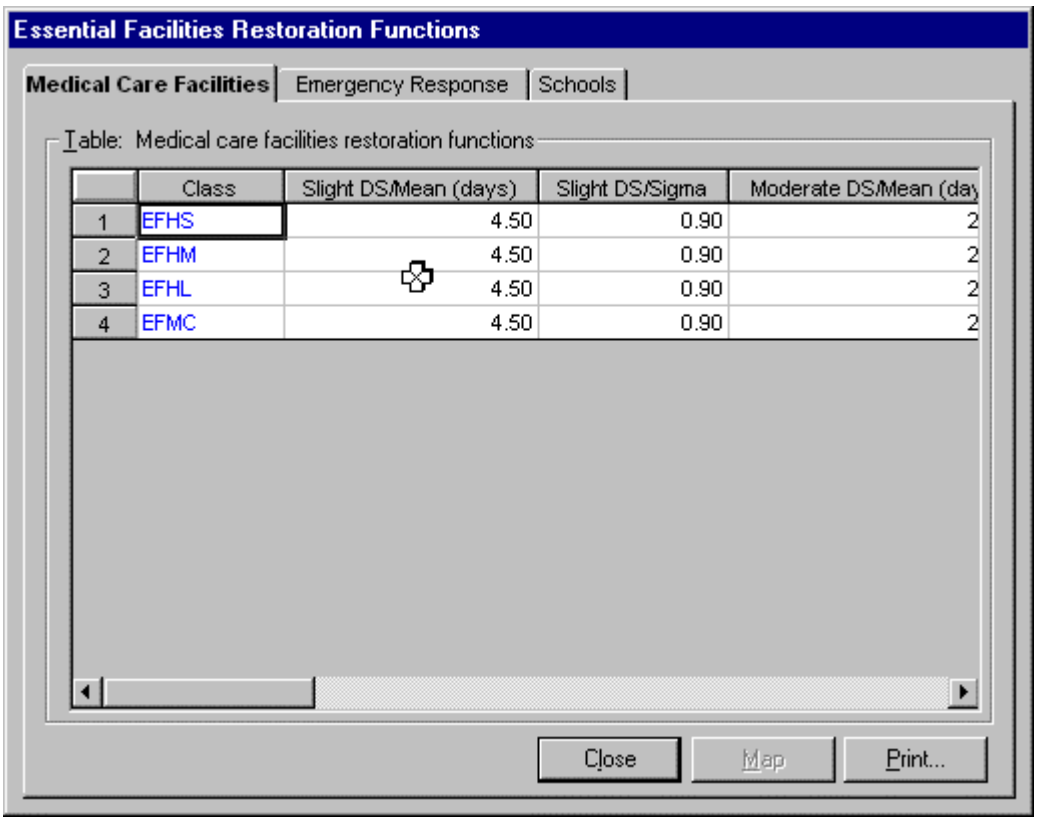


Figure 9.29 Example of window for reviewing and modifying restoration functions

9.4.10 Potable Water System Analysis Model (POWSAM)

POWSAM is a sophisticated network analysis model for water systems. The model relies on the same type of data information required for a Level Two **HAZUS** analysis with three main differences:

- Three additional components are required: junctions, hydrants, and valves.
- Connectivity of the components is must be specified (i.e., what facilities are connected to which pipeline links or valves).
- Serviceability considerations for the system are required (i.e., the demand pressures and flow demands at the different distribution nodes).

Input data for the water system need to be in one of the following three commercially available formats: KYPIPE, EPANET, or CYBERNET.

For a Level Two **HAZUS** for potable water systems, the input required to estimate damage includes the following items:

Transmission Aqueducts and Distribution Pipelines

- Geographical location of aqueduct/pipe links (longitude and latitude of end nodes)
- Peak ground velocity and permanent ground deformation (PGV and PGD)
- Classification (ductile pipe or brittle pipe)

Reservoirs, Water Treatment Plants, Wells, Pumping Stations and Storage Tanks

- Geographical location of facility (longitude and latitude)
- Peak ground acceleration (PGA) and PGD
- Classification (e.g., capacity and anchorage)

In addition to the attributes listed above, additional data is required for a **POWSAM** analysis. Appendix E provides the data requirements for the analysis.

Recent work by Khater and Waisman (EQE, 1999) provides detailed information on the model implementation in **HAZUS**. This work provides a comprehensive theoretical background on the governing equations for a water system and explains the format requirements for commercial data for incorporation into **HAZUS**. This work is available in a separate document entitled "Potable Water System Analysis Model (POWSAM)" that can be acquired directly from NIBS.

Results generated by **POWSAM** are similar to the Level Two **HAZUS** analysis. That is, probability estimates of (1) component functionality and (2) damage, expressed in terms of the component's damage ratio (repair cost to replacement cost). The main difference is that the **POWSAM** evaluation of the water system network performance is based on a comprehensive and technically rigorous approach while the simplified approach in **HAZUS** is based on empirical engineering work done for Oakland, Los Angeles, San Francisco and Tokyo. In addition, the outputs from **POWSAM** and the simplified **HAZUS** model include of an estimate of the flow reduction to areas served by the water system, and the number of households without water. Although fully functional in **HAZUS99**, **POWSAM** is still in the calibration phase.

9.5 Running the Induced Physical Damage Option

The **Induced physical damage** analysis option is for evaluating potential impacts from an earthquake other than damage resulting directly from ground shaking. Check the box next to **Induced physical damage** option to select all options for analysis. If you are interested in analyzing a subset of the options, then click the + sign next to **Induced physical damage** option and only check the options that you want selected. An **Induced physical damage** option window is shown in Figure 9.16.

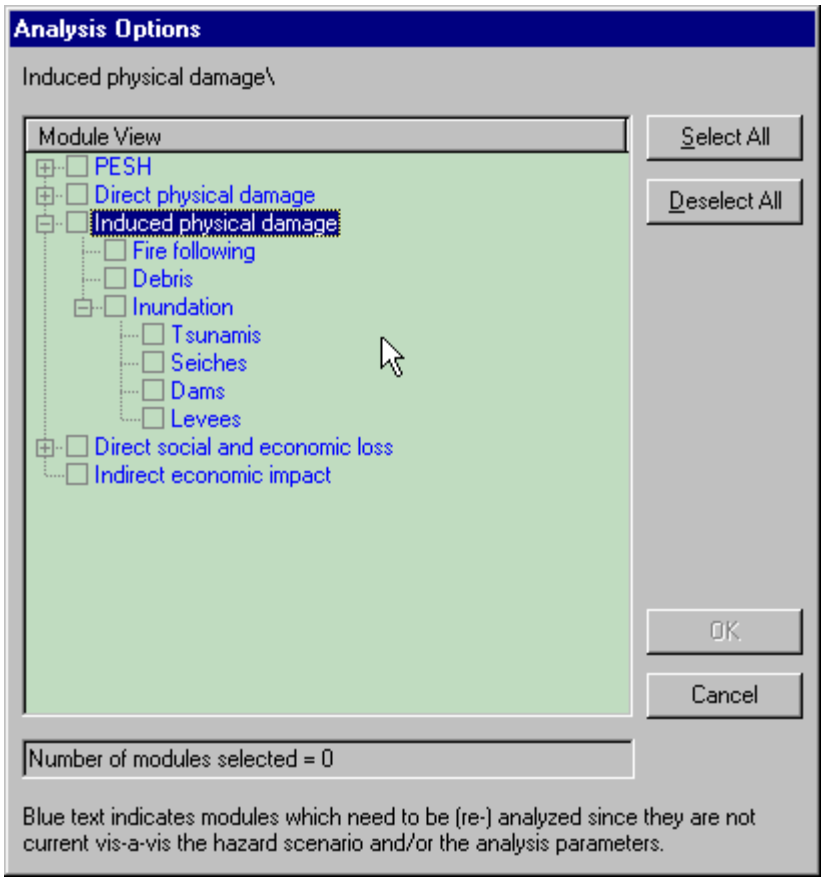


Figure 9.30 Menu for selecting Induced Physical Damage analysis options

9.5.1 Running the Inundation Module

In order to run the inundation module, you must specify an inundation map for the particular hazard you are interested in. Inundation map files are entered through the window shown in Figure 9.31. This is accessed from the **Analysis|Parameters |Inundation Data Files** menu.

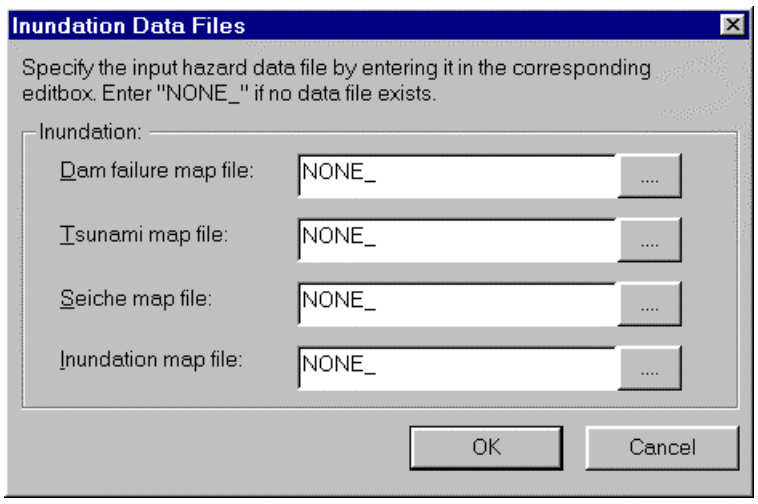


Figure 9.31 Entering inundation map files

9.5.1.1 Tsunami

Damage, fatalities and fires from inundation due to tsunami can be significant. A tsunami is an ocean wave that is generated as a result of earthquake induced motion of the ocean floor. While the wave can be quite small (almost undetectable) in the open ocean, it can grow to great heights when it reaches land. Tsunamis have occurred in California, Alaska and Hawaii. Since models for estimation of losses from tsunamis are not well established, the methodology is limited to assessment of inundation potential unless an expert is involved.

The first step in the analysis is to identify whether a tsunami hazard exists. To accomplish this, the user must define the following:

1. Location of the earthquake source (on-shore or off-shore event)
2. Type of faulting expected (strike-slip, dip-slip, reverse faulting)

If the earthquake source is on-shore, there is no tsunami hazard. The same is true if an offshore event occurs that involves primarily strike-slip movement. Alternatively, if the earthquake occurs offshore and there is significant vertical offset that may occur, a tsunami hazard may exist. The focus of this methodology is the assessment of tsunami inundation for nearby seismic events only. While tsunamis can travel thousands of miles and cause damage at great distances from their sources, **HAZUS** does not consider tsunamis based on distant events well beyond the study region.

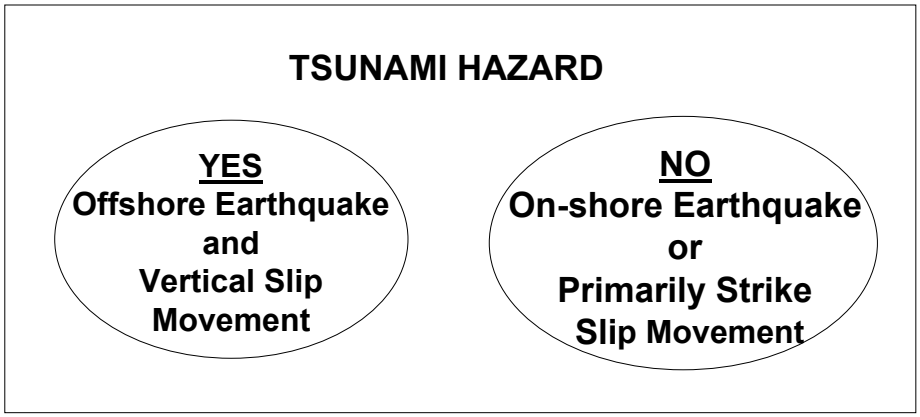


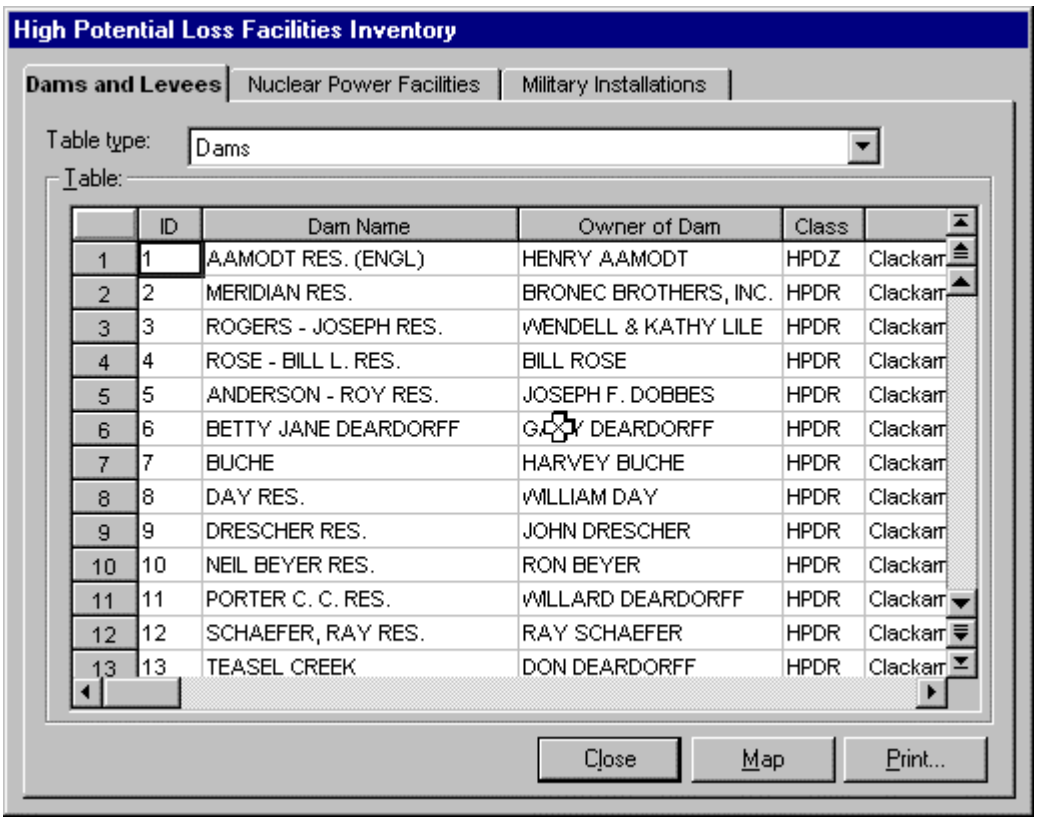
Figure 9.32 Evaluating the tsunami hazard

If a tsunami hazard is found to exist, the next step is to identify the area that could be subjected to flooding. This is done with an inundation map. Development of an inundation map for a particular earthquake scenario requires the involvement of a hydrologist. In some cases, inundation maps based on previous studies exist and can be entered into **HAZUS** (see Figure 9.31) to overlay with building and lifeline inventories or population information. Converting maps into a **HAZUS** compatible format is discussed in Section 6.1 of this manual.

It should be noted that existing inundation studies must be examined to determine the origin of the seismic events (assumed or real) that generated the tsunami. If existing inundation studies are based only on distant events, the results of these assessments cannot be used as the basis to identify areas potentially vulnerable to tsunami-generated-inundation resulting from regional earthquakes. In addition, the user should determine the size and location of the scenario earthquake that was assumed when estimating the tsunami inundation. This will provide a basis to judge whether the existing inundation map conservatively or non-conservatively estimates the inundation that would be produced by the study earthquake.

9.5.1.2 Seiche

Seiches are waves in a lake or reservoir that are induced because of ground shaking. If the waves are large, damage can occur to facilities along the shore of the lake, or dams can be overtopped. Since models for estimation of losses from these hazards are not well established, **HAZUS** is limited to assessment of inundation potential unless an expert is involved.



	ID	Dam Name	Owner of Dam	Class	
1	1	AAMODT RES. (ENGL)	HENRY AAMODT	HPDZ	Clackam
2	2	MERIDIAN RES.	BRONEC BROTHERS, INC.	HPDR	Clackam
3	3	ROGERS - JOSEPH RES.	WENDELL & KATHY LILE	HPDR	Clackam
4	4	ROSE - BILL L. RES.	BILL ROSE	HPDR	Clackam
5	5	ANDERSON - ROY RES.	JOSEPH F. DOBBES	HPDR	Clackam
6	6	BETTY JANE DEARDORFF	GARY DEARDORFF	HPDR	Clackam
7	7	BUCHE	HARVEY BUCHE	HPDR	Clackam
8	8	DAY RES.	WILLIAM DAY	HPDR	Clackam
9	9	DRESCHER RES.	JOHN DRESCHER	HPDR	Clackam
10	10	NEIL BEYER RES.	RON BEYER	HPDR	Clackam
11	11	PORTER C. C. RES.	WILLARD DEARDORFF	HPDR	Clackam
12	12	SCHAEFER, RAY RES.	RAY SCHAEFER	HPDR	Clackam
13	13	TEASEL CREEK	DON DEARDORFF	HPDR	Clackam

Figure 9.33 Default database of dams supplied with HAZUS

The first step in this inundation analysis consists of developing an inventory of natural or man-made bodies of water where a seiche may be generated. The default database of dams can be used to identify the man-made bodies of water (see Appendix D, Section 5.1.5, and Figure 9.33). For the study region that has been defined, more than 16 dams are found in the default database. You must generate an inventory of natural water bodies in the study region since no default database exists. The following criteria can be used to identify natural bodies of water that should be included in the assessment:

- The lake volume must be greater than 500,000 acre-feet
- There must be an existing population and/or property located in proximity to the lake shore that could be inundated

If these criteria are not met, the natural lake need not be considered in the study.

A search of the database of dams may be useful in identifying reservoirs with storage capacity greater than 500,000 acre-feet. To search the database, use the **Query** option found in the **HAZUS** menu bar. An example of a query is shown in Figure 9.34.

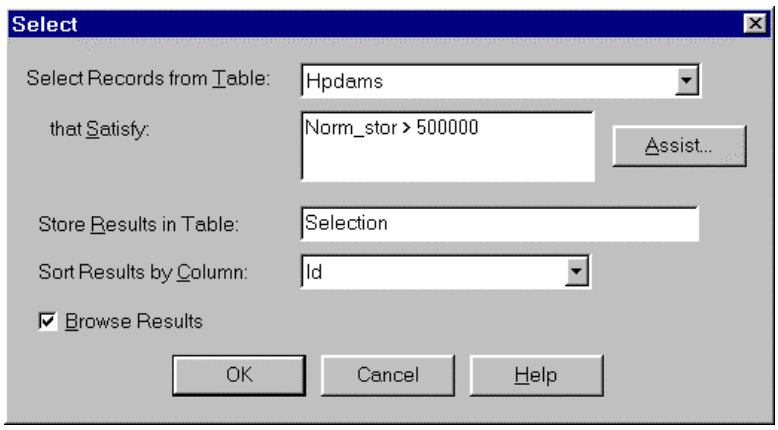


Figure 9.34 Identification of reservoirs with storage greater than 500,000 acre-feet

Once lakes or reservoirs with potential for generating seiches have been identified, the next step consists of locating and using existing seiche inundation maps to identify areas subject to flooding.

9.5.1.3 Dam or Levee Failure

In general, unless inundation maps already exist, you will limit your treatment of inundation due to dam failure to identifying those dams which have a high potential of causing damage. The database in its default form or augmented with additional data can be mapped.

Users are responsible for developing their own inventory of levees, as no default levee inventory exists.

If inundation maps exist, they can be input using the window shown in Figure 9.31.

9.5.2 Running the Fire Following Earthquake Module

Fires following earthquakes can cause severe losses. For example, in the 1995 Kobe earthquake more than 10,000,000 square feet of buildings were lost to fires. Fires occurred as a result of ruptured gas pipelines. Fires spread rapidly because of the densely packed construction, narrow streets and the readily available fuel (wood frame structures, gas, and other flammable materials). The large amount of debris blocking the streets prevented fire fighters from accessing areas to fight the fires. Furthermore, broken water lines prevented fire fighters from suppressing the flames. Losses could have been significantly greater had there been strong winds to fuel the fire. The losses from fire can sometimes outweigh the total losses from the direct damage caused by the earthquake, such as collapse of buildings and disruption of lifelines.

Many factors affect the severity of the fires following an earthquake, including but not limited to: ignition sources, types and density of fuel, wind conditions, the presence of ground failure, functionality of water systems, and the ability of fire fighters to suppress the fires. It should be recognized that a complete fire following earthquake (FFE) model requires extensive input with respect to the level of readiness of local fire departments and the types and availability (functionality) of water systems. To reduce the input requirements and to account for simplifications that are being made in the lifeline

module, the fire following earthquake model presented in this methodology is somewhat simplified. In particular the model makes simplifying assumptions about the availability of water and fire trucks in modeling fire suppression.

The FFE module performs a series of simulations of fire spread and bases estimates of burned area on the average of the results the simulations.

9.5.2.1 Parameters for the Fire Following Earthquake Module

The FFE module parameters can be modified by going to **Analysis|Parameters|Fire Following.** To test the sensitivity of the FFE module to certain conditions, the user can adjust the parameters shown in Figure 9.35.

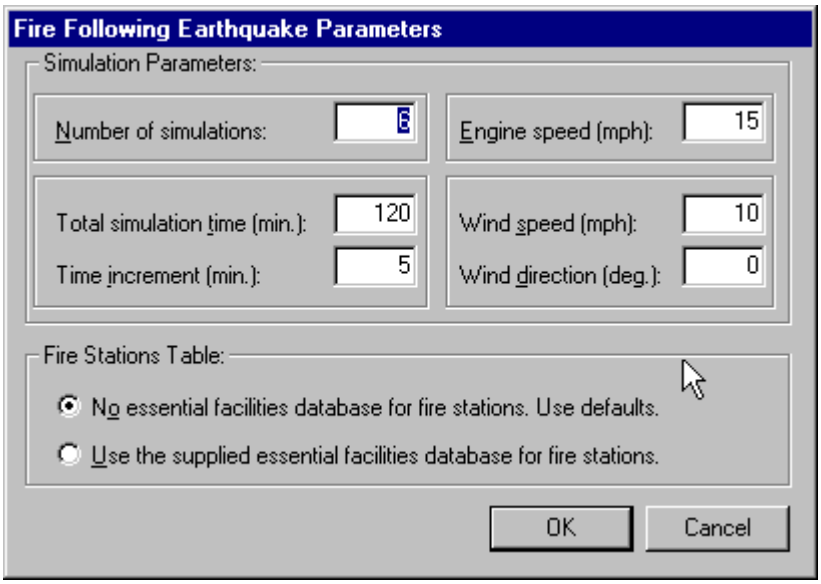


Figure 9.35 Parameter window for fire following earthquake module

The parameters are as follows:

9.5.2.1.1 Number of Simulations

Since estimates of the burned area are based upon averaging results of multiple simulations of fire spread, you can perform more simulations to improve the reliability of the estimates of burned area. The number of ignitions is based upon PGA and the square footage of inventory, and thus the number of simulations does not affect it. You can specify up to 99 simulations, but 6 to 10 simulations should be sufficient. This module takes some time to run. Increasing the number of simulations increases the run time.

9.5.2.1.2 Total Simulation Time and Time Increment

The total simulation time is an indicator of how long after the earthquake you want to look at the fire damage. For example if you specify 120 minutes, you will be provided with estimates of the burned area two hours after the occurrence of the earthquake. You can specify a maximum of 9999 minutes. The time increment is used to specify the time periods at which the program should sample and update the simulation. For example, if you specify a time increment of 15 minutes, the program will sample at 15, 30, 45 and so

on, minutes after the earthquake. You should provide a time increment of 1 to 15 minutes to get sufficiently accurate results.

9.5.2.1.3 Engine Speed

Engine speed is used in the suppression portion of the simulation. The faster the engines can access the sites of fires, the more quickly fires can be suppressed. Fire engines are slowed down by damaged transportation systems, damaged water or gas pipes or by debris in the road. You may specify a maximum speed of 60 miles per hour.

9.5.2.1.4 Wind Speed and Direction

High wind speeds will serve to fuel the fire. A calm day (zero wind) will produce the lowest estimates of burned area. You may specify a maximum wind speed of 100 miles per hour. The direction of wind is measured clockwise in degrees (0 to 360) with zero being due north.

9.5.3 Hazardous Materials Analysis Option

Hazardous materials are those chemicals, reagents or substances that exhibit physical or health hazards. Hazardous materials may be in a usable or waste state. Hazardous materials releases can also lead to fires. With specific reference to earthquake-caused hazardous materials incidents, the data thus far indicate that there have been no human casualties. The consequences of these incidents have been fires and contamination of the environment, and have led to economic impacts because of the response and clean-up requirements.

The hazardous materials analysis option has not been activated. Using the **Inventory|Hazardous Materials** menu can access a default database listing the types of hazardous materials in your region and locations of sites where hazardous materials are stored. Additional data can be added using the steps outlined in Section 6.3.

9.5.4 Debris Estimates

Very little research has been done to determine the amount of debris generated from earthquakes and other natural disasters. However, anecdotal evidence suggests that removal of debris can be a significant part of the clean up process and, as such, can be costly for a municipality. After Hurricane Hugo, the City of Charleston disposed of so much debris that 17 years were removed from the life of its landfill. Debris can also hinder emergency operations immediately after an earthquake if it is blocking streets, sidewalks or doorways. Where collapses or partial collapses of buildings occur, rescue of victims can be difficult if the walls or floors of the structure come down essentially intact. A short discussion of heavy debris generation and victim extrication can be found in FEMA publication 158 (1988).

9.5.4.1 Types and Sources of Debris

A major source of debris will be structures that have been completely damaged or have collapsed. Debris will include building contents as well as structural and non-structural elements. Completely damaged buildings may still be standing, but the cost of repair could be so high, that these buildings will be torn down and rebuilt. However, even buildings that do not suffer extensive damage can be sources of debris. If damage to the

building is slight or moderate, the majority of the damage may be to non-structural elements or contents inside the building. Examples of non-structural debris are suspended ceilings, light fixtures, and partition walls made of plaster or hollow clay tile. In addition, extensive damage could occur to contents of the building such as shelving, equipment, and inventory.

Different types of buildings will generate different types of debris. Unreinforced masonry structures will tend to generate piles of bricks. The bricks result from a collapse of a wall or from damage to some non-structural element such as an unbraced parapet. In single-family dwellings of wood construction, chimneys may separate from the rest of the structure causing them to be torn down and rebuilt. Many steel and concrete frame buildings that were built in the first half of the century have exterior cladding made of brick or terra cotta that may spall off when subjected to earthquake motion. Non-ductile concrete buildings may collapse in a pancake fashion, resulting in a stack of concrete slabs that are not broken up. In a tilt-up building, concrete wall panels, which are usually on the exterior of the structure, may fall outward remaining essentially intact. When the walls fall, the roof (typically of wood or light metal deck) will also collapse. In modern high rise structures, precast panels used for exterior cladding may come loose and fall to the ground or windows may break. Should a steel structure collapse, as one did in Mexico City in 1985, large pieces of twisted steel would result.

In reviewing the types of debris that are generated from an earthquake, the debris can be divided into two types:

- Debris Type 1 Brick, wood and other debris
- Debris Type 2 Wrecked reinforced concrete and steel members

The first type of debris includes everything except wrecked reinforced concrete and steel members. It would include glass, furniture, equipment, and plaster walls, as well as brick and wood. The difference in these two types of debris is that Type 1 can be moved and broken up with a bulldozer or hand held tools. Type 2 would require special treatment to break up the long steel members or the large pieces of concrete before they could be transported. It is likely cranes and other heavy equipment would be needed.

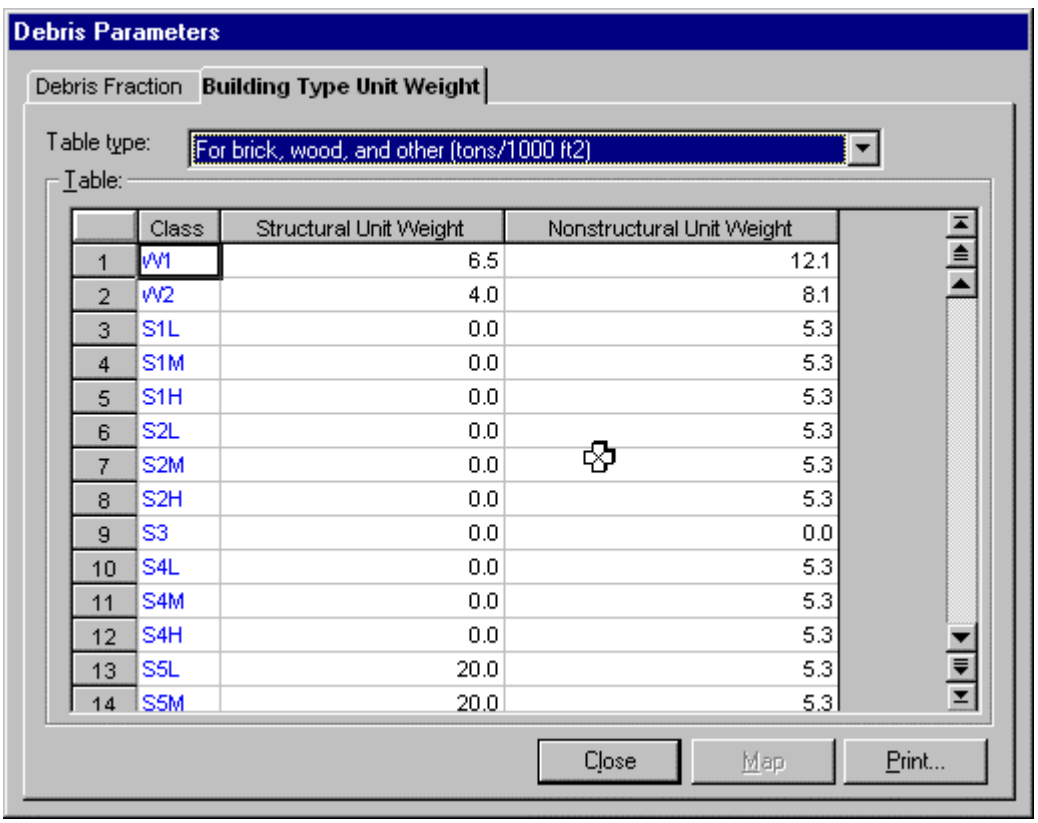
While estimates of debris could include debris due to collapsed bridges and overpasses as well as debris due to buildings, **HAZUS** ignores debris generated from collapsed bridges. Due to the simplifications that are introduced in the modeling of transportation systems, and in particular the lack of inventory detail regarding dimensions of individual bridges, any estimation of quantities of bridge debris would contain large uncertainties and might be misleading.

9.5.4.2 Debris Parameters

The debris module provides an estimate for each census tract of the amount (tons) of debris of each type that will be generated. Estimates of debris are based upon the structural and non-structural damage states that are output from the building damage module. Square footage of each model building type also is required, but is available from the building inventory databases. Two additional sets of data are required to estimate the amount of debris that is generated from damaged buildings. These are:

- Weight in tons of structural and non-structural elements per square foot of floor area for each model building type
- The amount of debris generated for each structural and non-structural damage state in terms of percent of weight of elements

Estimates of debris can be generated using the default data supplied with **HAZUS**. Figure 9.36 shows the default values of debris weight for each model building type. Clicking on the Analysis|Parameters|Debris menu accesses this window. For each model building type there are two unit weight tables. The first table includes Type 1 materials such as brick, wood and other debris, while the second is limited to the Type 2 materials such as reinforced concrete and steel. Both tables use the number of tons of material per 1000 square feet of building area. For example Figure 9.36 shows that for each 1000 square feet of W1 construction there are 6.5 tons of Type 1 structural material and 12.1 tons of Type 1 non-structural material. These values are based upon assumptions of "typical buildings". These values can be modified to more accurately reflect the buildings in your area if such data is available.

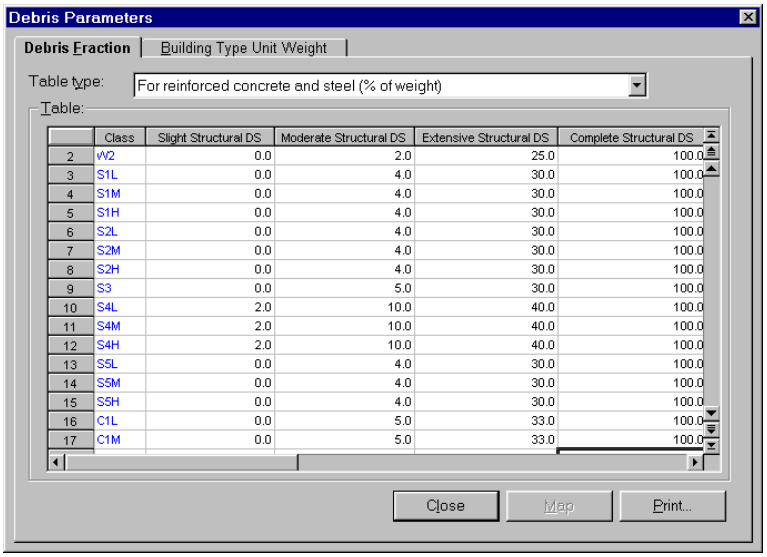


	Class	Structural Unit Weight	Nonstructural Unit Weight
1	W1	6.5	12.1
2	W2	4.0	8.1
3	S1L	0.0	5.3
4	S1M	0.0	5.3
5	S1H	0.0	5.3
6	S2L	0.0	5.3
7	S2M	0.0	5.3
8	S2H	0.0	5.3
9	S3	0.0	0.0
10	S4L	0.0	5.3
11	S4M	0.0	5.3
12	S4H	0.0	5.3
13	S5L	20.0	5.3
14	S5M	20.0	5.3

Figure 9.36 Weight of structural and non-structural elements for debris Type 1 in terms of tons per 1000 square feet of building area

Default values are also provided for both Type 1 and Type 2 debris in terms of percentage of weight of elements and the damage state. As shown in Figure 9.37, for low rise steel braced frames (S2L) no Type 2 debris is generated in the structural slight damage state but one can expect to remove debris equal to 30% of the weight of reinforced concrete and steel elements if the damage state is extensive. These default

values are based upon observations of damage in past earthquakes. These values can be modified to more accurately reflect the buildings in your area if such data is available.



	Class	Slight Structural DS	Moderate Structural DS	Extensive Structural DS	Complete Structural DS
2	W2	0.0	2.0	25.0	100.0
3	S1L	0.0	4.0	30.0	100.0
4	S1M	0.0	4.0	30.0	100.0
5	S1H	0.0	4.0	30.0	100.0
6	S2L	0.0	4.0	30.0	100.0
7	S2M	0.0	4.0	30.0	100.0
8	S2H	0.0	4.0	30.0	100.0
9	S3	0.0	5.0	30.0	100.0
10	S4L	2.0	10.0	40.0	100.0
11	S4M	2.0	10.0	40.0	100.0
12	S4H	2.0	10.0	40.0	100.0
13	S5L	0.0	4.0	30.0	100.0
14	S5M	0.0	4.0	30.0	100.0
15	S5H	0.0	4.0	30.0	100.0
16	C1L	0.0	5.0	33.0	100.0
17	C1M	0.0	5.0	33.0	100.0

Figure 9.37 Debris generated in terms of percent of weight of elements for each model building type and each structural and non-structural damage state

9.6 Running the Direct Social and Economic Loss Module

The **Direct social and economic loss** module is used for estimating casualties, displaced households due to loss of housing habitability, short-term shelter needs, and direct economic impacts resulting from damage to buildings and lifelines. Clicking on the **Direct social and economic loss** option in the window shown in Figure 9.16 will cause the following menu to appear.

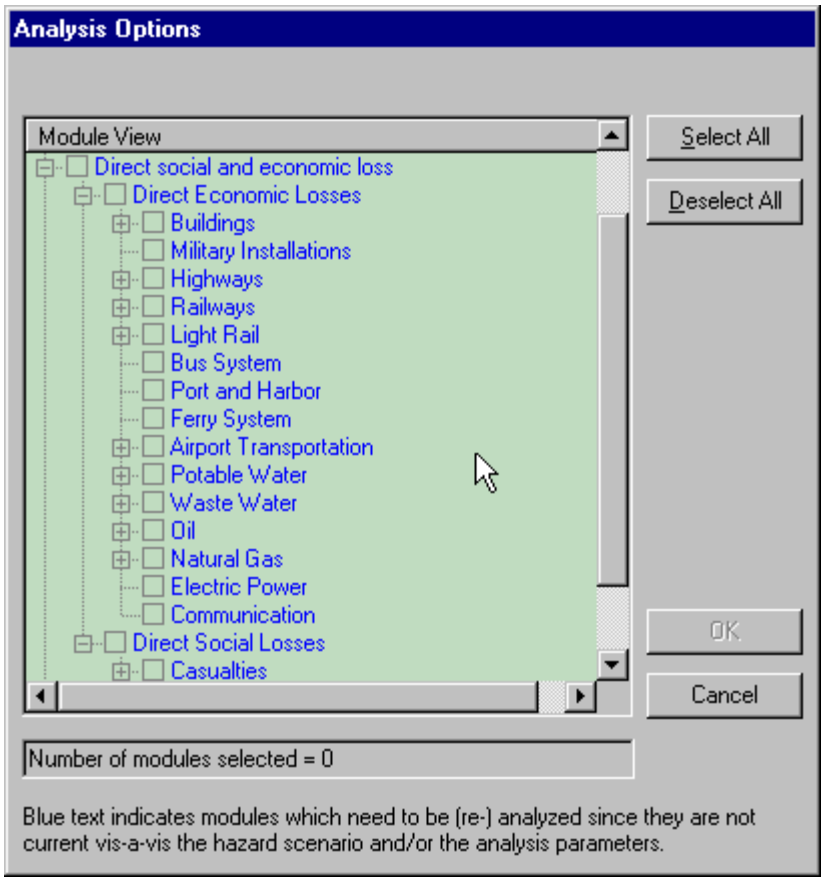


Figure 9.38 Window for selecting Direct Social and Economic Loss analysis options

Select the types of analyses you wish to run, click on the **Close** button and then click on the OK button shown in the window in Figure 9.16. The social and economic loss analyses can only be run if the direct physical damage module is either run simultaneously, or has previously been run.

9.6.1 Casualty Estimates

The casualty module calculates the following estimates for each census tract at three times of day (2 AM, 2 PM and 5 PM):

- Residential casualties (Severity 1, 2, 3 and 4)
- Commercial casualties (Severity 1, 2, 3 and 4)
- Industrial casualties (Severity 1, 2, 3 and 4)
- Commuting casualties (Severity 1, 2, 3 and 4)
- Total casualties (Severity 1, 2, 3 and 4)

The following inputs are needed to obtain estimates of casualties:

- Population distribution by census tract
- Population distribution within census tract (residential, commercial, industrial, commuting)
- Building stock inventory
- Damage state probabilities
- Time of day of estimate (2 AM, 2 PM or 5 PM)
- Casualty rates by damage state of model building
- Collapse rates due to collapse of model building/bridge type
- Number of commuters on or under bridges in the census tract

All of this information has already been provided by other modules or is available as a default.

9.6.1.1 Injury Classification Scale

The output from the module consists of a casualty breakdown by injury severity, defined by a four-tier injury severity scale (Coburn, 1992; Cheu, 1994). Table 9.8 defines the injury classification scale used in **HAZUS**.

Table 9.8 Injury Classification Scale

Injury Severity	Injury Description
Severity 1	Injuries requiring basic medical aid without requiring hospitalization
Severity 2	Injuries requiring a greater degree of medical care and hospitalization, but not expected to progress to a life threatening status
Severity 3	Injuries that pose an immediate life threatening condition if not treated adequately and expeditiously. The majority of these injuries result because of structural collapse and subsequent collapse or impairment of the occupants.
Severity 4	Instantaneously killed or mortally injured

Other, more elaborate casualty scales exist. They are based on quantifiable medical parameters such as medical injury severity scores, coded physiologic variables, etc. The selected four-tier injury scale used in **HAZUS** is a compromise between the demands of the medical community (in order to plan their response) and the ability of the engineering community to provide the required data. For example, medical professionals would like to have the classification in terms of "Injuries/Illnesses" to account for worsened medical conditions caused by an earthquake (e.g., heart attack). However, currently available casualty assessment methodologies do not allow for a finer resolution in the casualty scale definition.

9.6.1.2 Casualty Rates

In order to estimate the number and severity of the casualties, statistics from previous earthquakes were analyzed to develop relationships that reflect the distribution of injuries one would expect to see resulting from building and bridge damage. These casualty rates were developed for each casualty severity and are multiplied by the exposed population to estimate the number of casualties. An example of a calculation of casualties follows:

Severity 1 casualty rate for low rise unreinforced masonry buildings (URML) with slight structural damage		= 3 in 5,000
Number of people in the study region who were in slightly damaged URML buildings		= 50,000
Severity 1 casualties	= 50,000∗3/5,000	= 30 people

The following default casualty rates are defined by **HAZUS** and can be found in the *Technical Manual*:

- Casualty rates by model building type for slight structural damage
- Casualty rates by model building type for moderate structural damage
- Casualty rates by model building type for extensive structural damage
- Casualty rates by model building and bridge types for complete structural damage with no collapse
- Casualty rates after collapse by model building type.

Note that a separate set of casualty rates was developed for entrapped victims, and that collapse is only considered in the case of complete structural damage. It is assumed that in the cases of slight, moderate and extensive structural damage, collapses do not occur and building collapse is unlikely. Casualty rates for both buildings and bridges can be viewed and modified in the window shown in Figure 9.39. Selecting the Analysis|Parameters|Casualties menu accesses this window. These default casualty rates can be modified if improved information is available. To modify values, type in the new numbers and click on the **Close** button. You will be asked to confirm your changes.

It should be noted that complete data does not exist for all model building types and injury severity. Missing data were inferred from reviewing previous studies. Collection of better and more complete casualty statistics would involve a major research study.

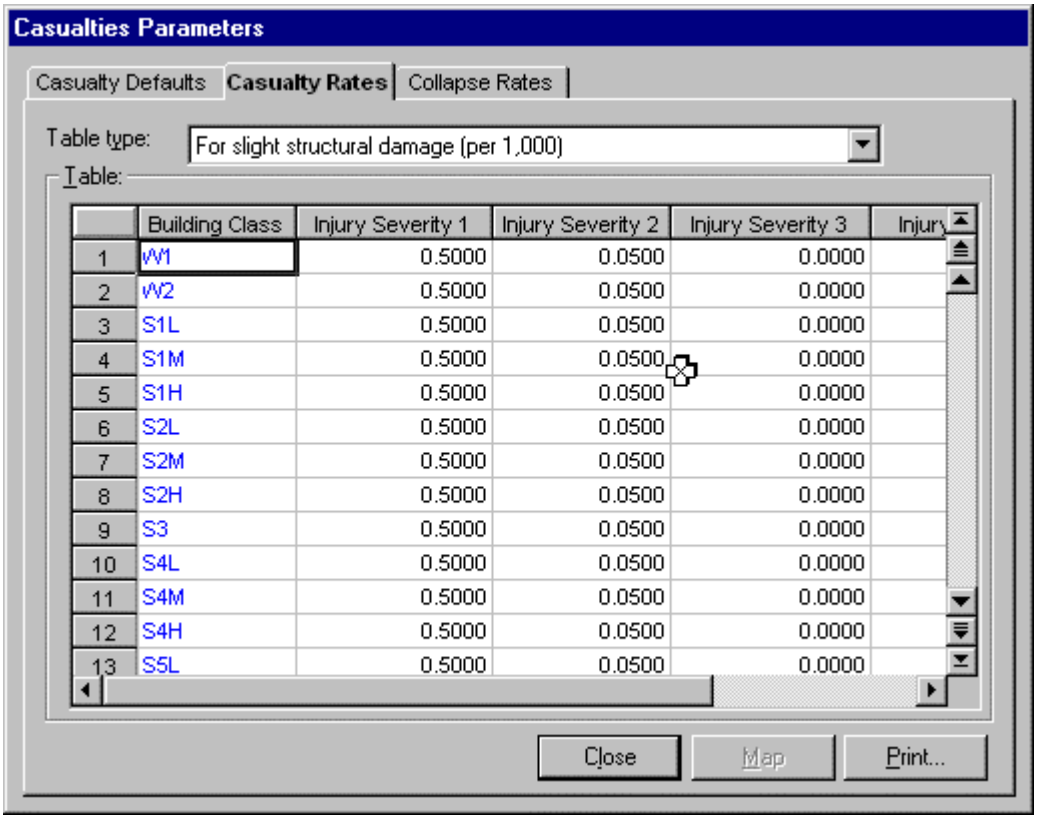


Figure 9.39 Casualty rates in number of casualties per 1,000 occupants by model building type for the extensive structural damage state

9.6.1.3 Collapse Rates

When collapses or partial collapses occur, individuals may become trapped under fallen debris or trapped in air pockets amongst the rubble. Casualties tend to be more severe in these cases, and as was discussed in Section 9.6.1.2 a separate set of casualty rates was developed for entrapped victims. It should be noted that building collapse rates (in percent of occupants) are developed only for the complete damage state. This is because it is assumed that no collapses or partial collapses occur in the slight, moderate or extensive damage states and collapse in these cases is unlikely. Collapse rates by model building type can be found in the *Technical Manual*. They can also be viewed within **HAZUS** as is shown in Figure 9.40. This window is accessed from the **Analysis|Parameters|Casualties** menu. To modify values, type in the new numbers and click on the **Close** button. You will be asked to confirm your changes.

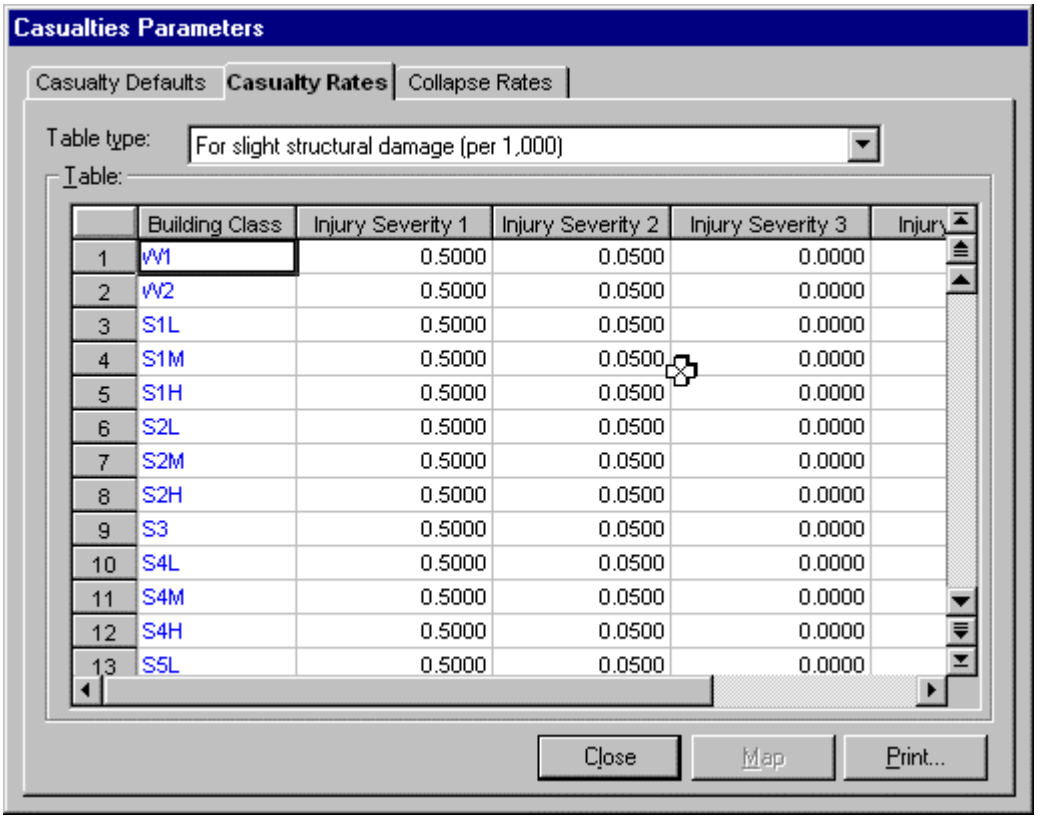


Figure 9.40 Collapse rates for buildings as displayed in HAZUS

9.6.1.4 Commuter Distribution Factor

The Commuter Distribution Factor (CDF) is used to calculate the number of commuters on or under bridges when an earthquake occurs. The CDF is defined as the fraction of commuters on or under bridges. It is multiplied by the total number of commuters in the census tract to compute the estimated number of commuters on or under a bridge. For example if there are 1000 commuters in the census tract and the CDF is set to 0.01, then 0.01*1000=10 commuters are likely to be on or under a bridge. The default values for the CDF can be viewed and modified as shown in Figure 9.41. To modify values, access this window from the **Analysis|Parameters|Casualties** menu, type in the new numbers and click on the **Close** button. You will be asked to confirm your changes.

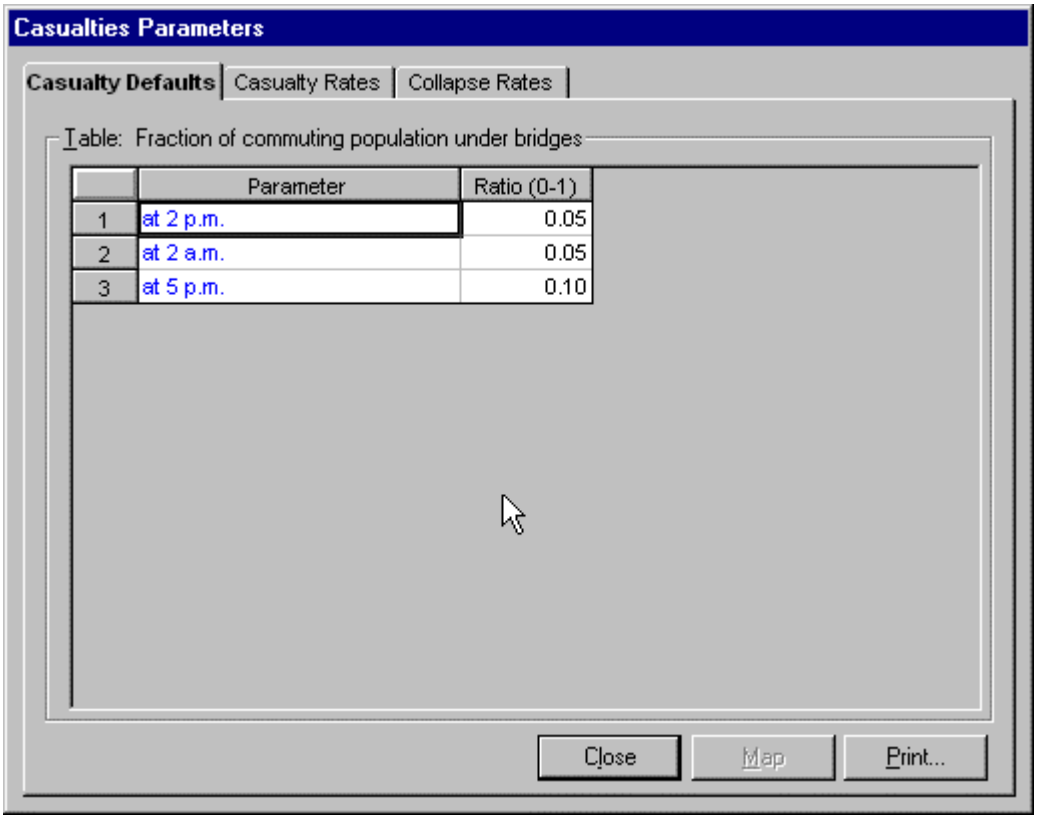


Figure 9.41 Commuter Distribution Factors for three times of day

9.6.2 Estimates of Displaced Households Due to Loss of Housing Habitability and Short-Term Shelter Needs

Earthquakes can cause loss of function or habitability of buildings that contain housing units resulting in predictable numbers of displaced households. These households will need alternative short-term shelter from family, friends, or public shelters provided by relief organizations such as the Red Cross and Salvation Army. For units where repair takes longer than a few weeks, long-term alternative housing can be achieved through importation of mobile homes, a reduction in vacant units, net emigration from the impacted area, and eventually by the repair or reconstruction of new public and private housing. While the number of people seeking short-term public shelter is of great concern to emergency response organizations, the longer-term impacts on the housing stock are of great concern to local governments such as cities and counties.

The shelter module provides two estimates:

- The total number of displaced households (due to loss of habitability)
- The number of people requiring short-term shelter

Loss of habitability is calculated directly from damage to the residential occupancy inventory and from loss of water and power. The methodology for calculating short-term shelter requirements recognizes that only a portion of those displaced from their homes will seek public shelter, and some will seek shelter even though their residence may have little, if any, damage.

Households also may be displaced as a result of fire following earthquake, inundation (or the threat of inundation) due to dam failure, and by significant hazardous waste releases. This module does not specifically deal with these issues, but an approximate estimate of displacement due to fire or inundation can be obtained by multiplying the residential inventory in affected census tracts by the areas of fire damage or inundation derived from those modules. No methodology for calculations of damage or loss due to hazardous materials is provided, and the user is confined to identifying locations of sites where hazardous materials are stored. If the particular characteristics of the study region give cause for concern about the possibility of loss of housing from fire, dam failure, or hazardous materials release, it would be advisable to initiate specific in-depth studies directed towards the problem.

All households living in uninhabitable dwellings will seek alternative shelter. Many will stay with friends and relatives or in the family car. Others will stay in hotels. Some will stay in public shelters provided by the Red Cross or others. **HAZUS** estimates the number of displaced persons seeking public shelter. In addition, observations from past disasters show that approximately 80% of the pre-disaster homeless will seek public shelter. Finally, data from Northridge indicate that approximately one-third of those in public shelters came from residences with no or insignificant structural damage. Depending on the degree to which infrastructure damage is incorporated into the number of displaced households, that number could be increased by up to 50% to account for "perceived" structural damage as well as lack of water and power.

9.6.2.1 Development of Input for Displaced Households

The following inputs are required to compute the number of uninhabitable dwelling units and the number of displaced households.

- Fraction of dwelling units likely to be vacated if damaged
- Probability that the residential units are without power and/or water immediately after the earthquake.
- Percentage of households affected by utility outages likely to seek alternative shelter.

9.6.2.1.1 Fraction of Dwelling Units Likely to be Vacated if Damaged

The number of uninhabitable dwelling units is not only a function of the amount of structural damage but it is also a function of the number of damaged units that are perceived to be uninhabitable by their occupants. All dwelling units located in buildings that are in the complete damage state are considered to be uninhabitable. In addition, dwelling units that are in moderately or extensively damaged multi-family structures can also be uninhabitable due to the fact that renters perceive some moderately damaged and most extensively damaged rental property as uninhabitable. On the other hand, those living in single-family homes are much more likely to tolerate damage and continue to live in their homes. Therefore weighting factors have been developed that describe the fraction of dwellings likely be vacated if they are damaged. These default weighting factors can be viewed and modified as shown in Figure 9.42. To access this window use the **Analysis|Parameters|Shelter** menu.

In this table, the subscript SF corresponds to single-family dwellings and the subscript MF corresponds to multi-family dwellings. The subscripts M, E, and C correspond to moderate, extensive and complete damage states, respectively. For example, based on these defaults, it is assumed that 90% of multi-family dwellings will be vacated if they are in the extensive damage state (see w_{MFE}). Discussion of how the defaults were developed can be found in the *Technical Manual*.

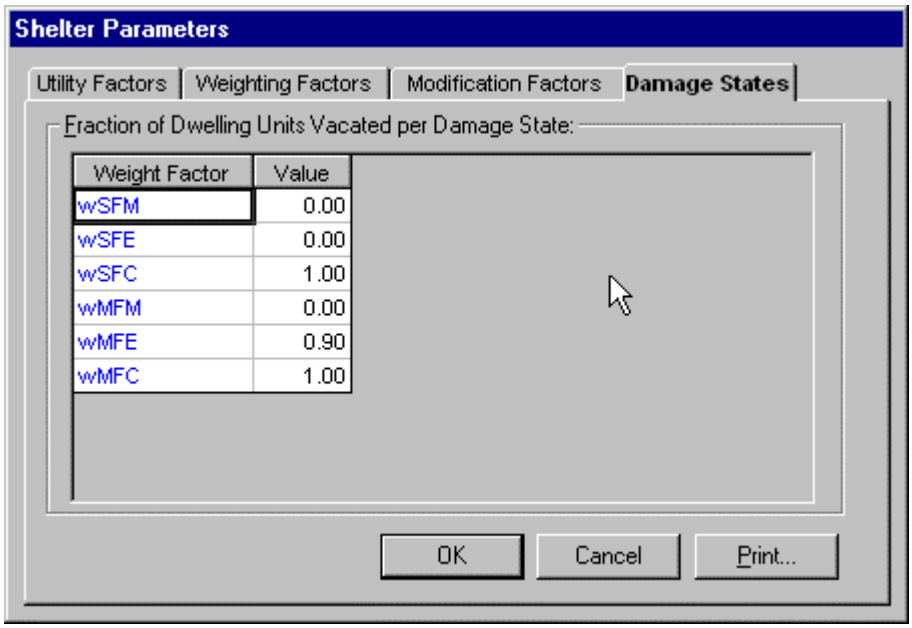


Figure 9.42 Default values for the fraction of dwelling units likely to be vacated if damaged

9.6.2.1.2 Percentage of Households Affected by Utility Outages Likely to Seek Alternative Shelter

Depending on weather conditions, families living in these units may require only food and sources of potable water or may be forced to seek alternative shelter. A cold-weather event will also trigger a higher percentage of those affected by loss of power (heat) leaving their otherwise undamaged homes. Because no data exists on the impact of power losses on perceived habitability, this assessment has been left to the user as part of the analysis. The user might pick a percentage of affected households that would likely seek alternative shelter based on, for example, the number of days that the temperature is below a specified value. Alternatively, the user might choose to run two scenarios, one in which 100% of those affected by a power outage needed to seek alternative shelter, and a second in which no one affected sought alternative shelter. The percent of households seeking alternative shelter can be viewed and modified in the Shelter Parameters window shown in Figure 9.43.

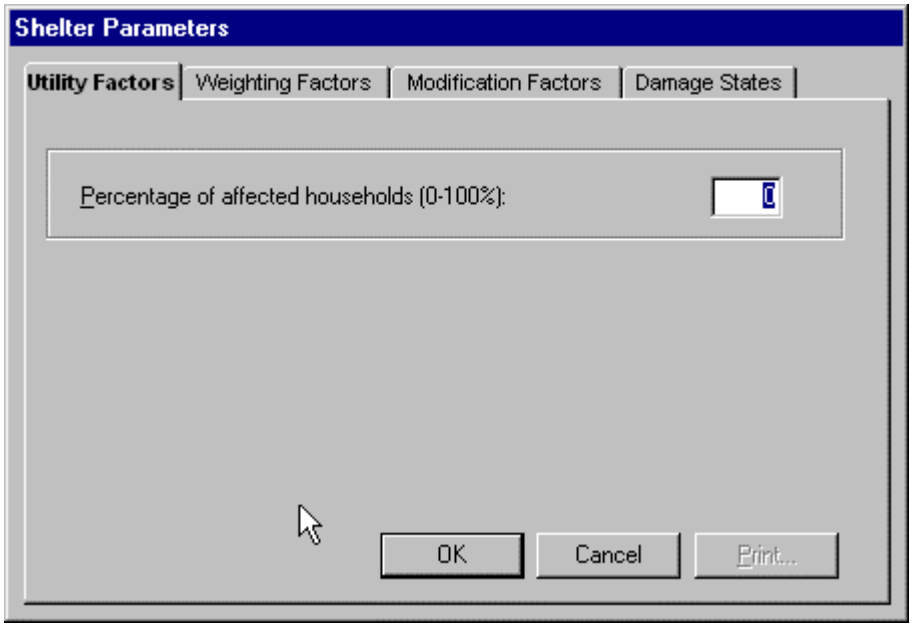


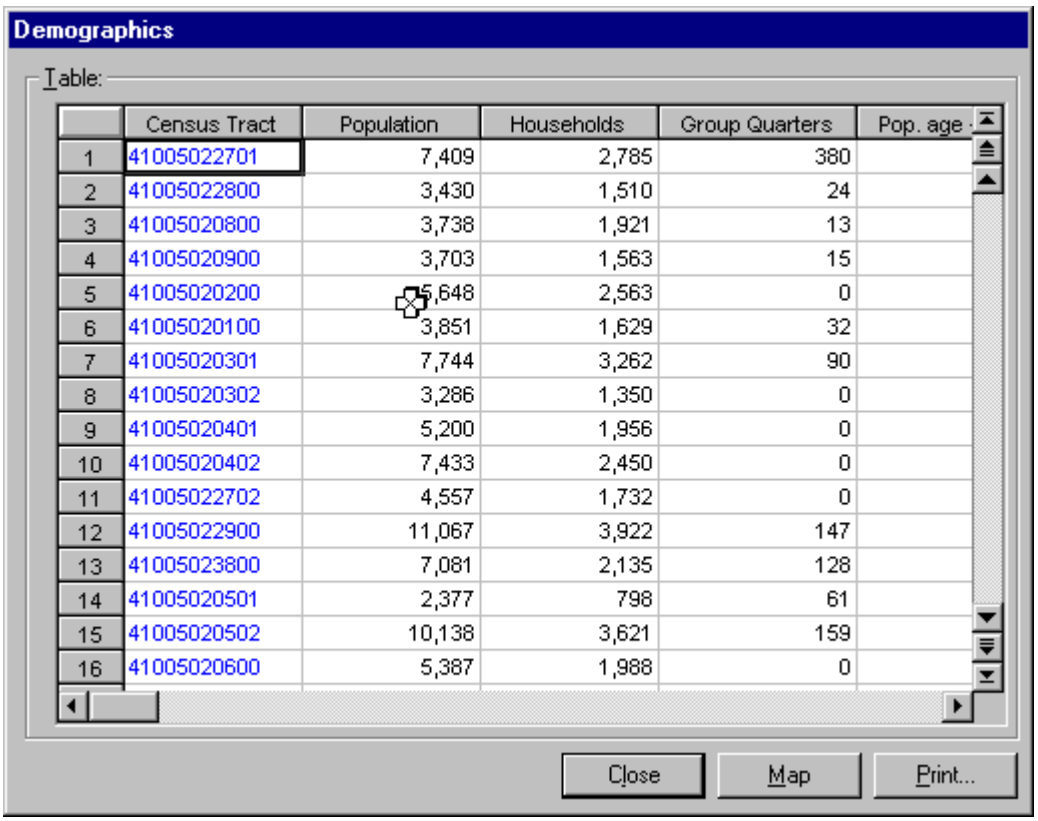
Figure 9.43 Utility factors in the shelter parameters window

9.6.2.2 Development of Input for Shelter Needs

The number of displaced households is combined with the following information to estimate shelter needs:

- Number of people in the census tract
- Number of households in census tract
- Income breakdown of households in census tract
- Ethnicity of households in census tract
- Percentage of homeowners and renters in the census tract
- Age breakdown of households in census tract

All of this information is provided in the default census database. The default census database can be viewed, modified and mapped in the inventory module as shown in Figure 9.44. Figure 9.45 is a map of households with incomes less than $10,000. Highlighting the Income column in the census database and clicking on the Map button created this map. Note that to see this column you would need to click on the right arrow at the bottom of Figure 9.44.



	Census Tract	Population	Households	Group Quarters	Pop. age
1	41005022701	7,409	2,785	380	
2	41005022800	3,430	1,510	24	
3	41005020800	3,738	1,921	13	
4	41005020900	3,703	1,563	15	
5	41005020200	5,648	2,563	0	
6	41005020100	3,851	1,629	32	
7	41005020301	7,744	3,262	90	
8	41005020302	3,286	1,350	0	
9	41005020401	5,200	1,956	0	
10	41005020402	7,433	2,450	0	
11	41005022702	4,557	1,732	0	
12	41005022900	11,067	3,922	147	
13	41005023800	7,081	2,135	128	
14	41005020501	2,377	798	61	
15	41005020502	10,138	3,621	159	
16	41005020600	5,387	1,988	0	

Figure 9.44 Demographic data supplied in HAZUS

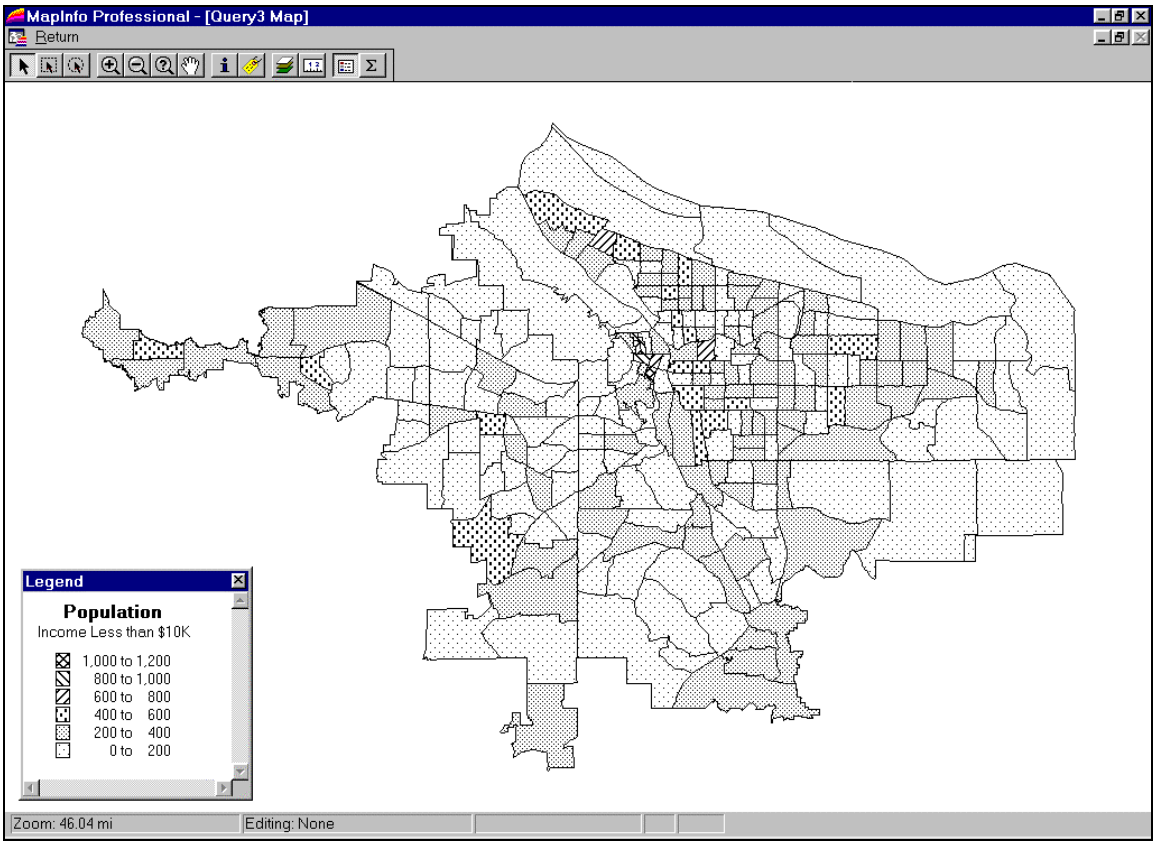


Figure 9.45 Map of households with incomes less than $10,000

Assumptions of the methodology are that the number of people who require short-term housing is a function of income, ethnicity, ownership and age. Based on experience in past disasters, including both hurricanes and earthquakes, those seeking shelter typically have very low incomes, and therefore have fewer options. In addition, they tend to have young children or are over 65. Finally, even given similar incomes, Hispanic populations from Central America and Mexico tend to be more concerned about reoccupying buildings than other groups. This tendency appears to be because of the fear of collapsed buildings instilled from past disastrous earthquakes.

To account for these trends, factors have been developed to represent the fraction of households in each category likely to seek public shelter if their dwellings become uninhabitable. The default values of these factors as shown in Table 9.9 are based upon data from the Northridge earthquake combined with expert opinion (see the *Technical Manual* for more information). From this table you can interpret that 62% of households with incomes less than $10,000 whose dwellings have become uninhabitable will seek public shelter.

Table 9.9 Fraction of Households Likely to Seek Public Shelter if Dwellings Become Uninhabitable

Household Description	Default
Income	
Household Income < $10,000	0.62

$10,000 < Household Income < $15,000	0.42
$15,000 < Household Income < $25,000	0.29
$25,000 < Household Income < $35,000	0.22
$35,000 < Household Income	0.13
Ethnicity	
White	0.24
Black	0.48
Hispanic	0.47
Asian	0.26
Native American	0.26
Ownership	
Own Dwelling Unit	0.40
Rent Dwelling Unit	0.40
Age	
Population Under 16 Years Old	0.40
Population Between 16 and 65 Years Old	0.40
Population Over 65 Years Old	0.40

The factors in Table 9.9 can be viewed and modified in the **Shelter Parameters** window as shown in Figure 9.46. The **Income**, **Ethnicity**, **Ownership** and **Age** buttons can be used to view the various tables.

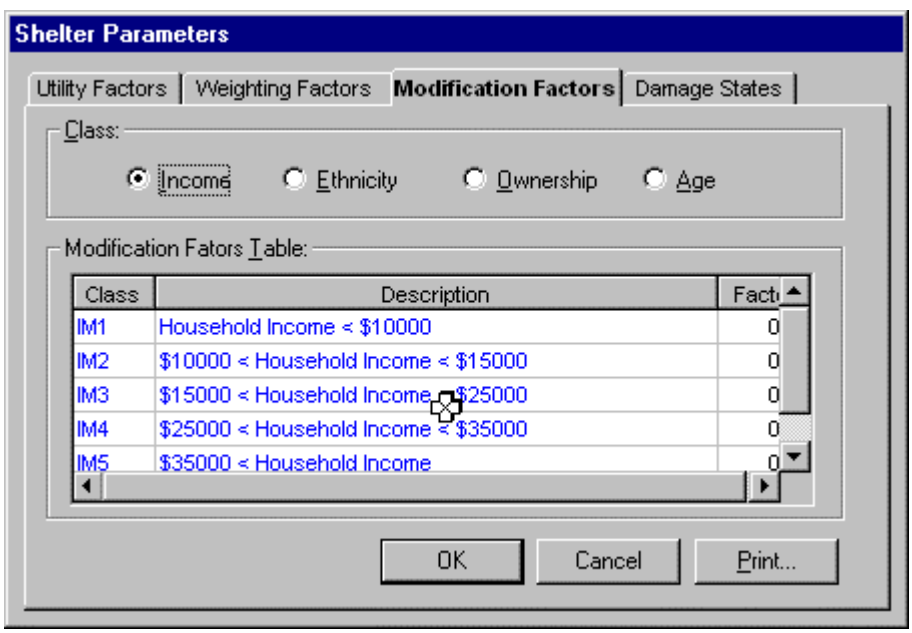


Figure 9.46 Fraction of households likely to seek public shelter as a function of household income

You have the option to weight the importance of the four factors that affect the fraction of households seeking public shelter: income, ethnicity, ownership and age. The **importance factors** must sum to one. Defaults of the importance factors are shown in Figure 9.47. The default importance factors indicate that no weight will be put on

ownership or age, and income will be weighted almost 3 times as much as ethnicity. If you wish to give all classes equal importance, then the factors should all be 0.25.

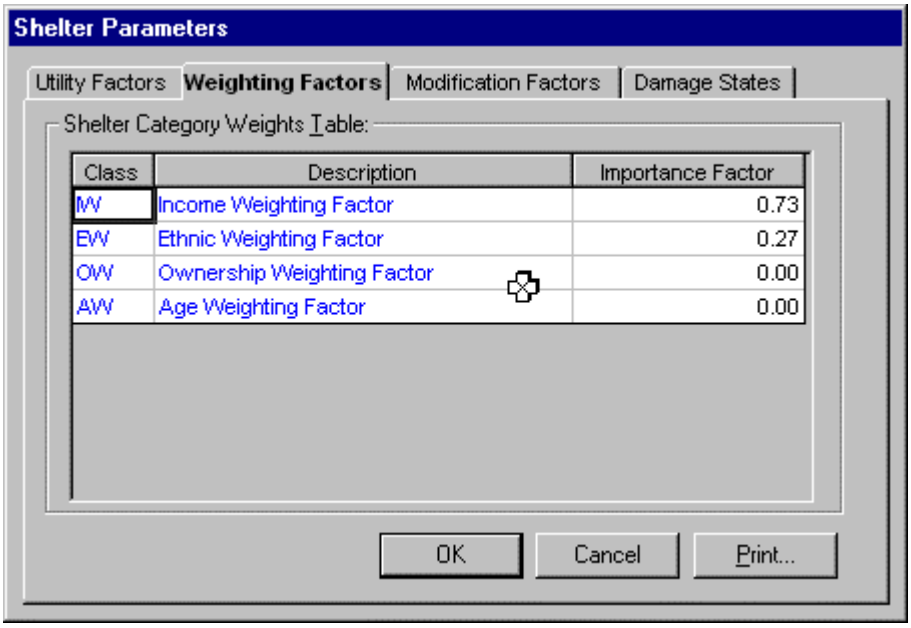


Figure 9.47 Importance Factors for determining shelter needs

9.6.3 Direct Economic Loss

Estimates of damage to the built environment are converted to dollar loss in this module. Beyond economic losses, whose dollar value can be estimated from the extent of building and lifeline damage, there are a number of common socioeconomic impacts from earthquakes that, though their impact is not readily quantifiable, may represent important earthquake effects. These impacts may vary, depending on socioeconomic aspects of the population at risk and the particular physical topography and layout of the affected region. These impacts include:

- Psychological and emotional trauma that may affect a variety of populations, such as school children, ethnic groups, recent immigrants, the elderly and the infirm. These effects may influence post-earthquake behavior, including the choice of or need for shelter.
- Changes in work and leisure travel time patterns caused by bridge or freeway failures. Large increases in travel time may result in hardship and family stress. At a large scale, they may impact the regional economy.
- Changes in community and family structure caused by large-scale housing losses and consequent relocation and demolition.

This methodology does not attempt to estimate such effects. If the user of the methodology is interested in the possible impact of these factors on the community or region under study, it is recommended that they consult bibliographic sources to obtain an understanding of the possible importance of these impacts for the area of study. A useful discussion of many of these impacts can be found in "The Loma Prieta, California,

Earthquake of October 17, 1989 - Public Response" (Bolton, 1993). This publication has bibliographic references that may be useful for further study.

9.6.3.1 Types of Direct Economic Loss

Direct economic losses begin with the cost of repair and replacement of damaged or destroyed buildings. However, building damage will result in a number of losses that, in **HAZUS**, are defined as direct. Thus, building-related direct economic losses (which are all expressed in dollars) comprise two groups. The first group consists of losses that are directly derived from building damage:

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

The second group consists of losses that are related to the length of time the facility is non-operational (or the immediate economic consequences of damage):

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

Damage to lifeline and transportation systems causes direct economic losses analogous to those caused by building damage. In **HAZUS**, direct economic loss for lifelines and transportation systems are limited to the cost of repairing damage to the systems, and estimates of elapsed time for their restoration. No attempt is made to estimate losses due to interruption of customer service or alternative supply services.

Dollar losses due to inundation are not explicitly addressed. **HAZUS** estimates the area of inundation and then relates this estimate to the quantity of building stock in the affected census tracts. This estimate in turn can be converted to a dollar value.

In a similar manner, a value for building losses from fire can be estimated by relating the area of fire spread to the volume of construction and construction cost. In both cases, the nature of damage state (which vary from those due to ground shaking damage) are not developed and estimates of dollar loss from these causes should be regarded as very broad estimates. In addition, one must be careful that double counting does not occur when evaluating damages due to earthquake, inundation, and fire (for example a collapsed building that burns to the ground in a flood zone).

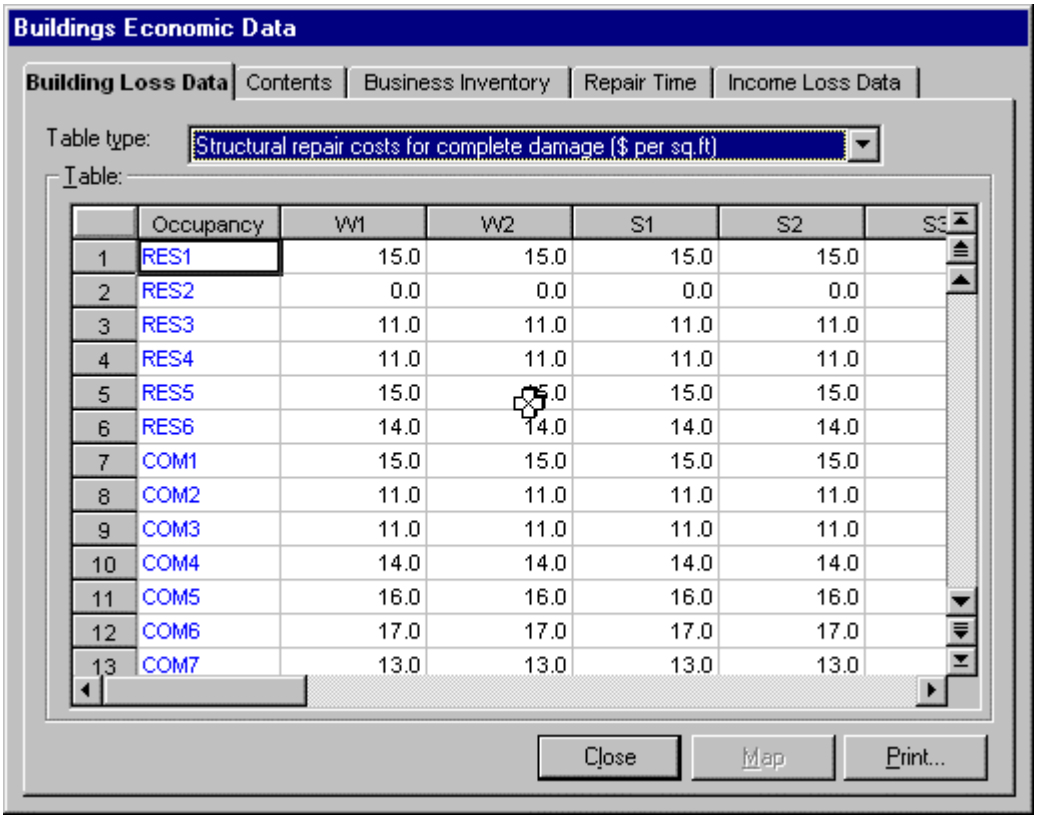
No methodology is provided for estimating losses due to release of hazardous materials.

9.6.3.2 Development of Input for Building Losses

A great deal of default economic data is supplied with **HAZUS**, as follows:

- Structural repair costs ($ per square foot) for each of the damage states, model building types and occupancies
- Non-structural repair costs ($ per square foot) for all occupancies (both acceleration sensitive and drift sensitive damage)
- Regional cost modifiers for each state in the United States
- Value of building contents as a percentage of building replacement value for all occupancies
- Contents damage as a function of damage state
- Annual gross sales or production in $ per square foot for agricultural, commercial and industrial occupancies
- Business inventory as a percentage of gross annual sales for agricultural, commercial and industrial occupancies
- Business inventory damage as a function of damage state for agricultural, commercial and industrial occupancies
- Building cleanup and repair time in days as a function of damage state and occupancy
- Parameters used to estimate facility loss of function for each damage state and occupancy
- Rental costs
- Disruption costs
- Percent of buildings that are owner occupied for each occupancy class
- Capital-related income and wage income in $/day per square foot for each occupancy

These data are described in detail in the *Technical Manual*. With the exception of repair costs, the default data represent typical values for the United States and thus no regional variations are included. The user will want to review the default data very carefully and modify the data to best represent the characteristics of the region. The default data can be viewed and modified from within **HAZUS**. The window that is used to view and modify economic default data is shown in Figure 9.48. This window is accessed from the **Analysis|Parameters|Buildings-Economic** menu.



	Occupancy	W1	W2	S1	S2	S3
1	RES1	15.0	15.0	15.0	15.0	
2	RES2	0.0	0.0	0.0	0.0	
3	RES3	11.0	11.0	11.0	11.0	
4	RES4	11.0	11.0	11.0	11.0	
5	RES5	15.0	15.0	15.0	15.0	
6	RES6	14.0	14.0	14.0	14.0	
7	COM1	15.0	15.0	15.0	15.0	
8	COM2	11.0	11.0	11.0	11.0	
9	COM3	11.0	11.0	11.0	11.0	
10	COM4	14.0	14.0	14.0	14.0	
11	COM5	16.0	16.0	16.0	16.0	
12	COM6	17.0	17.0	17.0	17.0	
13	COM7	13.0	13.0	13.0	13.0	

Figure 9.48 Economic data for estimating building repair costs, contents and business inventory losses, lost income and relocation costs

9.6.3.2.1 Replacement Costs

The replacement costs (damage state = complete) were derived from Means Square Foot Costs 1994, for Residential, Commercial, Industrial, and Institutional buildings (Jackson, 1994). The Means publication is a nationally accepted reference on building construction costs, which is published annually. This publication provides cost information for a number of low-rise residential model buildings, and for 70 other residential, commercial, institutional and industrial buildings. These are presented in a format that shows typical costs for each model building, showing variations by size of building, type of building structure, and building enclosure. One of these variations is chosen as "typical" for this typical model, and a breakdown is provided that shows the cost and percentages of each building system or component. A description of how to estimate costs from the Means publication is found in the *Technical Manual*. Since Means is published annually, fluctuations in typical building cost can be tracked and the user can insert the most up-to-date Means typical building cost into the default database. This procedure is outlined in the *Technical Manual*.

In **HAZUS**, selected Means models have been chosen from the 70 plus models that represent the 28 occupancy types. The wide range of costs shown, even for a single model, emphasize the importance of understanding that the dollar values shown should *only be used to represent costs of large aggregations* of building types. If costs for single

buildings or small groups (such as a college campus) are desired for more detailed loss analysis, then local *building specific* cost estimates should be used.

9.6.3.2.2 Building Contents

Building contents are defined as furniture, equipment that is not integral with the structure, computers, and supplies. Contents do not include inventory or non-structural components such as lighting, ceilings, mechanical and electrical equipment and other fixtures. Default values are provided for contents (by occupancy) as a percentage of the replacement value of the facility. These values are based on Table 4.11 of ATC-13 [ATC, 1985]. The damage to contents is expressed in terms of the percentage of damage to the contents based upon the acceleration-sensitive non-structural damage state of the building. The contents damage percentages are based upon the assumption that for the complete damage state some percentage of contents, 15%, can be retrieved. The default contents damage percentages are the same for all occupancies.

9.6.3.2.3 Business Inventory

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

9.6.3.2.4 Building Cleanup and Repair Time

A detailed description of repair times is provided in Section 9.6.3.3.

9.6.3.2.5 Relocation Expenses

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

9.6.3.2.6 Capital-related Income

Capital-related income is a measure of the profitability of a commercial enterprise. Income losses occur when building damage disrupts commercial activity. Income losses are the product of floor area, income realized per square foot and the expected days of loss of function for each damage state. The U.S. Department of Commerce's Bureau of Economic Analysis reports regional estimates of capital-related income by economic

sector. Capital-related income per square foot of floor space can then be derived by dividing income by the floor space occupied by a specific sector. Income will vary considerably depending on regional economic conditions. Therefore, default values need to be adjusted for local conditions. Default values were derived from information in Table 4.7 of ATC-13.

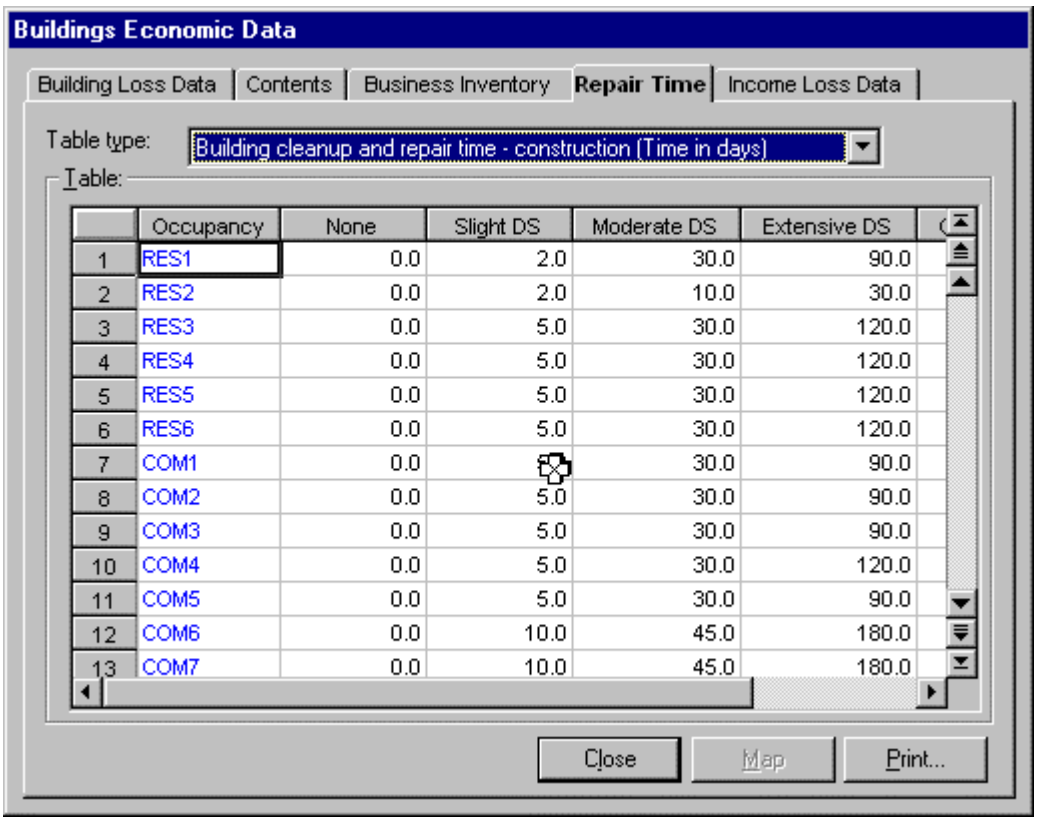
9.6.3.3 Repair and Clean-up Times

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

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

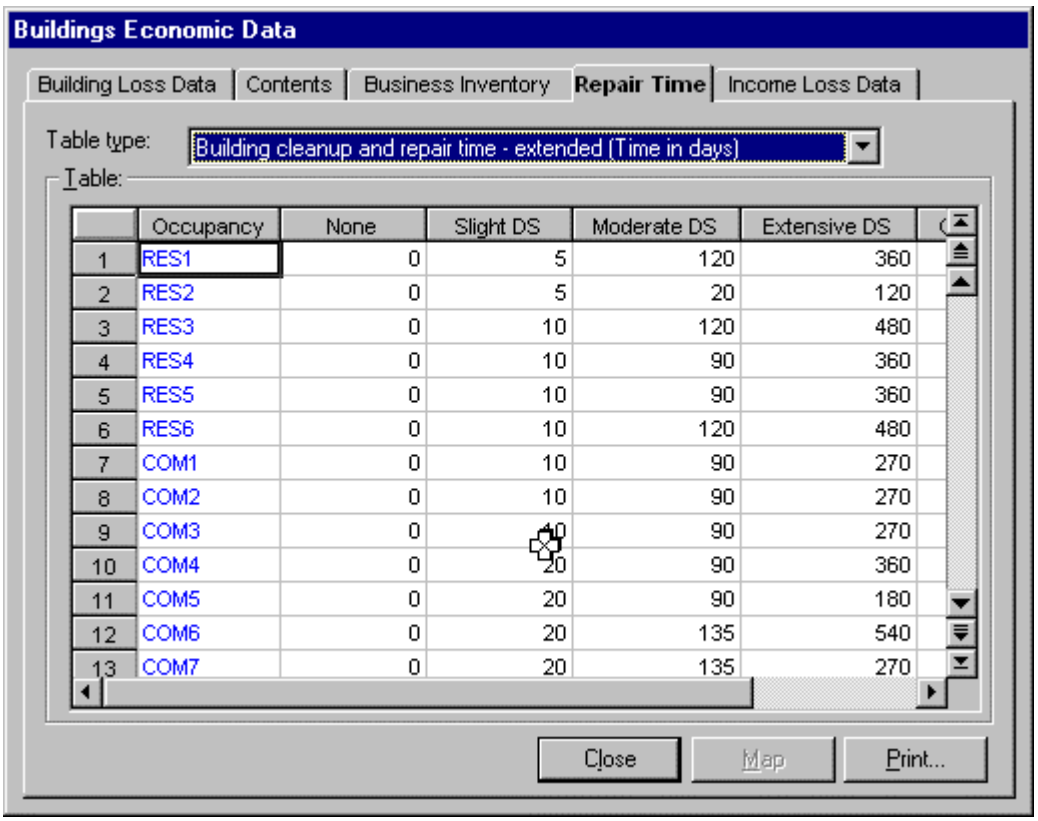
Default building repair and clean-up times are provided with **HAZUS**. These default values are broken into two parts: construction time and extended time. The construction time is the time to do the actual construction or repair. The extended time includes construction plus all of the additional delays described above. A discussion of these values is found in the *Technical Manual*. Default values can be viewed and modified using the window shown in Figure 9.49. Repair times are presented as a function of both amount of damage and occupancy class. Clearly there can be a great deal of variability in repair times, but these represent estimates of the *median* times for actual cleanup and repair. This window is accessed from the **Analysis|Parameters|Buildings-Economic** menu. To modify these values, type in the desired new values and click on the **Close** button. You will be asked to confirm your changes.

Default values of the extended building cleanup and repair times that account for delays in decision-making, financing, inspection etc., are viewed by clicking on the desired table listed under **Table type** as shown in Figure 9.50. Default extended estimates also can be modified.



	Occupancy	None	Slight DS	Moderate DS	Extensive DS
1	RES1	0.0	2.0	30.0	90.0
2	RES2	0.0	2.0	10.0	30.0
3	RES3	0.0	5.0	30.0	120.0
4	RES4	0.0	5.0	30.0	120.0
5	RES5	0.0	5.0	30.0	120.0
6	RES6	0.0	5.0	30.0	120.0
7	COM1	0.0	5.0	30.0	90.0
8	COM2	0.0	5.0	30.0	90.0
9	COM3	0.0	5.0	30.0	90.0
10	COM4	0.0	5.0	30.0	120.0
11	COM5	0.0	5.0	30.0	90.0
12	COM6	0.0	10.0	45.0	180.0
13	COM7	0.0	10.0	45.0	180.0

Figure 9.49 Default building cleanup and repair times

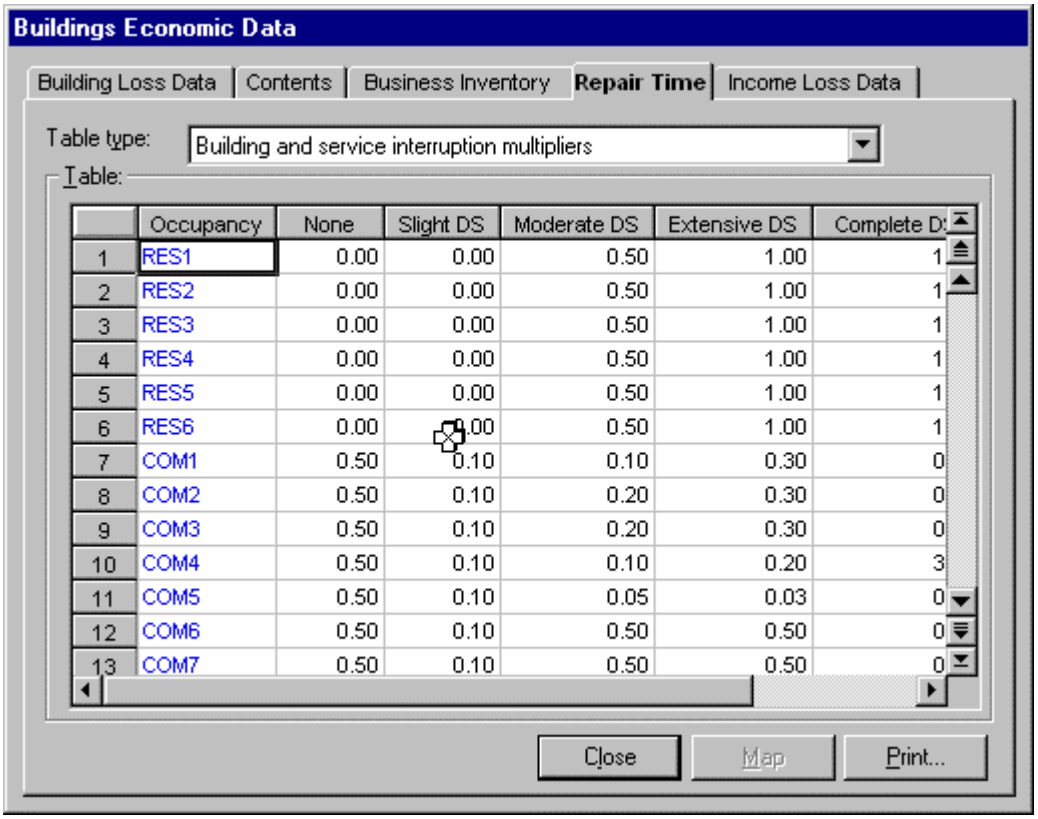


	Occupancy	None	Slight DS	Moderate DS	Extensive DS
1	RES1	0	5	120	360
2	RES2	0	5	20	120
3	RES3	0	10	120	480
4	RES4	0	10	90	360
5	RES5	0	10	90	360
6	RES6	0	10	120	480
7	COM1	0	10	90	270
8	COM2	0	10	90	270
9	COM3	0	10	90	270
10	COM4	0	20	90	360
11	COM5	0	20	90	180
12	COM6	0	20	135	540
13	COM7	0	20	135	270

Figure 9.50 Default extended building cleanup and repair times.

Repair times differ for similar damage states depending on building occupancy. Simpler and smaller buildings will take less time to repair than more complex, heavily serviced, or larger buildings. It has been also been noted that large well-financed corporations can sometimes accelerate the repair time compared to normal construction procedures.

However, establishment of a more realistic repair time does not translate directly into business or service interruption. For some businesses, building repair time is largely irrelevant, because these businesses can rent alternative space or use spare industrial/commercial capacity elsewhere. Thus Building and Service Interruption Time Multipliers have been developed to arrive at estimates of business interruption for economic purposes. These values are multiplied by the extended building cleanup and repair times. Service and building interruption multipliers can be viewed using the window shown in Figure 9.51.



Buildings Economic Data

Building Loss Data | Contents | Business Inventory | **Repair Time** | Income Loss Data

Table type: Building and service interruption multipliers

Table:

	Occupancy	None	Slight DS	Moderate DS	Extensive DS	Complete D
1	RES1	0.00	0.00	0.50	1.00	1
2	RES2	0.00	0.00	0.50	1.00	1
3	RES3	0.00	0.00	0.50	1.00	1
4	RES4	0.00	0.00	0.50	1.00	1
5	RES5	0.00	0.00	0.50	1.00	1
6	RES6	0.00	0.00	0.50	1.00	1
7	COM1	0.50	0.10	0.10	0.30	0
8	COM2	0.50	0.10	0.20	0.30	0
9	COM3	0.50	0.10	0.20	0.30	0
10	COM4	0.50	0.10	0.10	0.20	3
11	COM5	0.50	0.10	0.05	0.03	0
12	COM6	0.50	0.10	0.50	0.50	0
13	COM7	0.50	0.10	0.50	0.50	0

Close | Map | Print...

Figure 9.51 Default building and service interruption time multipliers

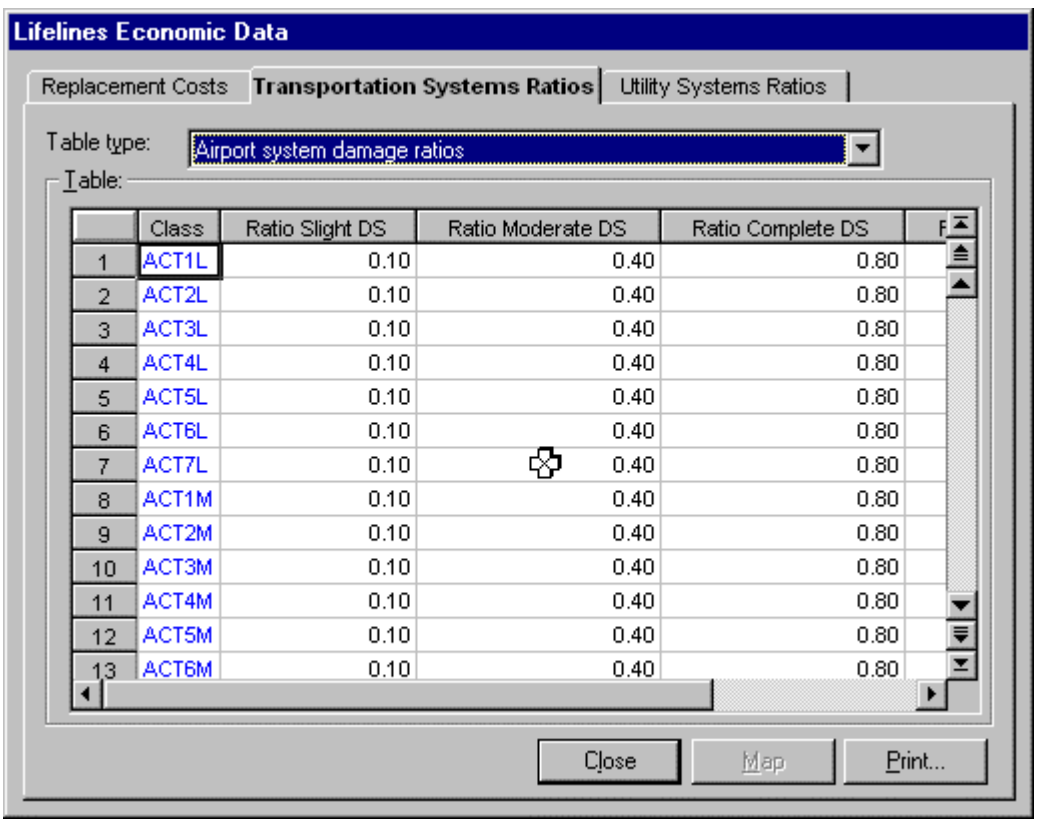
Application of the interruption multipliers to the extended building cleans up and repair times results in average values for the business or service interruption. For low levels of damage the time loss is assumed to be short, with cleanup by staff, and work can resume while slight repairs are being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

The median value of repair time applies to a large inventory of facilities. At moderate damage some marginal businesses may close, while others will open after a day's cleanup. Even with extensive damage some businesses will accelerate repair, while a number of others will close or be demolished. For example, one might reasonably assume that a URM building that suffers moderate damage is more likely to be demolished than a newer building that suffers moderate, or even extensive damage. If the URM building is a historic structure, its likelihood of survival and repair will probably

increase. There will also be a small number of extreme cases: the slightly damaged building that becomes derelict, or the extensively damaged building that continues to function for years with temporary shoring, until an expensive repair is financed and executed.

9.6.3.4 Development of Input for Lifeline Losses

For lifelines, estimates of economic losses are limited to the costs of repair. For each damage state, a default damage ratio has been defined. A damage ratio is the cost of repair as a fraction of the replacement cost. A sample of default damage ratios is shown in Figure 9.52. For example, the cost to repair slight damage to an airport control tower of type ACT1L is 10% of the replacement cost. This window is accessed from the **Analysis|Parameters|Lifelines-Economic** menu. The damage ratios are defined based upon the model lifeline components discussed in Chapters 7 and 8 of the *Technical Manual*. Development of damage ratios for lifeline components from damage to sub-components is discussed in Section 15.3 of the *Technical Manual*. Damage ratios can be modified to perform sensitivity analyses, however, damage ratios should be kept in the ranges defined in Chapter 15 of the *Technical Manual*.



	Class	Ratio Slight DS	Ratio Moderate DS	Ratio Complete DS
1	ACT1L	0.10	0.40	0.80
2	ACT2L	0.10	0.40	0.80
3	ACT3L	0.10	0.40	0.80
4	ACT4L	0.10	0.40	0.80
5	ACT5L	0.10	0.40	0.80
6	ACT6L	0.10	0.40	0.80
7	ACT7L	0.10	0.40	0.80
8	ACT1M	0.10	0.40	0.80
9	ACT2M	0.10	0.40	0.80
10	ACT3M	0.10	0.40	0.80
11	ACT4M	0.10	0.40	0.80
12	ACT5M	0.10	0.40	0.80
13	ACT6M	0.10	0.40	0.80

Figure 9.52 Default damage ratios for airport components

To make estimates of losses to lifelines, damage ratios must be multiplied by replacement costs. Default replacement costs provided with the methodology (see Figure 9.53) are mostly based on values found in ATC 13 and ATC-25. Replacement costs can be viewed and modified in the window shown in Figure 9.53.

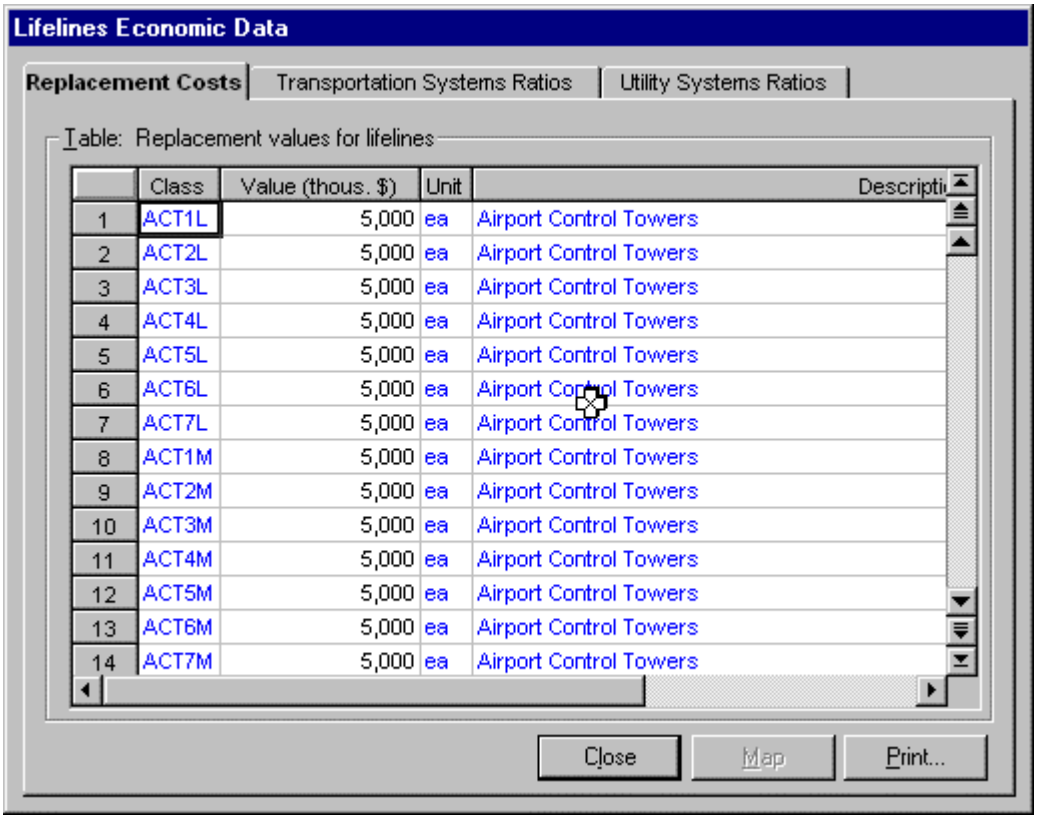


Figure 9.53 Default replacement costs for lifeline components

9.7 Running the Indirect Economic Loss Module

Indirect economic impacts are defined in **HAZUS** as the long-term economic impacts on the region that occur as a result of direct economic losses. Examples of indirect economic impacts include changes in unemployment or changes in sales tax revenues.

Earthquakes may produce impacts on economic sectors not sustaining direct damage. Activities that rely on regional markets for their output or that rely on a regional source of supply could experience interruptions in business operations. Such interruptions are called **indirect** economic losses. The extent of these losses depends upon such factors as the availability of alternative sources of supply and markets for products, the length of the production disturbance, and deferability of production.

In a sample economy Company A ships to Company B, and Company B to Company C. C supplies households with a final product and is also a supplier of inputs to A and B. There are two factories producing product B, one of which is destroyed in the earthquake. Indirect damages occur because: 1) direct damage to production facilities and inventories cause supply shortages for firms needing these; 2) because damaged production facilities reduce their demand for inputs from other producers; or 3) because of reductions in government, investment, or export demands for goods and services caused by an earthquake.

The supply shortages caused as a result of losing B could cripple C, providing C is unable to locate alternative sources. Three options are possible: 1) secure additional supplies

from outside the region (imports); 2) obtain additional supplies from the undamaged factory (excess capacity); and 3) draw from B's inventories.

Modeling of a regional economy is a very complex problem if it is to include such factors as the ability to replace lost inventory or lost production by products from other regions. The model included with **HAZUS** is a simplified model based on a set of equations that were derived from a statistical analysis of a large number of loss scenarios. Therefore, while it will give the user insight into the possible consequences of an earthquake, a more detailed model may be necessary to accurately represent the individual characteristics of a particular region.

To run this module, select the **Indirect economic impact** option in the **Analysis|Run...** menu (Figure 9.16).

9.7.1 Economic Sectors

To simplify modeling, the regional economy has been divided into 10 sectors as follows:

- Agriculture
- Mining
- Construction
- Manufacturing
- Transportation
- Trade (Wholesale and Retail)
- Finance, Insurance and Real Estate
- Services
- Government
- Other

Changes in payroll, employment, etc., are reported for each of these economic sectors.

9.7.2 Running the Indirect Economic Loss Module with a Synthetic Economy

Estimates of indirect losses can be calculated using a very simplified model of the regional economy. **HAZUS** contains twelve built-in "synthetic" economies. These "synthetic economies" are based on aggregating characteristics from a number of regional economies around the country and creating three typical economy types:

- Primarily manufacturing
- Primarily service with manufacturing as the secondary sector
- Primarily service with trade as the secondary sector

Each economy is broken into four size classifications:

- Super (greater than 2 million in employment)
- Large (greater than 0.6 million but less than 2 million in employment)
- Mid Range (greater than 30,000 but less than 0.6 million in employment)
- Low (less than 30,000 in employment)

The indirect economic impact module selects the most appropriate synthetic economy to use for the study region based on user inputs describing the size of the economy (number of employees) and the type of economy. In order to run the module using a synthetic economy, you must identify the type and size of economy using the window shown in Figure 9.54. To get to this screen, select the **Indirect economic** option in the **Analysis|Parameters** menu.

The default type of economy is "primarily manufacturing." You should overwrite this if "service/manufacturing" or "service/trade" is a more accurate characterization of your region. The economy type can be determined by evaluating the percent of regional employment in each of the major industries. For further guidance, consult the *Technical Manual*.

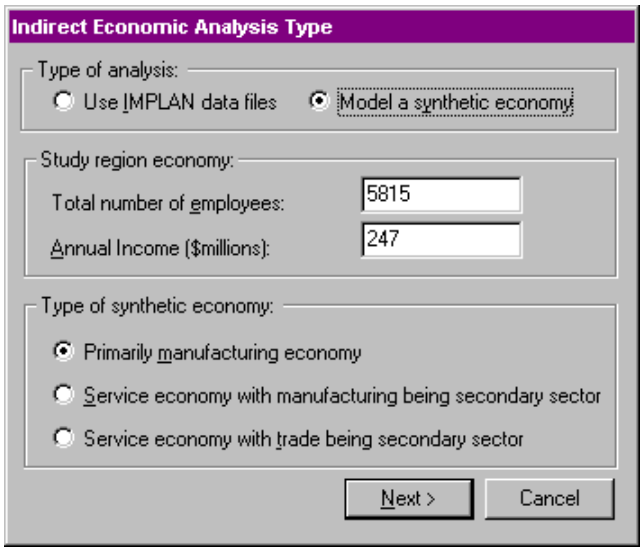


Figure 9.54 Setting parameters for synthetic economy

HAZUS provides a default employment figure based on the counties in the study region. The source of this default data is the Bureau of Economic Analysis. You should review this number against available local information and overwrite it if appropriate. Employment should be measured by place of *work* rather than by place of *residence*. This distinction is especially significant when there is substantial commuting across the region's borders. In addition to employment, the default figure provided for regional income should be reviewed and overwritten if appropriate.

After you have defined the synthetic economy and clicked on the **OK** button in Figure 9.54, the window in Figure 9.55 will appear. Figures 9.55 through 9.57 allow you to change factors in the economy that relate to the general capacity and the economy's ability to restore itself following the event. Default values for all of the factors are

provided for use in analysis. However, you should still review at the least the following factors and replace the default values as appropriate:

- Unemployment rate
- Level of outside aid and/or insurance
- Interest rate on loans

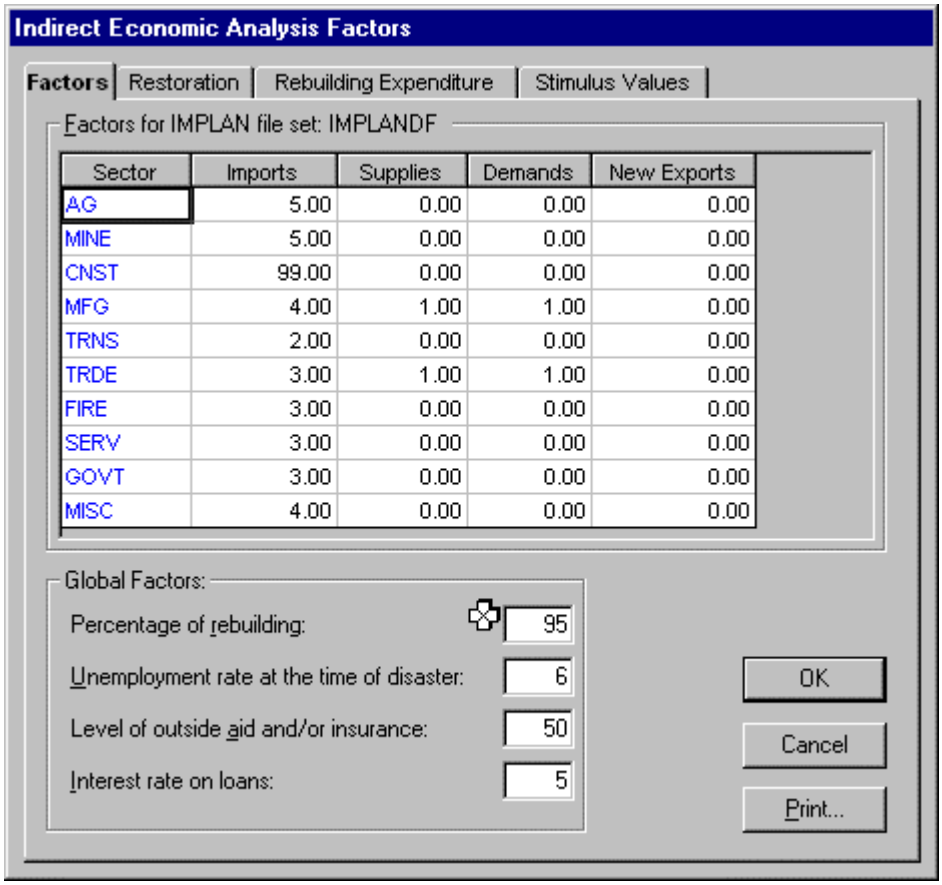


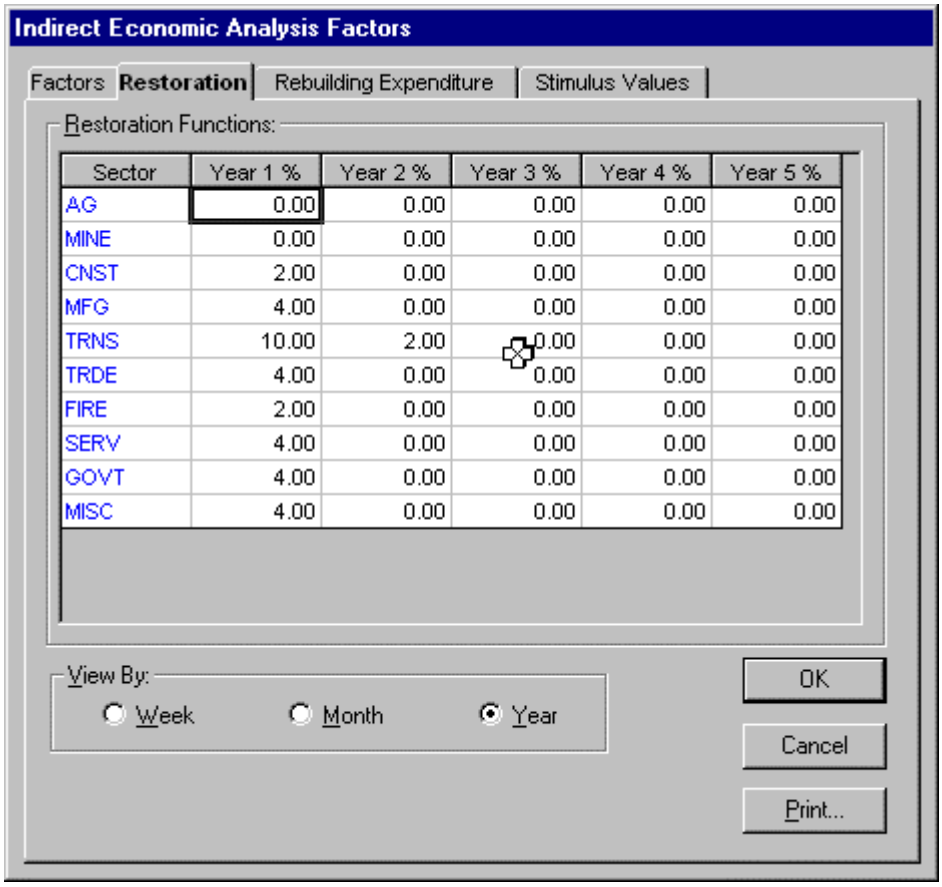
Figure 9.55 Setting the indirect economic factors

The top portion of the Factors screen in Figure 9.55 shows default values in each industry for availability of supplemental imports ("Imports"), inventories supplies ("Supplies"), inventories demands ("Demands"), and new export markets ("New Exports"). These factors were defined in Section 5.1.13. Units for the factors are percentage points, e.g., 90 = 90 percent. The defaults may be used or factors can be reviewed and modified as appropriate (see the *Technical Manual* for more information).

Default values are provided for four global factors as shown in the bottom part of the window in Figure 9.55. The **Percentage of rebuilding** is used by the module to estimate the size of the reconstruction stimulus to the economy. The **Unemployment rate at the time of the disaster** serves as an indicator of excess capacity or slack in the economy; the indirect losses are generally higher when the economy has low unemployment because there is less unused capacity that can help make up for capacity lost due to earthquake damage. The **Level of outside aid and/or insurance** is a major determinant

of the long-term income effects of the disaster since the amount of reconstruction funded by borrowing within the region will in the long term cause indebtedness. The **Interest rate on loans** also affects the amount of indebtedness arising from reconstruction financing.

Again, these should be reviewed and modified where appropriate. In some cases you may wish to run several analyses using different values, such as **Level of outside aid and/or insurance**, to investigate the effect of this parameter on indirect economic impacts. When you have finished with the **Factors** tab, click on the **Restoration & Rebuilding** tab to view the screen in Figure 9.56.



Sector	Year 1 %	Year 2 %	Year 3 %	Year 4 %	Year 5 %
AG	0.00	0.00	0.00	0.00	0.00
MINE	0.00	0.00	0.00	0.00	0.00
CNST	2.00	0.00	0.00	0.00	0.00
MFG	4.00	0.00	0.00	0.00	0.00
TRNS	10.00	2.00	0.00	0.00	0.00
TRDE	4.00	0.00	0.00	0.00	0.00
FIRE	2.00	0.00	0.00	0.00	0.00
SERV	4.00	0.00	0.00	0.00	0.00
GOVT	4.00	0.00	0.00	0.00	0.00
MISC	4.00	0.00	0.00	0.00	0.00

Figure 9.56 Setting the indirect economic restoration and rebuilding factors

The dialog shows default values for industry restoration functions for each of the first 5 years. Units are in percentage points of industry *loss* of function or production capacity in each year. Default values may be overwritten for consistency with results related to physical damage (See section 16.5.2.2 in the *Technical Manual*).

The rebuilding factors as shown in Figure 9.57 has default values for "% of Total Rebuilding Expenditures" in each of the first 5 years for buildings and lifelines, respectively. In general, most of the rebuilding is expected to occur in the first 1-2 years after the disaster. Lifeline reconstruction expenditures are expected to be made proportionately earlier than buildings reconstruction. However, the default values may

overwritten for consistency with results on physical damage (See the *Technical Manual* for more information).

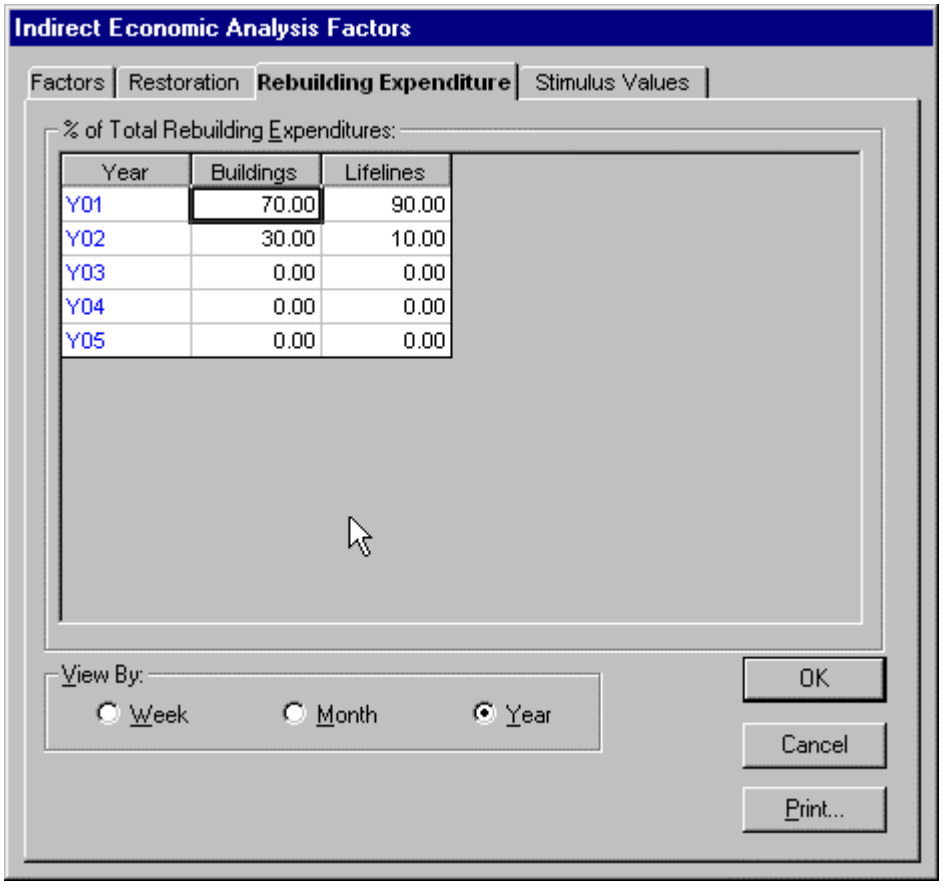


Figure 9.57 Setting the indirect economic rebuilding factors

The last factors that can be altered are the Stimulus Values. By clicking on the Stimulus Values tab, you can access the screen shown in Figure 9.57.

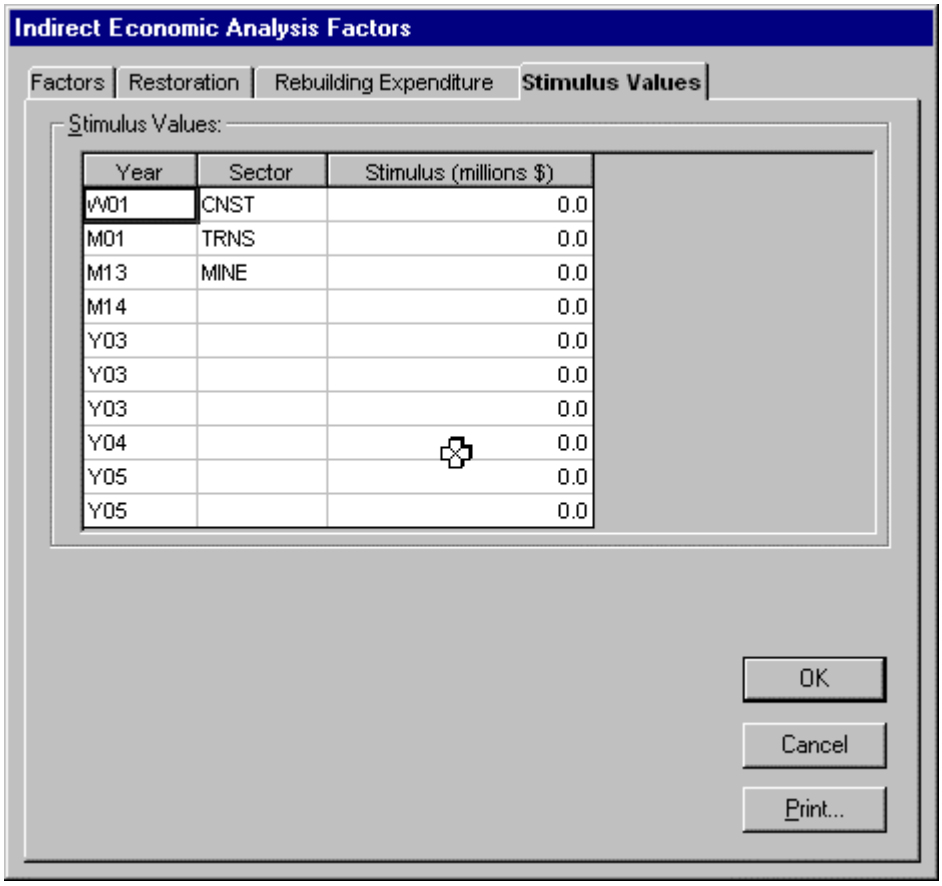


Figure 9.58 Setting the stimulus values.

The parameters in Figure 9.58 represent an anticipated stimulus to the economy in addition to repair and reconstruction of buildings and lifelines. The defaults are all zero.

A feature new in **HAZUS 99** is the capability of inputting a higher resolution timeframe for the restorations factors, the rebuilding factors and the stimulus values. While it was limited to yearly values in **HAZUS 97**, in **HAZUS 99** the factors can be specified on a weekly basis for the first 2 months (8 weeks), on a monthly basis for the first 2 years (month 3 through 24), and yearly thereafter (year 3 through 5.)

Click **OK** after completing selections on this screen. This completes the user input requirements. The module can be run by clicking on the **Indirect economic loss** option in the **Analysis|Run...** menu.

9.7.3 Running the Indirect Economic Loss Module with IMPLAN Data

For a more realistic analysis the indirect economic module can use IMPLAN data for modeling the economy. Select **Use IMPLAN data files** from the **Indirect Economic Analysis Type** screen in Figure 9.54. The default employment and income figures on the screen will not be used. Instead, the module will automatically pick off more accurate data from the IMPLAN data files you provide (see the *Technical Manual*). You do not have to make a selection under **Type of Synthetic Economy**.

Click **OK** after completing selections on this screen and the **IMPLAN** Files screen shown in Figure 9.59 will appear.

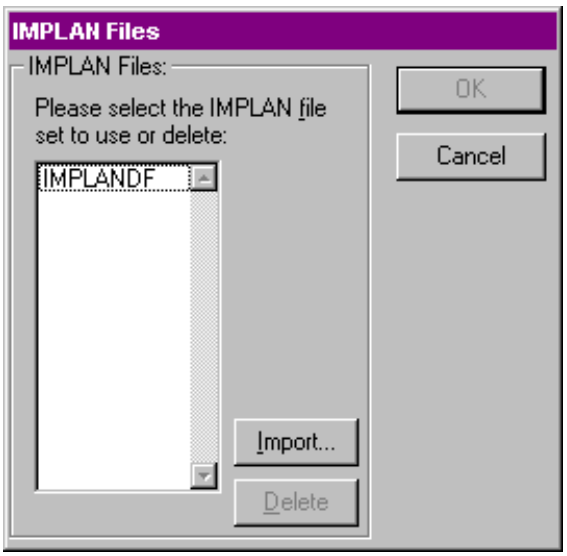


Figure 9.59 Screen for importing IMPLAN files

The screen contains a box listing available **IMPLAN** files. If the user has not imported any files, only one file labeled **IMPLANDF** (for IMPLAN default) is listed. This indicates the default synthetic economy.

Use the **Import** button to import **IMPLAN** files into **HAZUS**. Use the window in Figure 9.60 to locate the **IMPLAN** file with the .402 filename extension. Highlight the correct files (.402, .403 and .404) and click **OK**. This returns you to the **IMPLAN** Files screen in Figure 9.59. Note that even though **HAZUS** only prompts you for the .402 file, the associated .403 and .404 files are also required. All three files should be located in the same directory.

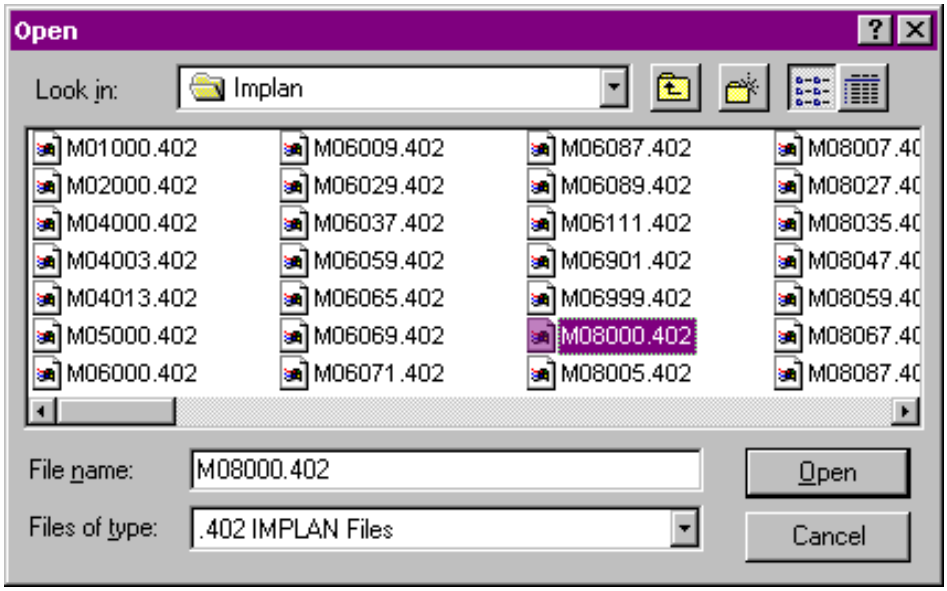


Figure 9.60 Locating IMPLAN files

The newly imported **IMPLAN** file name now appears underneath **IMPLANDF**. Use the mouse to highlight the new **IMPLAN** file, thus selecting it for use in the analysis. Click **OK** and the Indirect Economic Analysis Factors screen will appear (Figures 9.55 to 9.58).

If you have previously imported an **IMPLAN** data file(s), its name(s) will appear on the list. Remember to highlight the correct file each time before clicking **OK** to ensure that **HAZUS** does not return to using the default **IMPLANDF** file.
Follow the steps outlined in Section 9.7.2 for specifying indirect economic analysis factors. Run the module by clicking on the **Indirect economic loss** option in the **Analysis|Run...** menu.

9.8 Dealing with Uncertainty

As was mentioned earlier, **HAZUS** does not explicitly include uncertainty. The results obtained will be mean (or average) values of losses, and do not include ranges that would help you estimate bounds on your results. To some extent you can examine the variability of the model by performing a sensitivity analysis.

In a sensitivity analysis you would change inputs or parameters one at a time and see how sensitive the results are to these changes. For example, you might modify the scenario earthquake by one half magnitude up or down and rerun your analysis. Obviously if you increase the magnitude, for example from 6.0 to 6.5, the losses will increase. The question is how much. If the results change a great deal then your model is very sensitive to this input and you should evaluate that input carefully to make sure you are using a reasonable value. This may involve obtaining the advice of an expert. Alternatively, when you write the final report you can provide a range of losses based on the high and low values you obtain from your sensitivity analysis. On the other hand, if the results don't vary significantly, then you don't have to worry a great deal about the exact value of the parameter or input.

Types of inputs that you may wish to alter in your sensitivity analysis are listed below. This list contains suggestions only and is not intended to be comprehensive.

- Magnitude of scenario earthquake (up or down 1/2 magnitude)
- The attenuation relationship used (choose from the relationships supplied with **HAZUS**)
- Mix of construction quality levels (inferior, code and superior)
- Repair and replacement costs
- Fire module wind speed and engine speed
- Shelter module utility, modification and weighting factors
- Type of economy in indirect module
- Amount of outside aid in indirect module
- Unemployment rate in indirect module
- Interest rate on loans in indirect module

You can modify the inputs depending on the time and resources that are available. It is important to remember, though, that you must alter them one at a time if you want to be able to see any trends due to a particular parameter. It is suggested that you set up a system for keeping track of the results so that you understand which inputs produced which results. You might set up a table such as Tables 9.10 and 9.11, to record inputs and results.

Table 9.10 Sample Table of Sensitivity Analysis Scenarios

	Inputs	
Scenario Name	Magnitude	Const. Quality Mix
Port1	6.0	Default
Port2	6.0	New
Port3	6.5	Default
Port4	6.5	New
Port5	5.5	Default
Port6	5.5	New

Table 9.11 Sample Table of Sensitivity Analysis Results
($ values in Thousands)

Value	Port1	Port 2	Port3	Port4	Port5	Port6
Direct Economic Losses						
Cost Structural Damage	$300,000	$310,000	$350,000	$365,000	$260,000	$270,000
Cost Non-Structural Damage	•	•	•	•	•	•
Cost Contents Damage	•	•	•	•	•	•
Inventory Loss	•	•	•	•	•	•
Relocation Loss	•	•	•	•	•	•
Capital Related Income Loss	•	•	•	•	•	•
Wage Losses	•	•	•	•	•	•
Rental Income Loss						
Total Loss						
Transportation System Dollar Loss						
Highway						
Railway						
Light Rail						
Bus						
Port						
Ferry						
Airport						
Total Loss						
Utilities System Dollar Loss						
Potable Water						
Waste Water						
Oil						
Natural Gas						
Electric Power						
Communication						
Total Loss						
Casualties						
Severity 1						
Severity 2						
Severity 3						
Severity 4						
Shelter Needs						
…•						
•						