EARTHQUAKE LOSS ESTIMATION METHODOLOGY

HAZUS®99

Service Release 2 (SR2)

User Manual - ArcView

Developed by:

Federal Emergency Management Agency

Washington, D.C.

Through agreements with:

National Institute of Building Sciences

Washington, D.C.

PREFACE

Earthquakes pose a threat to life and property in 45 states and territories. As the United States has become more urbanized, more frequent smaller earthquakes in the 6.5 to 7.5 Magnitude range now have the potential of causing damage equal to or exceeding the estimated $40 billion from the 1994 Northridge earthquake. Earthquakes in urban areas, such as Kobe, Japan and Izmit, Turkey, are grim reminders of the kind of damage that may result from larger earthquakes, like the San Francisco event of 1906 and eastern events that occurred in New Madrid in 1811-12.

The Federal Emergency Management Agency is committed to mitigation as a means of reducing damages and the social and economic impacts from earthquakes. FEMA, under agreements with the National Institute of Building Sciences, has developed HAZUS® (HAZUS® stands for "Hazards U.S."), a standard, nationally-applicable methodology for assessing earthquake risk. HAZUS® was first released in 1997, followed by three subsequent releases, HAZUS®99and two HAZUS®99service releases, HAZUS®99-SR1 and HAZUS®99-SR2. With each new edition, significant enhancements have been added to increase the capabilities of HAZUS®. In HAZUS®99, a disaster response application was added to facilitate the use of HAZUS® in the immediate post-disaster environment. In the most recent edition, HAZUS®99-SR2, an Advanced Engineering Building Module (AEBM) has been implemented to enable high-end users to explicitly conduct building-specific or portfolio-specific loss estimation. HAZUS®97, HAZUS®99, and the two service releases of this earthquake loss estimation methodology, represent the dedicated efforts of more than 130 nationally-recognized earthquake and software professionals.

FEMA is making HAZUS® available to all states and communities and the private sector. Communities find HAZUS® to be a valuable tool in promoting a broader understanding of potential earthquake losses and in helping to build a community consensus for disaster loss prevention and mitigation.

Since the first release of HAZUS®, FEMA has been expanding the capability of HAZUS® by initiating loss estimation models for flood and hurricane hazards. The HAZUS Flood Model and a Preview Hurricane Model are being readied for release in 2002.

FEMA is pleased to offer this manual to state and local users.

FOREWORD

The work that provided the basis for this publication was supported by funding from the Federal Emergency Management Agency (FEMA) under agreements with the National Institute of Building Sciences. The substance and findings of that work are dedicated to the public. NIBS is solely responsible for the accuracy of the statements and interpretations contained in this publication. Such interpretations do not necessarily reflect the views of the Federal Government.

The National Institute of Building Sciences (NIBS) is a non-governmental, non-profit organization, authorized by Congress to encourage a more rational building regulatory environment, to accelerate the introduction of existing and new technology into the building process and to disseminate technical information.

Copies of this report are available through the Federal Emergency Management Agency. For information contact FEMA @ www.fema.gov/hazus or:

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MESSAGE TO USERS

HAZUS is designed to produce loss estimates for use by federal, state, regional and local governments in planning for earthquake risk mitigation, emergency preparedness, response and recovery. The methodology deals with nearly all aspects of the built environment, and a wide range of different types of losses. Extensive national databases are embedded within HAZUS, containing information such as demographic aspects of the population in a study region, square footage for different occupancies of buildings, and numbers and locations of bridges. Embedded parameters have been included as needed. Using this information, users can carry out general loss estimates for a region. The HAZUS methodology and software are flexible enough so that locally developed inventories and other data that more accurately reflect the local environment can be substituted, resulting in increased accuracy.

Uncertainties are inherent in any loss estimation methodology. They arise in part from incomplete scientific knowledge concerning earthquakes and their effects upon buildings and facilities. They also result from the approximations and simplifications that are necessary for comprehensive analyses. Incomplete or inaccurate inventories of the built environment, demographics and economic parameters add to the uncertainty. These factors can result in a range of uncertainty in loss estimates produced by HAZUS, possibly *at best* a factor of two or more.

The methodology has been tested against the judgement of experts and, to the extent possible, against records from several past earthquakes. However, limited and incomplete data about actual earthquake damage precludes complete calibration of the methodology. Nevertheless, when used with embedded inventories and parameters, HAZUS has provided a credible estimate of such aggregated losses as the total cost of damage and numbers of casualties. HAZUS has done less well in estimating more detailed results - such as the number of buildings or bridges experiencing different degrees of damage. Such results are depend heavily upon accurate inventories. HAZUS assumes the same soil condition for all locations, and this has proved satisfactory for estimating regional losses. Of course, the geographic distribution of damage may be influenced markedly by local soil conditions. In the few instances where HAZUS has been partially tested using actual inventories of structures plus correct soils maps, it has performed reasonably well.

Users should be aware of the following specific limitations:

- While HAZUS can be used to estimate losses for an individual building, the results must be considered as average for a group of similar buildings. It is frequently noted that nominally similar buildings have experienced vastly different damage and losses during an earthquake.

- When using embedded inventories, accuracy of losses associated with lifelines may be less than for losses from the general building stock. The embedded databases and assumptions used to characterize the lifeline systems in a study region are necessarily incomplete and oversimplified.

- Based on several initial studies, the losses from small magnitude earthquakes (less than M6.0) centered within an extensive urban region appear to be overestimated.

- Because of approximations in modeling of faults in California, there may be discrepancies in motions predicted within small areas immediately adjacent to faults.

- There is considerable uncertainty related to the characteristics of ground motion in the Eastern U.S. The embedded attenuation relations in HAZUS, which are those commonly recommended for design, tend to be conservative. Hence use of these relations may lead to overestimation of losses in this region, both for scenario events and when using probabilistic ground motion.

- As yet, there have not been adequate tests for the following features of HAZUS:
  - Effects of liquefaction and landsliding
  - Debris generation
  - Indirect economic losses

HAZUS should still be regarded as a work in progress. Additional damage and loss data from actual earthquakes and further experience in using the software will contribute to improvements in future releases. To assist us in further improving HAZUS, users are invited to submit comments on methodological and software issues by letter, fax or e-mail to:

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WHAT IS NEW IN HAZUS99-SR2?

- An Advanced Engineering Building Module (AEBM) has been implemented to enable high-end users to explicitly conduct building-specific or portfolio-specific loss estimation. A manual is provided to guide users in implementation of the AEBM and to describe underlying theory and concepts.

- In the Casualties Module, relationships between damage and casualties and the injury classification scale have been revised. Capability has been added for calculating casualties in the outdoors. Details of the updated methodology can be found in Chapter 13 of the *Technical Manual*.

- Occupancy mapping data for the State of California has been updated.

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Chapter 1. Introduction to the Earthquake Loss Estimation Methodology

The earthquake loss estimation provides local, state and regional officials with a state-of-the-art decision support tool for estimating future losses from scenario earthquakes. This forecasting capability will enable users to anticipate the consequences of future earthquakes and to develop plans and strategies for reducing risk. The GIS-based software can be utilized at multiple levels of resolution to accommodate not only budget constraints, but also varying levels of user expertise. The modular approach of the methodology (with different modules addressing various user needs) provides additional flexibility in a variety of applications.

The various users of a loss estimation study will have different needs. A local or state government official may be interested in the costs and benefits of specific mitigation strategies, and thus may want to know the expected losses if mitigation strategies have been applied. Health officials will want information about the demands on medical care facilities and will be interested in the number and severity of casualties for different scenario earthquakes. Fire fighters may be interested in areas where large fires can be expected or where hazardous materials might be released. Emergency response teams may use the results of a loss study in planning and performing emergency response exercises. In particular, they might be interested in the operating capacity of emergency facilities such as fire stations, emergency operations centers, and police stations. Emergency planners may want to know how much temporary shelter will be needed and for how long. Utility company representatives, as well as planners want to know about the locations and lengths of potential utility outages. Federal and state government officials may require an estimate of economic losses (both short term and long term) in order to direct resources toward affected communities. In addition, government agencies may use loss studies to obtain quick estimates of impacts in the hours immediately following an earthquake so as to best direct resources to the disaster area. Insurance companies may be interested in monetary losses so they can assess their exposure. This list of uses of earthquake loss estimation studies is not comprehensive. As users become familiar with the loss estimation methodology, they will determine which uses are most appropriate for their needs and also the limitations of the loss studies.

Some of the first earthquake loss estimation studies were performed in the early 1970's following the 1971 San Fernando earthquake. These earlier studies were funded by Federal agencies and were intended to provide a basis for disaster relief and recovery. These studies put a heavy emphasis on loss of life, injuries and the ability to provide emergency health care. More recent studies have focused on disruption to roads, telecommunications and other lifeline systems. An understanding of disruptions to these systems is essential in planning for post earthquake emergency response. More recently, a few municipalities have invested in earthquake loss estimation methodologies based on geographic information systems (GIS). These municipalities have found that once inventories are collected, these systems have uses beyond the scope of earthquake loss estimation. For example, data collected for an earthquake loss estimation model in San Bernardino County, California (FEMA, 1985) are now being used for city planning purposes. Two useful resources on loss estimation studies are “Estimating Losses from Future Earthquakes” (FEMA, 1989) and “Assessment of the State-of-the-Art of Earthquake Loss Estimation Methodologies” (FEMA, 1994). Other useful applications of earthquake loss estimation methodologies are contained in “Comprehensive Earthquake Preparedness Planning Guidelines” (FEMA, 1985) and “A Cost Benefit Model for the Seismic Rehabilitation of Buildings” (FEMA, 1992).

1.1 Overview of the Methodology

This brief overview of the earthquake loss estimation methodology is intended for local, regional, or state officials contemplating an earthquake loss study. The methodology has been developed for the Federal Emergency Management Agency (FEMA) by the National Institute of Building Sciences (NIBS) to provide a tool for developing earthquake loss estimates for use in:

- Anticipating the possible nature and scope of the emergency response needed to cope with an earthquake-related disaster,
- Developing plans for recovery and reconstruction following a disaster, and
- Mitigating the possible consequences of earthquakes.

If developed for areas of seismic risk across the nation, estimates also will help guide the allocation of federal resources to stimulate risk mitigation efforts and to plan for federal earthquake response.

Use of the methodology will generate an estimate of the consequences to a city or region of a "scenario earthquake", i.e., an earthquake with a specified magnitude and location. The resulting "loss estimate" generally will describe the scale and extent of damage and disruption that may result from a potential earthquake. The following information can be obtained:

- *Quantitative estimates of losses* in terms of direct costs for repair and replacement of damaged buildings and lifeline system components; direct costs associated with loss of function (e.g., loss of business revenue, relocation costs); casualties; people displaced from residences; quantity of debris; and regional economic impacts.
- *Functionality losses* in terms of loss-of-function and restoration times for critical facilities such as hospitals, and components of transportation and utility lifeline systems and simplified analyses of loss-of-system-function for electrical distribution and potable water systems.
- *Extent of induced hazards* in terms of fire ignitions and fire spread, exposed population and building value due to potential flooding and locations of hazardous materials.

To generate this information, the methodology includes:

- Classification systems used in assembling inventory and compiling information on the building stock, the components of highway and utility lifelines, and demographic and economic data.
- Methods for evaluating damage and calculating various losses.
- Databases containing information used as default (built-in) data and useable in calculation of losses.

These systems, methods, and data have been coded into user-friendly software that operates through a Geographic Information System (GIS). GIS technology facilitates the manipulation of data on building stock, population, and the regional economy. The software (**HAZUS**®[1]) can be run under two different GIS platforms: MapInfo and ArcView. The software makes use of GIS technologies for displaying and manipulating inventory, and permitting losses and consequences to be portrayed on both spreadsheets and maps. Collecting needed information and entering it in an analysis program are the major tasks involved in generating a loss estimate. The methodology permits estimates to be made at several levels of sophistication, based on the level of data into the analysis (i.e., default data versus locally enhanced data). The better and more complete the inventory information, the more meaningful the results.

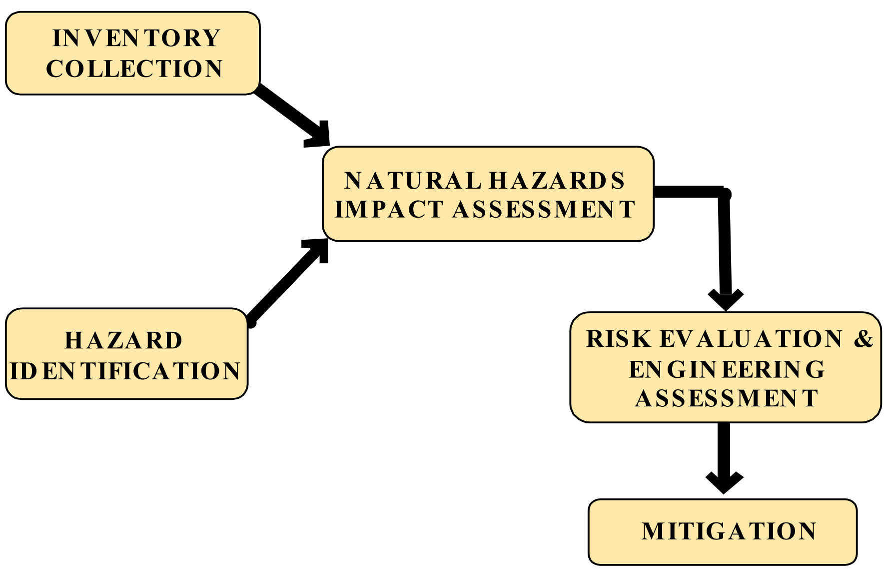


Figure 1.1 Steps in assessing and mitigating losses dues to natural hazards.

Figure 1.1 shows the steps that are typically performed in assessing and mitigating the impacts of a natural hazard such as an earthquake. The methodology incorporates the inventory collection, the hazard identification and the natural hazards impact assessment. In a simplified form, the steps are:

[1] **HAZUS** is a registered trademark of the National Institute of Building Sciences (NIBS) assigned to the Federal Emergency Management Agency (FEMA).

- Select the area to be studied. This may be a city, a county or a group of municipalities. It is generally desirable to select an area that is under the jurisdiction of an existing regional planning group.
- Specify the magnitude and location of the scenario earthquake. In developing the scenario earthquake, consideration should be given to the potential fault locations.
- Provide additional information describing local soil and geological conditions, if available.
- Using formulas embedded in **HAZUS**, probability distributions are computed for damage to different classes of buildings, facilities, and lifeline system components and loss-of-function estimates are made.
- The damage and functionality information is used to compute estimates of direct economic loss, casualties and shelter needs. In addition, the indirect economic impacts on the regional economy are estimated for the years following the earthquake.
- An estimate of the number of ignitions and the extent of fire spread is computed. The amount and type of debris are estimated. If an inundation map is provided, exposure to flooding can also be estimated.

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

1.2 Earthquake Hazards Considered in the Methodology

The earthquake-related hazards considered by the methodology in evaluating casualties, damage, and resultant losses are collectively referred to as *potential earth science hazards* (PESH). Most damage and loss caused by an earthquake is directly or indirectly the result of *ground shaking*. Thus, it evaluates the geographic distribution of ground shaking resulting from the specified scenario earthquake and expresses the ground shaking using several quantitative parameters such as peak ground acceleration and spectral acceleration.

Three other features of earthquakes that can cause permanent ground displacements and have an adverse effect upon structures, roadways, pipelines, and other lifeline structures also are considered:

- *Fault rupture*: Ground shaking is caused by fault rupture, usually at some depth below the ground surface. However, fault rupture can reach the surface of the earth as a narrow zone of ground offsets and tear apart structures, pipelines, etc. within this zone.
- *Liquefaction*: This sudden loss of strength and stiffness in soils can occur when loose, water-saturated soils are shaken strongly and can cause settlement and horizontal movement of the ground.
- *Landsliding*: This refers to large downhill movements of soil or rock that are shaken free from hillsides or mountainsides which can destroy anything in their path.

Soil type can have a significant effect on the intensity of ground motion at a particular site. The software contains several options for determining the effect of soil type on ground motions for a given magnitude and location. The user may select the default relations or choose an alternative.

Tsunamis (waves moving across oceans) and seiches (oscillatory waves generated in lakes or reservoirs) are also earthquake-caused phenomena that can result in inundation or waterfront damage. In the methodology, potential sites of these hazards may be identified but they are evaluated only if special supplemental studies are performed.

The definition of the scenario earthquake is not just a matter of earth science. Hazard management and political factors must be considered as well. Planning for mitigation and disaster response generally is based on large, damaging events, but the probability that such events will occur also should be considered. In a region of high seismicity, the *maximum credible earthquake* is generally a suitable choice. In areas of lower seismicity, it may not be prudent to assume a very large but very unlikely earthquake even though it is realized that such an event is possible. In such regions, it is often most appropriate to choose an earthquake with a specified mean recurrence interval, such as the "500 year earthquake." Consideration should be given to repeating loss calculations for several scenario earthquakes withdifferent magnitudes and locations and different probabilities of occurrence, since these factors are a major source of uncertainty.

Data concerning past earthquakes are provided within HAZUS. Chapter 9 provides guidance concerning the selection of scenario earthquakes. It is always desirable to consult local earth science experts during the process of choosing scenario events.

1.3 Types of Buildings and Facilities Considered

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

- *General building stock*: The majority of commercial, industrial and residential buildings in your region are not considered individually when calculating losses. Instead, they are grouped together into 36 model building types and 28 occupancy classes and degrees of damage are computed for groups of buildings. Examples of model building types are light wood frame, mobile home, steel braced frame, concrete frame with unreinforced masonry infill walls, and unreinforced masonry. Each model building type is further subdivided according to typical number of stories and apparent earthquake resistance (based primarily upon the earthquake zone where they are constructed). Examples of occupancy types are single family dwelling, retail trade, heavy industry, and churches. All structures that are evaluated in this manner are referred to as General Building Stock.

- *Essential facilities*: Essential facilities, including medical care facilities, emergency response facilities and schools, are those vital to emergency response and recovery following a disaster. School buildings are included in this category because of the key role they often play in housing people displaced from damaged homes. Generally there are very few of each type of essential facility in a census tract, making it easier to obtain site-specific information for each facility. Thus, damage and loss-of-function are evaluated on a building-by-building basis for this class of structures, even though the uncertainty in each such estimate is large.
- *Transportation lifeline systems*: Transportation lifelines, including highways, railways, light rail, bus systems, ports, ferry systems and airports, are broken into components such as bridges, stretches of roadway or track, terminals, and port warehouses. Probabilities of damage and losses are computed for each component of each lifeline; however, total *system* performance cannot be evaluated (for example, - how well various sections, nodes and connections of the total system perform to enable to move from point A to point B after an earthquake).
- *Utility lifeline systems*: Utility lifelines, including potable water, electric power, waste water, communications, and liquid fuels (oil and gas), are treated in a manner similar to transportation lifelines. Examples of components are electrical substations, water treatment plants, tank farms and pumping stations. System analyses can be performed for potable water systems and electrical systems.

In any region or community there will be certain types of structures or facilities for which damage and losses will not be evaluated unless supplemental studies specific to these facilities are carried out. These omitted structures are referred to as *high potential loss facilities*. Such facilities include dams, nuclear power plants, liquefied natural gas facilities, military installations, and large one-of-a-kind residential or commercial structures. Given the nature of these facilities it would be potentially misleading and politically and legally unwise to estimate damage and losses unless a detailed engineering analysis was performed with the agreement of the owner of the facility. Hence, the approach is to call attention to these facilities, include their locations in the inventory and indicate a potential for loss in the final report. Although the loss cannot be quantified without further investigation, the location of the structures with respect to ground failure or intense ground motions may provide a starting point for more in-depth studies. To include these structures in the loss estimation study outputs, results from supplemental studies, such as damage-motion curves, can be entered.

1.4 Levels of Analysis

To provide flexibility, the losses at estimated at three levels. For each level, the several hazards and the various types of buildings and facilities can be selectively used as appropriate, to meet the needs and desires of the local or regional user.

1.4.1 Analysis Based on Default Information

The basic level of analysis uses only the default databases built into the methodology for information on building square footage and value, population characteristics, costs of building repair, and certain basic economic data. One average soil condition is assumed for the entire study region. The effects of possible liquefaction and landsliding are ignored. Direct economic and social losses associated with the general building stock and essential facilities are computed. Default data for transportation and utility lifelines are included, thus these lifelines are considered in the basic level of analysis. Uncertainty, however, is large. Fire ignitions and fire spread are considered using a simplified model. Indirect economic impacts for the region are calculated but are based on a synthetic economy that may or may not accurately reflect the characteristics of the region. Table 1.1 summarizes the output that can be obtained from an analysis. Outputs that cannot be obtained using only default data are indicated with a star (*).

Table 1.1 Earthquake Loss Estimation Methodology Output

Maps of seismic hazards ▪ Intensities of ground shaking for each census tract ▪ Contour maps of intensities of ground shaking ▪ Permanent ground displacements for each census tract* ▪ Contour map of permanent ground displacements* ▪ Liquefaction probability* **Landsliding probability*** ▪ Characterization of damage to general building stock ▪ Structural and nonstructural damage probabilities by census tract, building type and occupancy class. **Transportation and utility lifelines** ▪ For components of the 13 lifeline systems: damage probabilities, cost of repair or replacement and expected functionality for various times following earthquake ▪ For all pipeline systems: the estimated number of leaks and breaks ▪ For potable water and electric power systems: estimate of service outages **Essential facilities** ▪ Damage probabilities ▪ Probability of functionality ▪ Loss of beds in hospitals **High potential loss (HPL) facilities** ▪ Locations of dams ▪ Locations of nuclear plants ▪ Damage probabilities and cost of repair for of military facilities* ▪ Locations of other identified HPLs	**Fire following earthquake** ▪ Number of ignitions by census tract ▪ Percentage of burned area by census tract **Inundated areas** ▪ Exposed population and exposed dollar value of general building stock* **Hazardous material sites** ▪ Location of facilities which contain hazardous materials **Debris** ▪ Total debris generated by weight and type of material **Social losses** ▪ Number of displaced households ▪ Number of people requiring temporary shelter ▪ Casualties in four categories of severity based on three different times of day **Dollar losses associated with general building stock** ▪ Structural and nonstructural cost of repair or replacement ▪ Loss of contents ▪ Business inventory loss ▪ Relocation costs ▪ Business income loss ▪ Employee wage loss ▪ Loss of rental income **Indirect economic impact** ▪ Long-term economic effects on the region based on a synthetic economy ▪ Long-term economic effects on the region based on an IMPLAN model *

* Outputs cannot be obtained using only default data.

Other than defining the study region, selecting the scenario earthquake(s) and making decisions concerning the extent and format of the output, an analysis based on default data requires minimal effort from the user. As indicated, however, estimated losses are incomplete and, since default rather than actual data are used to represent local conditions, the estimates involve large uncertainties. This level of analysis is suitable primarily for preliminary evaluations and crude comparisons among different regions.

1.4.2 Analysis with User-Supplied Inventory

Results from an analysis using only default inventory can be improved greatly with a minimum amount of locally developed input. This is generally the intended level of implementation. Table 1.1 summarizes the output that can be obtained from this level of analysis. However, there is no standard analysis with user-supplied data and hence, no minimum or standard amount of input. Such an effort might involve:

- Development of maps of soil conditions affecting ground shaking, liquefaction and landsliding potential. These maps would be used for evaluation of the effects of these local conditions upon damage and losses.
- Use of locally available data or estimates concerning the square footage of buildings in different occupancy classes.
- Use of local expertise to modify, primarily by judgment, the databases concerning percentages of model building types associated with different occupancy classes.
- Preparation of a detailed inventory for all essential facilities.
- Collection of detailed inventory and cost data to improve evaluation of losses and lack of function in various transportation and utility lifelines.
- Use of locally available data concerning construction costs or other economic parameters.
- Collections of data, such as number of fire trucks, for evaluation of the probable extent of areas affected by fires.
- Development of inundation maps.
- Gathering of information concerning high potential loss facilities and facilities housing hazardous materials.
- Synthesis of data for modeling the economy of the study region used in calculation of indirect economic impacts.

Depending upon the size of the region and the number of these features selected by the user, months may be required to assemble the required input. The effort put into preparing the inventory of the building stock can range from minimal to extensive, depending upon the desire to reduce uncertainty in computed results. Assembling and entering required data for lifelines also can involve considerable effort, but the user can choose to omit some lifelines. It will generally be necessary to employ consultants to develop the various soil-related maps and the data needed for the indirect economic analysis. Depending upon the extent of user-supplied inventory, it may be necessary to obtain services of experts in the use of geographic information systems - specifically the platform used by **HAZUS**.

The most detailed type of analysis would include incorporating results from other loss studies that have been completed. A special input concerning the vulnerability of particular model building types or specific high-potential-loss facilities can be entered. It is possible to add the output of loss estimates performed using locally developed traffic models by overlaying maps with links limited to a specific number of damaged bridges. Similar analyses of links can provide information on water distribution or other pipeline systems.

1.5 Assumed Level of Expertise of Users

Users can be broken into two groups: those who are performing the study, and those who are using the results of the study. For some studies these two groups will consist of the same people, but generally this will not be the case. However, the more interaction that occurs between these two groups, the better the study will be. Those who are performing the study must, at minimum, have a basic understanding of earthquakes, their causes and their consequences. In many cases, the results will be presented to audiences (i.e. city councils and other governing bodies) that have little technical knowledge of the earthquake loss problem.

It is assumed that a loss study will be performed by a team consisting of geologists or geotechnical engineers, structural engineers or architects, economists, emergency planners and a representative from the group who will be reviewing/using the loss estimates. These individuals are needed to develop earthquake scenarios, identify problematic soils, develop and classify building inventories, provide and interpret economic data, provide information about the local population, and provide input as to what types of loss estimates are needed to fulfill the goals of the loss study. Ideally, the team would also include representatives from local utilities and public works departments. Other members of the team that would be valuable are a fire official, a hydrologist and a sociologist.

It should be noted that the involvement of the ultimate user of the study on the team is very important. A workshop of earthquake-loss-study users convened in 1986, concluded that many earthquake studies have been of limited usefulness because results were too technical or presented in such a way as to make them difficult for users to interpret (FEMA, 1989). In essence, users in the loss estimation study need to be involved from the beginning to make results more usable.

If a municipality, local acency or state agency is performing the study, it is possible that some of the expertise can be found in-house. For example, the building department may have engineers who know about local seismic design and building practices. The state Department of Geology is another useful source of expertise..

1.5.1 When to Seek Help

Although a loss study can be performed with a minimum of expertise using only the defaults provided by the computer program, the results of such a study should be interpreted with caution, as default values have a great deal of uncertainty associated with them. If the loss estimation team does not include individuals with expertise in the areas described above, then it is likely that one or more outside consultants may be required. Unless a scenario earthquake for the study region has already been developed and is documented in published literature or in previous loss studies, the user may require the expertise of a geologist. Even if a scenario event has been documented, it may be defined using the ground motion characteristics that are different from those used in this methodology (such as MMI or M_s). In this case, a seismologist will be needed to review the scenario earthquake and describe it in terms of moment magnitude (**M**), spectral velocity and spectral acceleration. A scenario event that is defined without an in-depth understanding of earthquake sources, recurrence and the geology of the region, may not be appropriate for the loss study.

If the user intends to modify the defaults data or parameters, it is likely that he will need input from someone with expertise in the field. For example, if the user wishes to change default percentages of model building types for the region, he will need the input of a structural engineer who has knowledge of design and construction practices of the region. Similarly if he wishes to modify the damage-motion relationships (fragility curves), input from a structural engineer will be required. Modifications to defaults in the direct and indirect economic modules will require input from an economist.

Technical help for the users of HAZUS has been established by NIBS via telephone, fax or e-mail support. Users should contact FEMA or NIBS at the addresses given in the "Message to Users" section of this manual for information on technical support.

1.6 Displaying Methodology Results

There is a great deal of flexibility in displaying output. Tables of social and economic losses can be displayed on the screen, printed out or pasted into electronic documents. Most output could also be mapped. Colors, legends and titles can be altered easily. Examples of the type of graphical and numerical output that can be produced by the program are found in Figures 1.2 and 1.3.

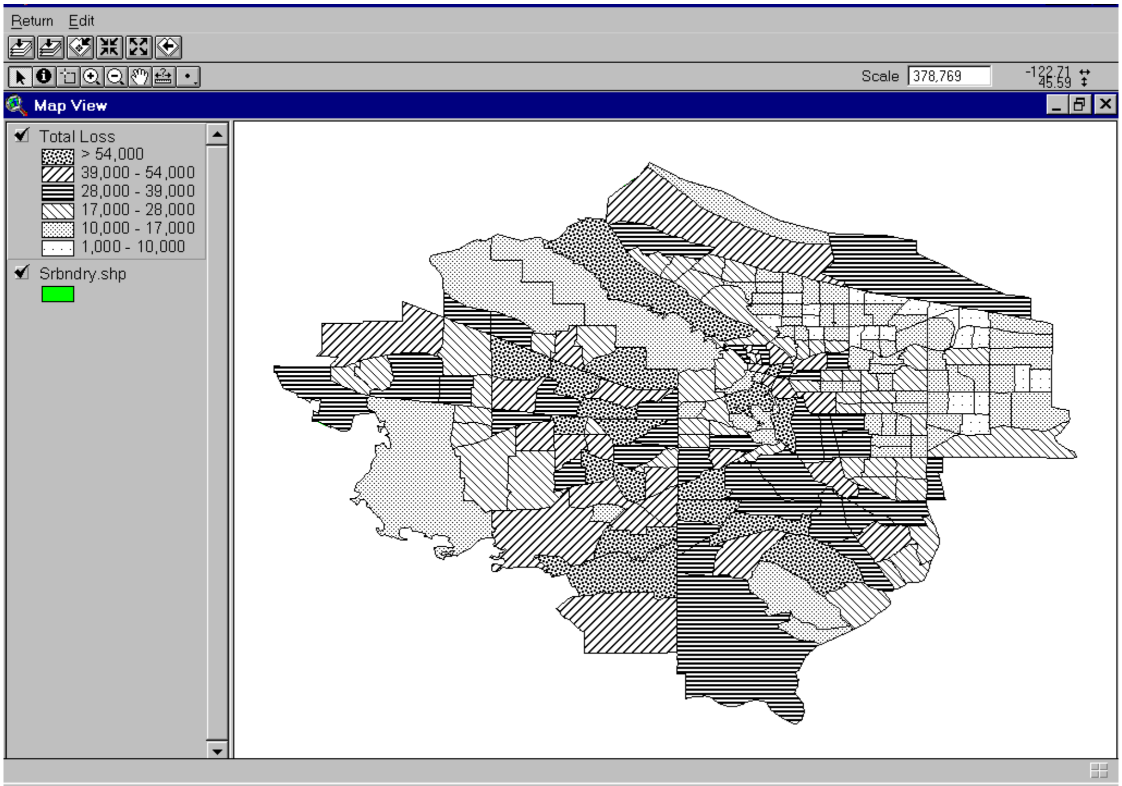
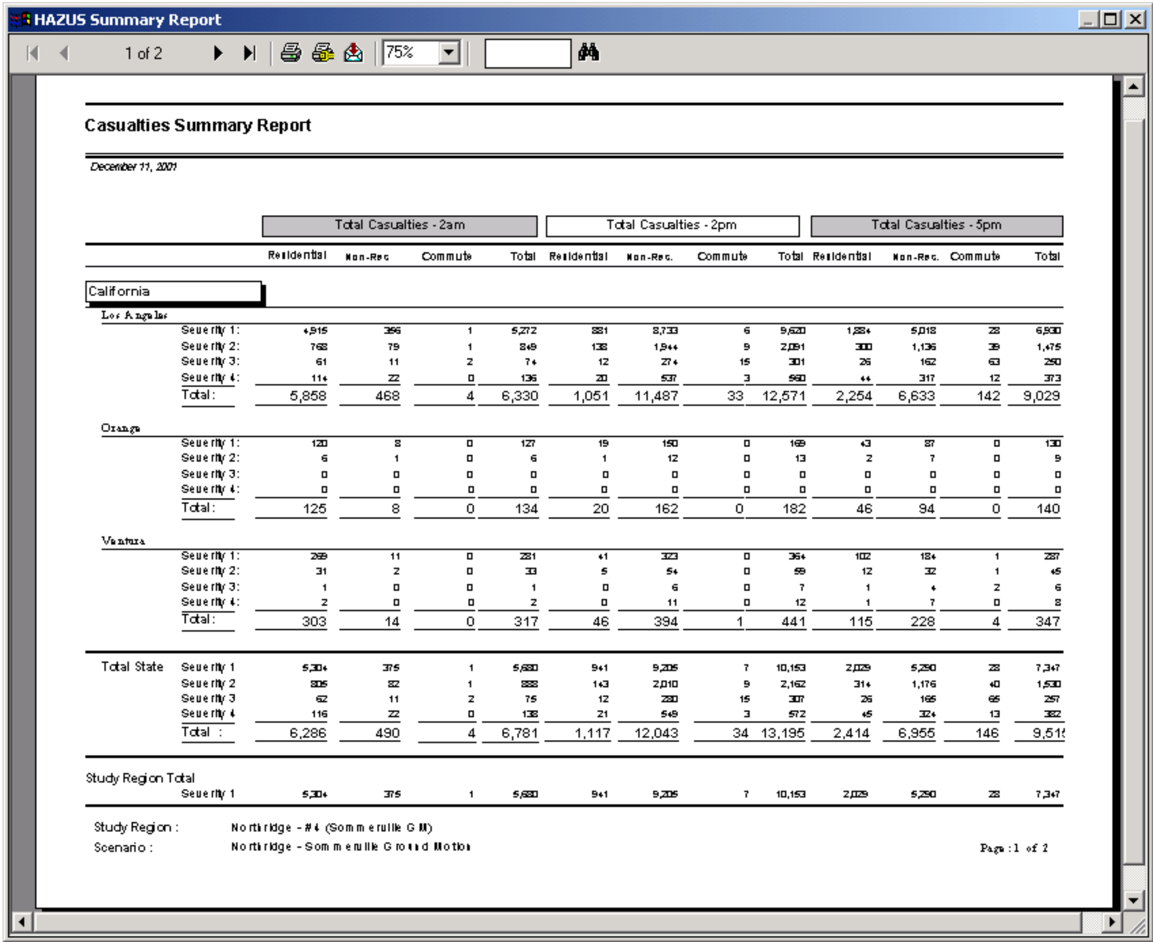


Figure 1.2 Sample output: total loss for a study region.



		Total Casualties - 2am				Total Casualties - 2pm				Total Casualties - 5pm			
		Residential	Non-Res	Commute	Total	Residential	Non-Res.	Commute	Total	Residential	Non-Res.	Commute	Total
California													
Los Angeles													
	Severity 1:	4,915	396	1	5,272	881	8,733	6	9,620	1,884	5,018	28	6,930
	Severity 2:	768	79	1	849	138	1,944	9	2,091	300	1,136	39	1,475
	Severity 3:	61	11	2	74	12	274	15	301	26	162	63	250
	Severity 4:	114	22	0	136	20	537	3	560	44	317	12	373
	Total:	5,858	468	4	6,330	1,051	11,487	33	12,571	2,254	6,633	142	9,029
Orange													
	Severity 1:	120	8	0	127	19	150	0	169	43	87	0	130
	Severity 2:	6	1	0	6	1	12	0	13	2	7	0	9
	Severity 3:	0	0	0	0	0	0	0	0	0	0	0	0
	Severity 4:	0	0	0	0	0	0	0	0	0	0	0	0
	Total:	125	8	0	134	20	162	0	182	46	94	0	140
Ventura													
	Severity 1:	269	11	0	281	41	323	0	364	102	184	1	287
	Severity 2:	31	2	0	33	5	54	0	59	12	32	1	45
	Severity 3:	1	0	0	1	0	6	0	7	1	4	2	6
	Severity 4:	2	0	0	2	0	11	0	12	1	7	0	8
	Total:	303	14	0	317	46	394	1	441	115	228	4	347
Total State	Severity 1	5,304	375	1	5,680	941	9,205	7	10,153	2,029	5,290	28	7,347
	Severity 2	805	82	1	888	143	2,010	9	2,162	314	1,176	40	1,530
	Severity 3	62	11	2	75	12	280	15	307	26	165	65	257
	Severity 4	116	22	0	138	21	549	3	572	45	324	13	382
	Total :	6,286	490	4	6,781	1,117	12,043	34	13,195	2,414	6,955	146	9,51
Study Region Total													
	Severity 1	5,304	375	1	5,680	941	9,205	7	10,153	2,029	5,290	28	7,347

Study Region : Northridge - #4 (Sommerville GM)
Scenario : Northridge - Sommerville Ground Motion
Page : 1 of 2

Figure 1.3 Sample output; casualties summary report.

1.7 Uncertainties in Loss Estimates

Although the software offers users the opportunity to prepare comprehensive loss estimates, it should be recognized that, even with state-of-the-art techniques, uncertainties are inherent in any such estimation methodology.

History has taught that the next major earthquake to affect a U.S. city or region will likely be quite different from the "scenario earthquake" anticipated as part of an earthquake loss estimation study. The magnitude and location of the earthquake and the associated faulting, ground motions and landsliding will not be precisely what was anticipated. Hence, the results of an earthquake loss study should not be looked upon as a *prediction* but rather as an indication of what the future may hold. This is particularly true in areas where seismicity is poorly understood. Obviously, the better the understanding of the seismic regime of a region, the closer to future reality the loss estimates may be.

Any region or city studied will have an enormous variety of buildings and facilities of different sizes, shapes, and structural systems constructed over the years under diverse seismic design codes. Similarly many different types of components with differing seismic resistance will make up transportation and utility lifeline systems. Due to this complexity, relatively little is certain concerning the structural resistance of most buildings and other facilities. Further, there simply are not sufficient data from past earthquakes or laboratory experiments to permit precise predictions of damage based on known ground motions even for specific buildings and other structures. To deal with this complexity and lack of data, buildings and components of lifelines are lumped into categories, based upon key characteristics. Relationships between key features of ground shaking and average degree of damage and associated losses for each category are based on limited data and available theories. While state-of-the-art in terms of loss estimation, these relationships do contain a certain level of uncertainty.

Possible ranges of losses are best evaluated by conducting multiple analyses and varying certain input parameters to which the losses are most sensitive. Guidance concerning the planning of such *sensitivity studies* is found in Section 9.8.

1.8 Applying Methodology Products

The products of the FEMA methodology for estimating earthquake losses have several pre-earthquake and/or post-earthquake applications in addition to estimating the scale and extent of damage and disruption.

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

- *Development of earthquake hazard mitigation strategies* that outline polices and programs for reducing earthquake losses and disruptions indicated in the initial loss estimation study. Strategies can involve rehabilitation of hazardous existing buildings (e.g., unreinforced masonry structures), the development of appropriate zoning ordinances for land use planning in areas of liquefiable soils, and the adoption of advanced seismic building codes.
- *Development of preparedness (contingency) planning measures* that identify alternate transportation routes and planning earthquake preparedness and survival education seminars.
- *Anticipation of the nature and scope of response and recovery efforts* including: identifying alternative housing and the location, availability and scope of required medical services; and establishing a priority ranking for restoration of water and power resources.

Post-earthquake applications of the outputs would include:

- *Projection of immediate economic impact assessments for state and federal resource allocation and support* including supporting the declaration of a state and/or federal disaster by calculating direct and indirect economic impact on public and private resources, local governments, and the functionality of the area.
- *Activation of immediate emergency recovery efforts* including search and rescue operations, rapid identification and treatment of casualties, provision of emergency housing shelters, control of fire following earthquake, and rapid repair and availability of essential utility systems.
- *Application of long-term reconstruction plans* including the identification of long-term reconstruction goals, the institution of appropriate wide-range economic

development plans for the entire area, allocation of permanent housing needs, and the application of land use planning principles and practices.

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

1.9 Organization of the Manual

The *User's Manual* provides the background and instructions for developing an inventory to complete an earthquake loss estimation study using **HAZUS.** It also provides information on how to install and run the software, and how to interpret and report model output. The contents and organization of the User's Manual are outlined below.

The Technical Manual, a companion publication, documents the methods of calculating losses and the default data. Taken together, the two manuals provide a comprehensive overview of the nationally applicable loss estimation methodology.

Chapter 1 provides the user with a general understanding of the purpose, uses and components of a regional earthquake loss estimation study.

Chapter 2 gives instructions for installing and starting **HAZUS**.

Chapter 3 runs through an analysis using only default data.

An overview of the types of data required to run the loss study, as well as a description of the default databases is found in Chapter 4.

Chapter 5 contains information about what data are needed to complete a loss study, sources of inventory, how to collect inventory, how to convert data to the correct format for the methodology, and how to enter data into **HAZUS**. The user is provided with estimated costs (in terms of labor) to collect the inventory.

Chapter 6 includes instructions for entering data, editing records and geocoding addresses.

Chapter 7 provides the user with a discussion of how to display, modify and print databases.

Chapter 8 discusses The Building Data Import Tool (BIT). This utility is designed to help the user analyze and query existing databases to develop general building stock inventory information.

Chapter 9 provides a detailed step-by-step description of how to run an analysis using **HAZUS,** including analysis with user-supplied data**.**

Chapter 10 discusses how to view results and provides suggestions about putting together a report.

Chapter 11 contains a general discussion of vulnerability to natural hazards and key factors that should be considered in estimating losses as well as brief discussions of supplemental data that are available with **HAZUS.**

Chapter 12 covers QASEM, the Quick Assessment Event Monitoring tool.

The *User's Manual* is written in language that should be easily understood by a user of the methodology. Highly technical terms are avoided where possible, but a glossary of terms is provided in Appendix H to supplement any definitions that are needed. A compilation of relevant references is found in References Section.

The appendices contain detailed information about the structure of the methodology. Appendix A lists all of the classification systems that are used.

Appendices B and C provide descriptions of the model building types and lifeline components that are used in the methodology.

Appendix D describes the content and origin of the default databases.

Appendix E is a database dictionary containing details about the format of all of the databases used by **HAZUS**.

Appendix F includes a sample questionnaire that was used for assessing characteristics of regional building stock.

Appendix G describes the hazardous materials that are covered under SARA Title III, including their Chemical Abstracts Service (CAS) registry numbers, and the threshold quantities for reporting purposes.

Chapter 2. Installing and Starting HAZUS

2.1 System Requirements

In order for **HAZUS** to run properly, your system must meet certain minimum requirements.

2.1.1 Minimum System Configurations

- System must contain a Pentium class CPU (400 MHz or better recommended)
- 32 MB of (RAM) memory (64 MB are recommended)
- 1 GB of free disk space (2 GB are recommended)[2]
- A color graphics card and monitor (SVGA is recommended)
- A mouse
- A CD-ROM reader

2.1.2 Software Requirements

- Windows 98, Windows 2000 or Windows NT version 4.0 installed
- ESRI ArcView 3.2a installed

ArcView can be purchased by contacting the ESRI Incorporation at 1-800-447-9778. ArcView and Windows products should be installed using the manufacturer's instructions.

2.2 Installation

Before installing **HAZUS**, the minimum requirements listed in Section 2.1 should be met. If you are upgrading from **HAZUS99**, read the section at the end of this chapter entitled "Upgrading from **HAZUS99-SR1** to **HAZUS99-SR2**.

To install **HAZUS**, follow the steps outlined below.

1. Start Windows.
2. Insert **HAZUS** CD in your CD-ROM drive. It is likely that your CD-ROM drive will be drive D:.
3. From the Windows **Start** menu select **Run...**. The following screen will appear.

[2] **HAZUS** makes extensive use of the hard disk for reading and writing its intermediate database files. For this reason, disk space is very important. The required free disk space is a function of the size of the study region being analyzed. A typical study region requires a 20 MB of disk space but can be as large as 1 GB (1,000 MB).

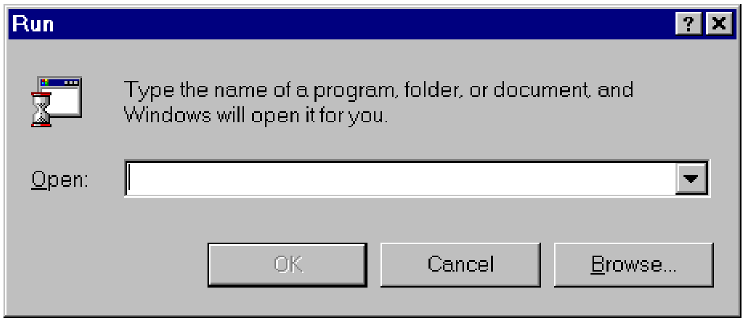


Figure 2.1 The Run command dialog box.

1. To start the **HAZUS** setup program type ***x*:\setup** in the command line box as shown in Figure 2.2, where ***x*** is the CD-ROM drive letter. Press Enter or click the **OK** key.

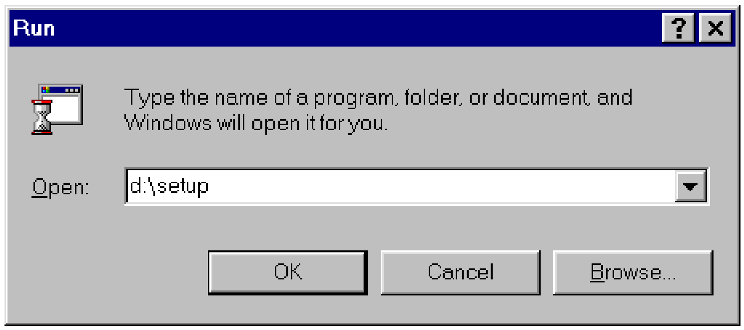


Figure 2.2 Starting the HAZUS setup program.

2. After you start the setup program as shown in Figure 2.2, the dialog box in Figure 2.3 will appear. Click on the **Next** button.

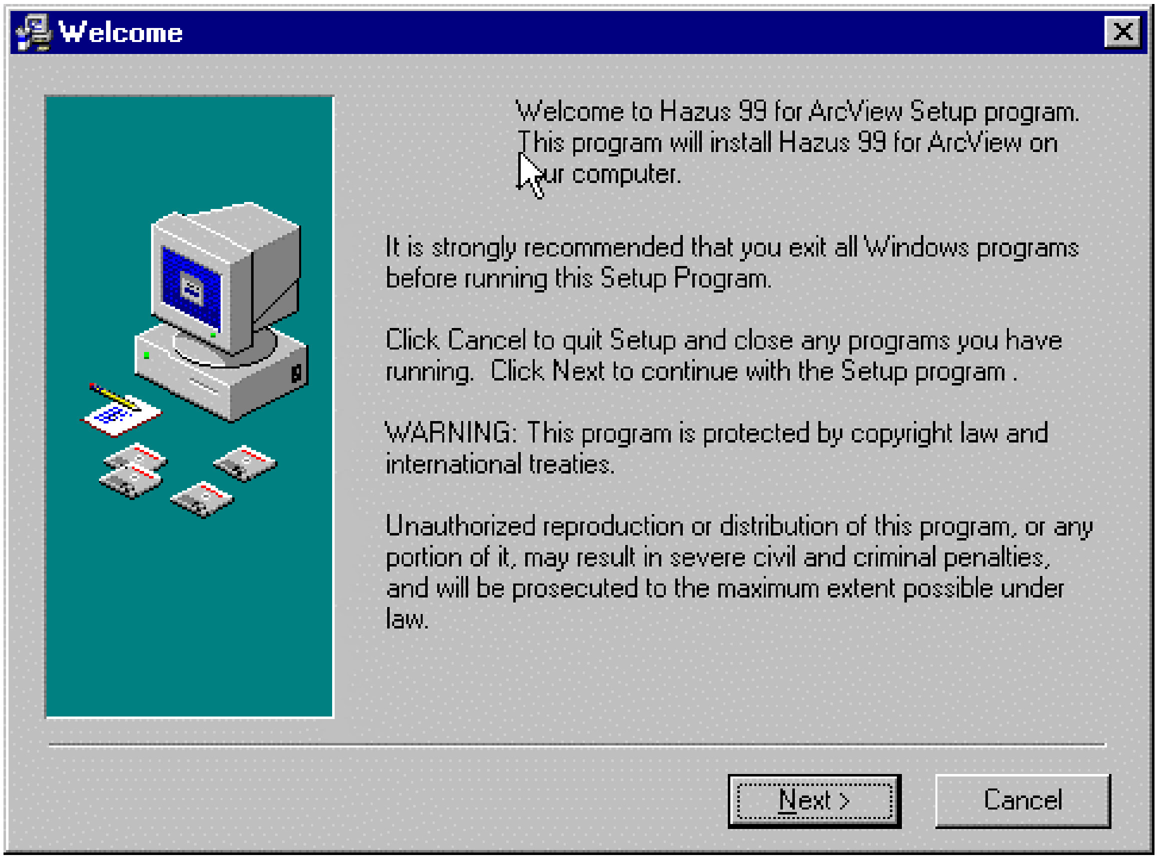


Figure 2.3 Starting the HAZUS installation program.

3. Specify the directory where you wish **HAZUS** to be installed. The default directory is C:\Program files\HAZUS99 for ArcView as shown in Figure 2.4. If you accept the default destination directory, click on the **Next** button. Otherwise click on the Browse button at which an interactive "Select Destination Directory" will appear as shown in Figure 2.5. You can select or type-in a new directory path and click on **OK**. You will be returned to the original "Select Installation Directory" window and the directory that you have selected will appear in the middle of the window. Click the **Next** button.

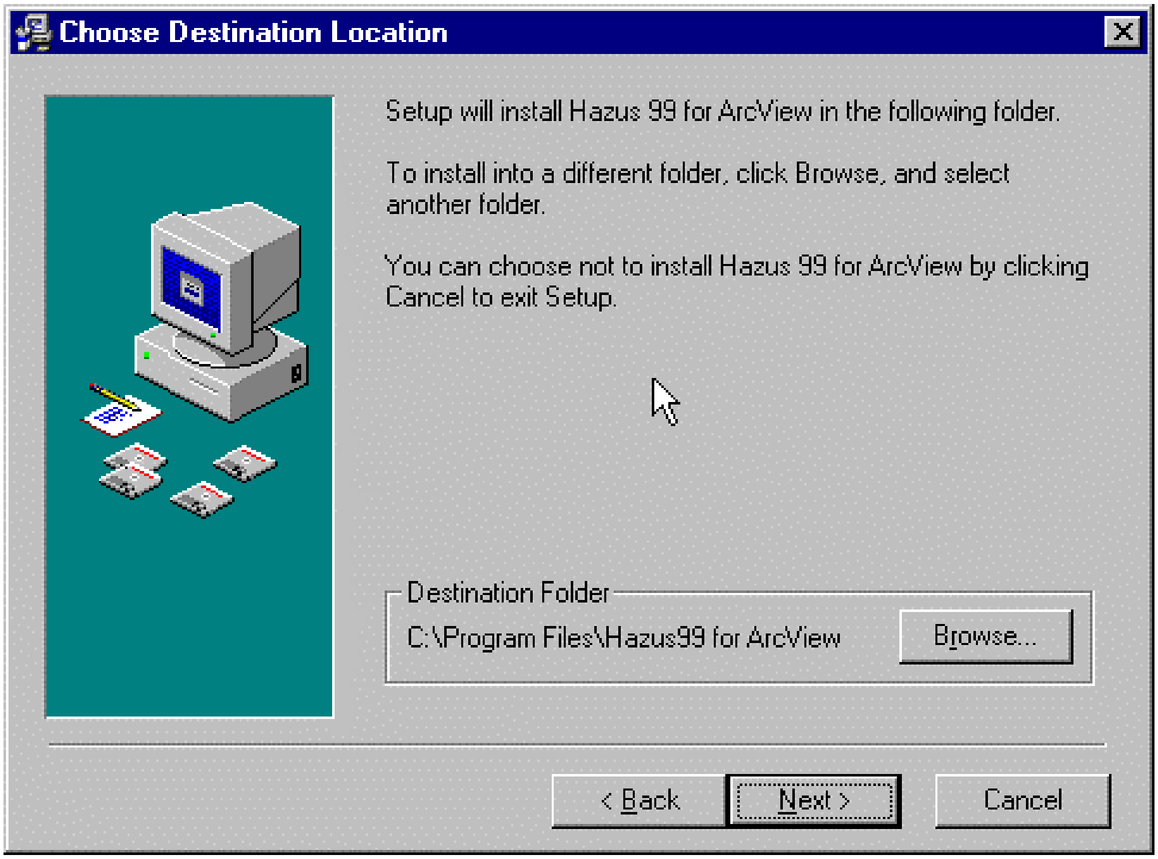


Figure 2.4 Specifying the path of the HAZUS directory.

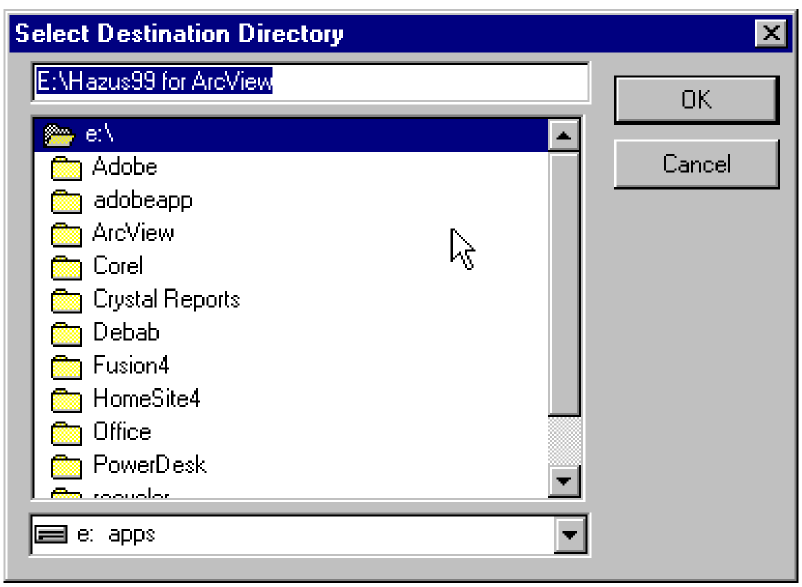


Figure 2.5 Specifying the path of the HAZUS directory interactively.

4. If you already have **HAZUS** installed on your machine under the same path you have specified for installation, you will be prompted with a window that will ask you if you are interested in creating backup files of the files that will be replaced during the new installation as shown in Figure 2.6. If you have any data or

regions that you have added or created and you don't want to lose them then you should choose **Yes.** After making your selection click **Next**.

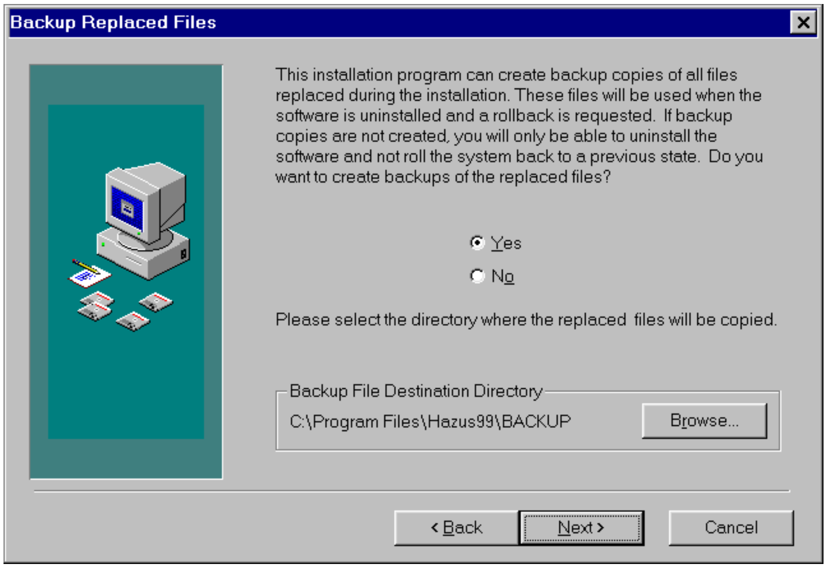


Figure 2.6 Creating backup files.

5. Choose a name for the **HAZUS** Program Folder as shown in Figure 2.7. The default name is **FEMA Risk Assessment System.** If you accept that name click **OK,** otherwise you can change it to a more suitable name for you.

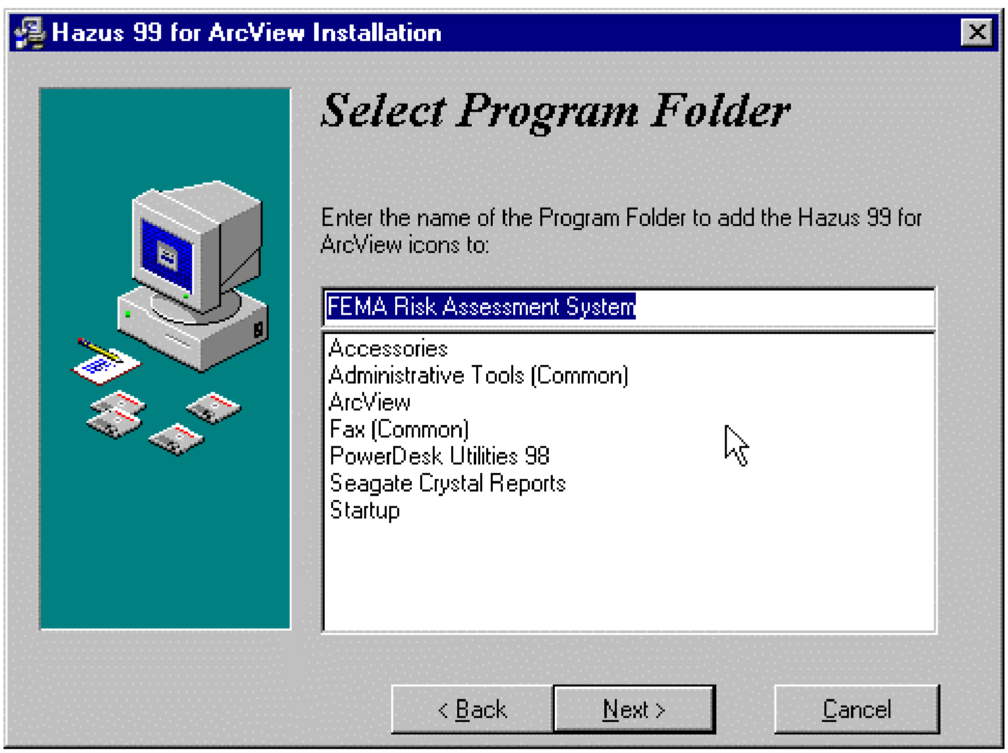


Figure 2.7 Specifying the name of the HAZUS program folder.

6. A list of the programs that you can install will appear as shown in Figure 2.8. Choose the program (s) that you would like to be installed from the components list by checking the box next to each program name.

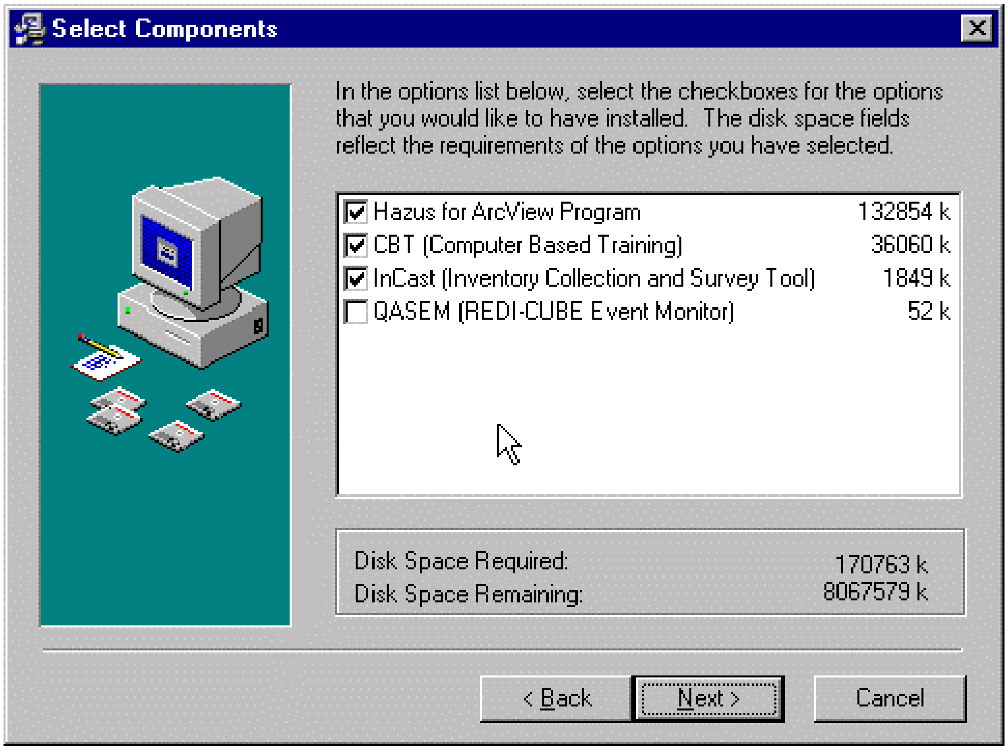


Figure 2.8 Choosing a program (s) for installation.

Here is a brief description of the different components:

- **HAZUS** Program is the main component, which you need to install at least once.
- **CBT** is the Computer-based tutorial, i.e. a program that teaches **HAZUS** interactively. If you are new to **HAZUS**, this is highly recommended.
- **InCAST** is a stand-alone tool to use for collecting inventory data in a format compatible with the **HAZUS** format.
- **QASEM** is a tool that is useful in the regions that have the REDI-CUBE system available (currently, this is limited to California). Given a REDI-CUBE system installed on the target machine, when an earthquake occurs, QASEM automatically launches **HAZUS**, creates a region and runs the event automatically.

7. Windows will prompt with a last ***Ready to Install*** window as shown in Figure 2.9. Click on the **Back** button to go back to any of the previous windows and change the previous selection. If everything is O.K., click the **Next** button.

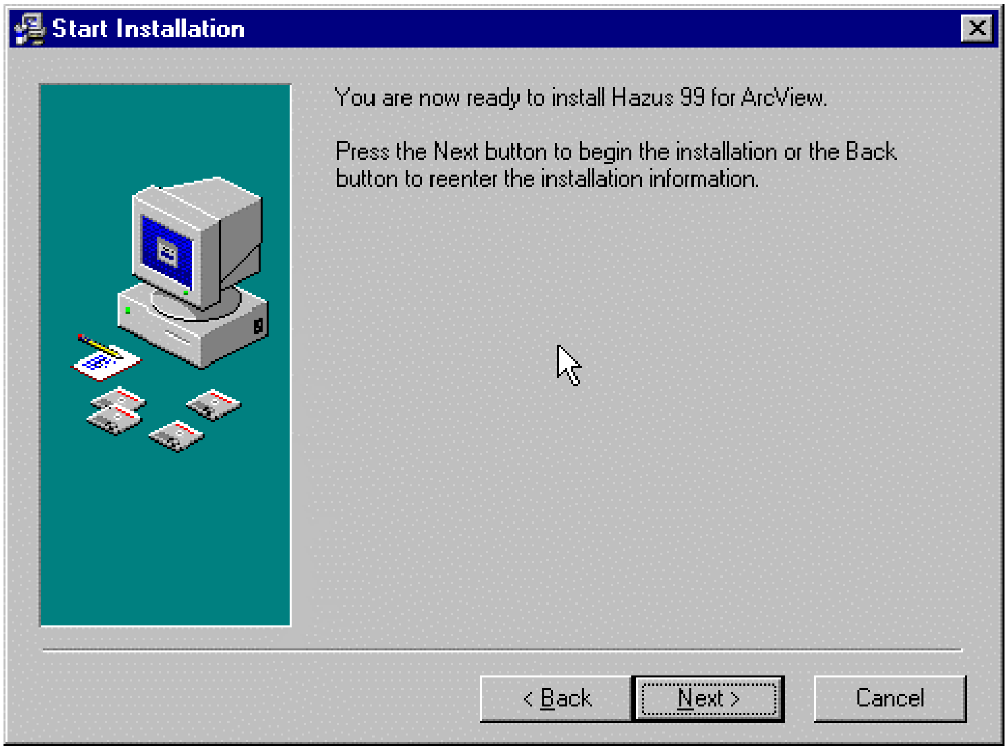


Figure 2.9 Ready to Install window.

8. It will take four or five minutes for the program to install. When the installation is complete the dialog box shown in Figure 2.10 will appear and **HAZUS** program icon will automatically be created on your desktop. Click **Finish** to return to the Windows Setup.

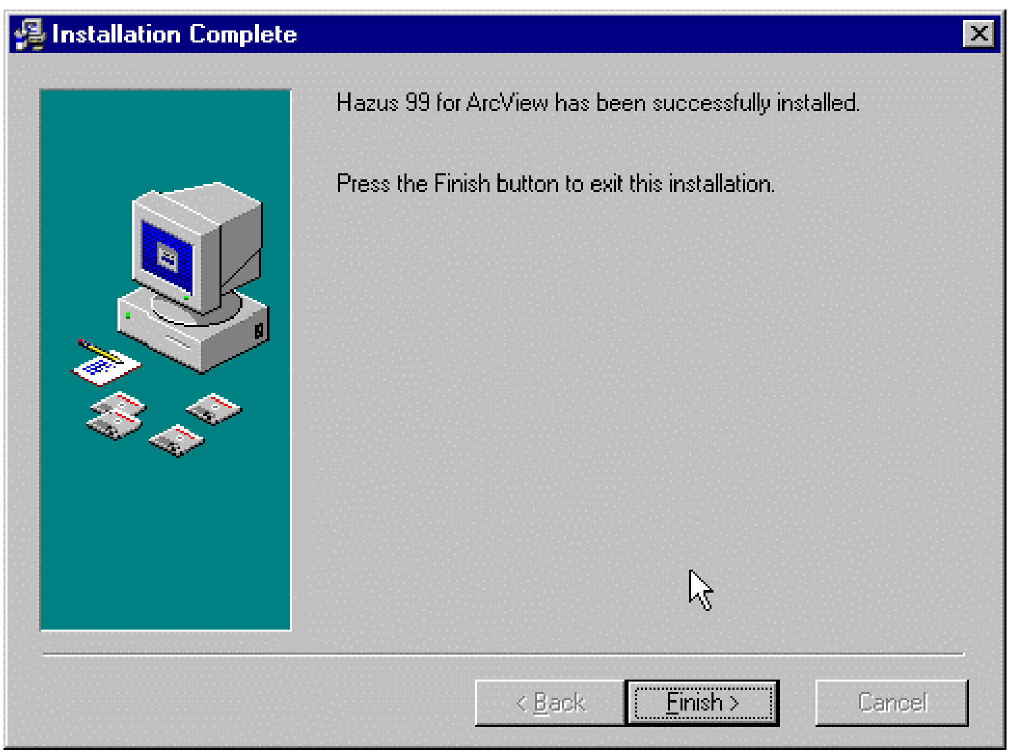


Figure 2.10 Dialog box indicating successful HAZUS installation.

2.3 Upgrading from HAZUS97 to HAZUS99

This current version of **HAZUS** (**HAZUS99**) added many new features and enhancements that required a change in the format of the study region tables.

If you are a current user of **HAZUS97** and you have invested considerable time in customizing your study region(s), and you prefer to use your customized regions in **HAZUS99** instead of recreating them, then follow the steps below:

1. Before installing **HAZUS99**, and from within **HAZUS97** export the study regions you would like to keep. The "Export" feature is accessible through the "Study Regions" dialog. When prompted for the destination path, it is recommended to select a folder outside the HAZUS folder.
2. Uninstall **HAZUS97** (refer to the next section for instructions). By design, the un-install program does not delete any customized files or folders; therefore, all the study region(s) you created still remain on your hard disk. For extra safety, don't delete them until later when you're sure they are not needed.
3. Install **HAZUS99** as described above.
4. Launch **HAZUS99** and import the region(s) you exported in step 1. The "import" process will take care of translating the study region tables from **HAZUS97** format to the **HAZUS99** format.

It is important to note that only inventory data is translated to the new format. Analysis results tables are not converted. Re-run the analysis in **HAZUS99** to take advantage of the improved data and algorithms.

2.4 Starting the Program

The installation program described in Section 2.2 creates a **HAZUS** icon/shortcut on the computer's desktop. To start the program, double click on the **HAZUS** icon. In order to enter inventory or run an analysis, you must first create a study region. Creating a study region is discussed in Section 3.1.

2.5 Uninstalling the Program

To uninstall **HAZUS** in Window 98 and Window NT, go to **Start|Settings|Control Panel** as shown in Figure 2.12.

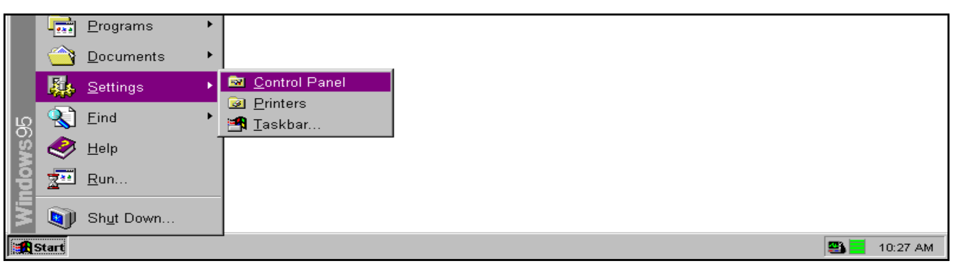


Figure 2.12 Opening the Control Panel.

From the Control Panel window, double click on **Add/Remove Programs** as shown in Figure 2.13.

Figure 2.13 Selecting from Control Panel window.

You will be prompted with an **Add/Remove Program Properties** window as shown in Figure 2.14. From the **Install/Uninstall** tab, highlight **HAZUS99 for ArcView** and double click on **Add/Remove Programs.**

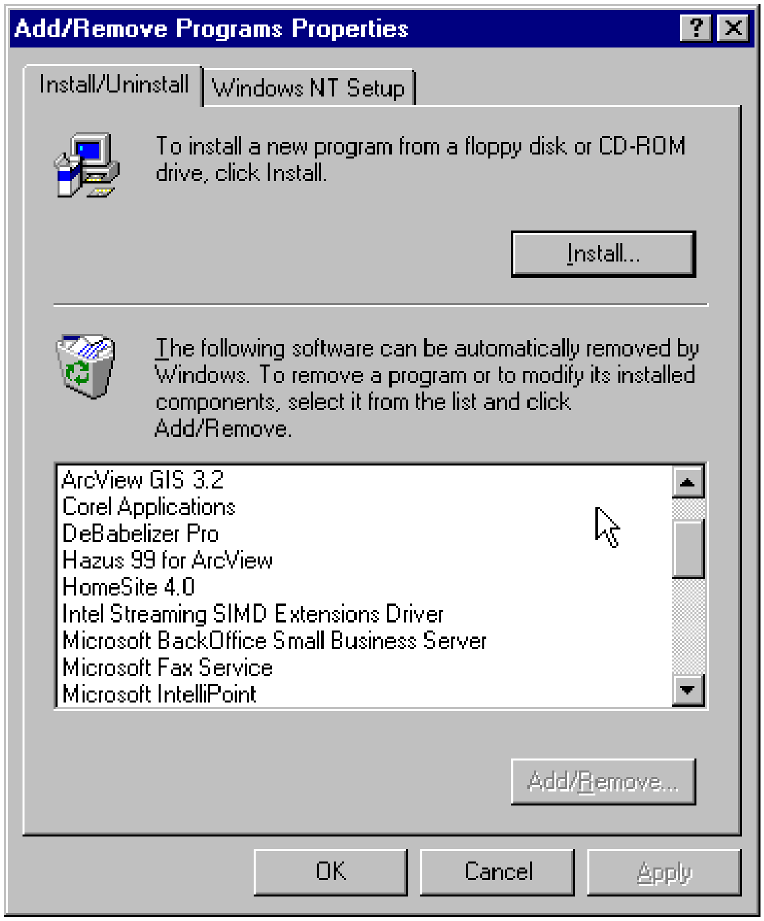


Figure 2.14 Removing HAZUS program.

You can perform an **Automatic** or **Custom** uninstall as shown in Figure 2.15. Select the **Automatic** uninstall method if you want to remove all **HAZUS** program files (except the study regions that you have created under **HAZUS** subdirectory); otherwise, you can use the **Custom** uninstall method and select only the directories that you would like to remove.

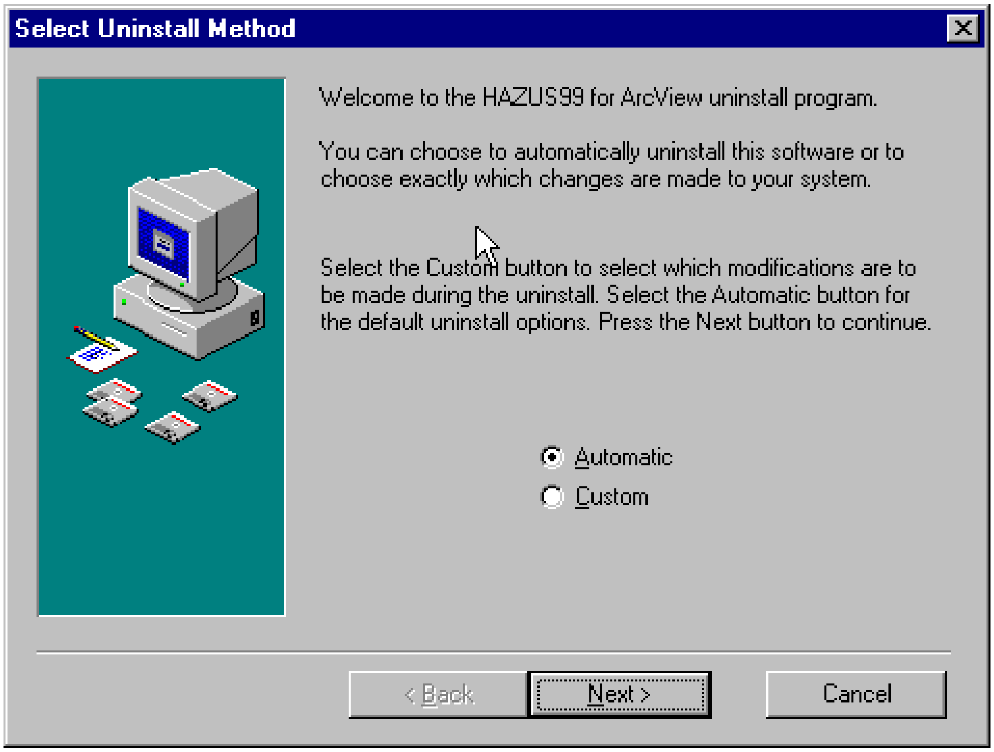


Figure 2.15 Selecting an uninstall method.

Before the program goes through the uninstall process, it prompts you one last time with a window that confirms your desire to uninstall the program as shown in Figure 2.16.

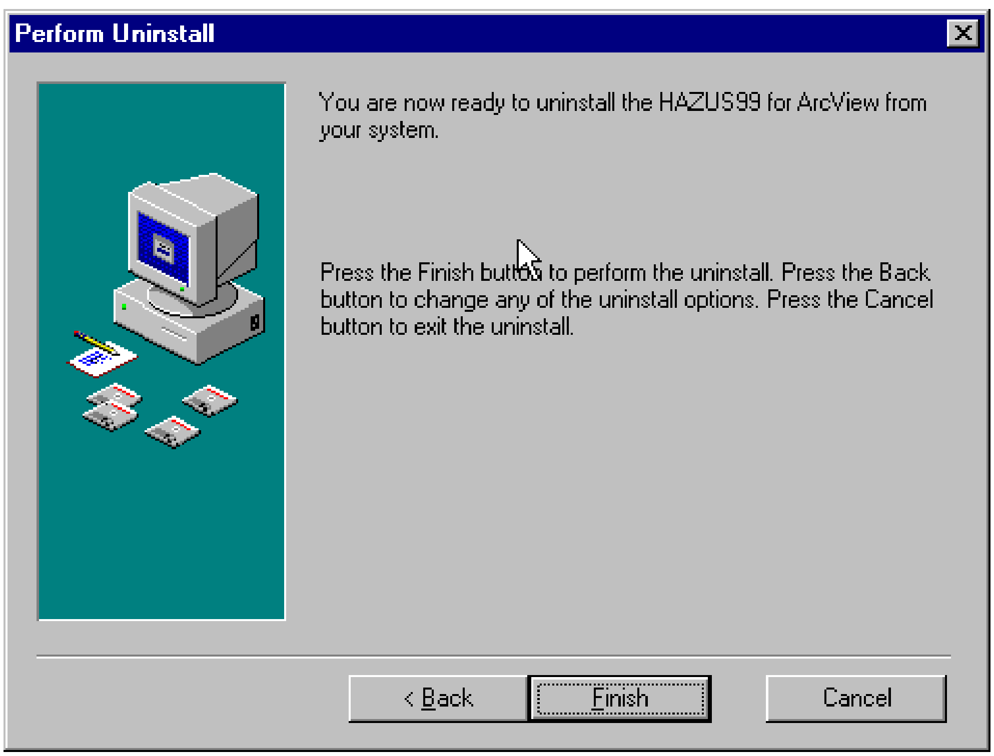


Figure 2.16 Uninstall confirmation window.

2.6 Program Basics

HAZUS is an ArcView-based program with a standard Windows interface that provides a familiar working environment. The user interface is comprised of a menu bar, tool bar and various screens and windows. These elements follow standard Windows conventions and allow you to manipulate and analyze data within **HAZUS**. This section briefly describes some of the features.

2.6.1 Menu Bar

After launching **HAZUS** and creating a study region (as will be explained in Chapter 6), a screen such as the one shown in Figure 2.17 will be used to control the software operation. The menu bar is displayed at the top of the screen. **Bold** menu items indicate that the items are available; grayed out menu items are not available.

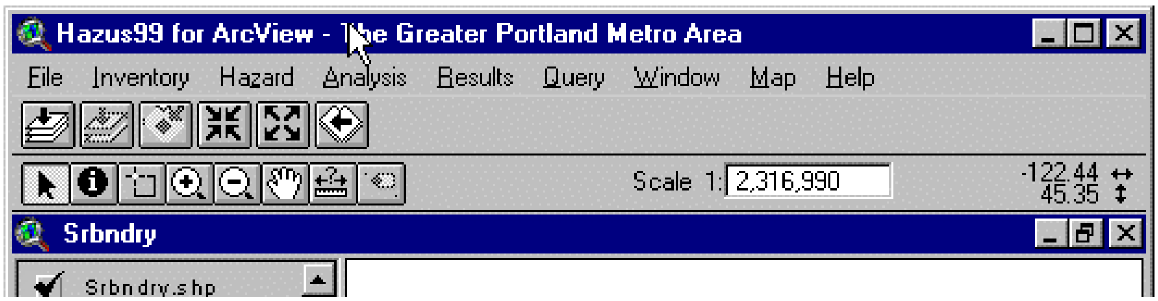


Figure 2.17 The menu bar in HAZUS software.

Menu items are organized according to their basic functionality as listed below:

FILE	Execute standard software actions such as open table, save and print.
INVENTORY	Add, modify, delete and copy inventory information.
HAZARD	Select hazard maps and the scenario event you wish to work with.
ANALYSIS	Modify the analysis data, parameters and assumptions.
RESULTS	Used to view and map analysis results.
QUERY	Locate multiple inventory items based on criteria you provide, and search for specific record information.
WINDOW	Basic GIS utilities menu.
MAP	Control of the map layers, modification of the map views, and "quick start option" for certain common maps.
HELP	The help system due to budget constraints is not available in the current version of **HAZUS.**

2.6.2 Tool Bar

A Tool bar is a set of buttons that execute commands by clicking on them. The standard **HAZUS** tool bar appears under the menu bar. Depending on the window that is currently open in **HAZUS**, the available tool bar options change. The tool bar buttons are used for object selection, zooming in or out, moving around maps, obtaining information, measuring distance and creating points. Details of the tool bar buttons can be found in the ArcView Manual. **Bold** buttons indicate that the buttons are available; grayed out buttons are not available.

Chapter 3. Running HAZUS with Default Data

HAZUS contains a variety of default parameters and databases. You can run a loss estimation analysis using only default data, but your results will be subject to a great deal of uncertainty. Default data supplied with **HAZUS** are described in Section 3.5. If you wish to reduce the uncertainty associated with your results, you can augment or replace the default information with improved data collected for your region of study. This chapter will guide you through a very simple analysis using only default data. For more detailed information about collecting and entering additional data or modifying default parameters and data, see Chapters 4 through 8.

Before running a loss estimation analysis you must define a study region. *The Study Region*, in **HAZUS** terminology, is the geographic unit for which data are aggregated, the earthquake hazard defined, and the analysis carried out.

3.1 Defining the Study Region

The study region can be any combination of states, counties, cities, or census tracts. The study region you define will depend upon the purpose of the loss study. In many cases the region will follow political boundaries such as city or county limits. If you are performing a study for a particular city, then the region may include only the area within the city limits. On the other hand, if you are looking at an entire metropolitan area the region may consist of several counties. Defining the study region requires only that you be able to identify the census tracts that comprise the region. However, it is important to note that HAZUS will not include any inventory data that you have defined outside the region. In fact, if you include facilities that are located outside the defined study region, HAZUS will automatically eliminate these facilities from the inventory databases.

The methodology is based upon using census tracts as the smallest geographic unit. Census tracts are divisions of land that are designed to contain 2,500 to 8,000 inhabitants with relatively homogeneous population characteristics, economic status and living conditions. For this reason the physical area within census tracts will vary depending on the density of the population. In densely populated regions census tracts can be a few city blocks, whereas in rural areas a census tract may be many square miles. Census tract divisions and boundaries change only once every ten years. Census tract boundaries never cross county boundaries; hence census tracts can completely and uniquely define all the area within a county. This characteristic allows for a unique division of land from country to state to county to census tract. Note, however, that a census tract can cross city boundaries. A unique 11-digit number identifies census tracts. The first two digits represent the tract's state; the next three digits represent the tract's county, while the last 6 digits represent a number that identifies the tract within the county. For example, a census tract numbered 10050505800 would be located in Delaware (10) in Sussex County (050).

You have the flexibility to define any arbitrary study region by selecting a set of census tracts. The study region may overlap multiple states and counties and may contain only portions of counties or cities. You can define any number of study regions (limited only by disk space), and can switch between them at any time. Each study region has its own copy of the inventory data that can be edited/modified independently from other regions. The steps you will use to define the study region are summarized in Figure 3.1.

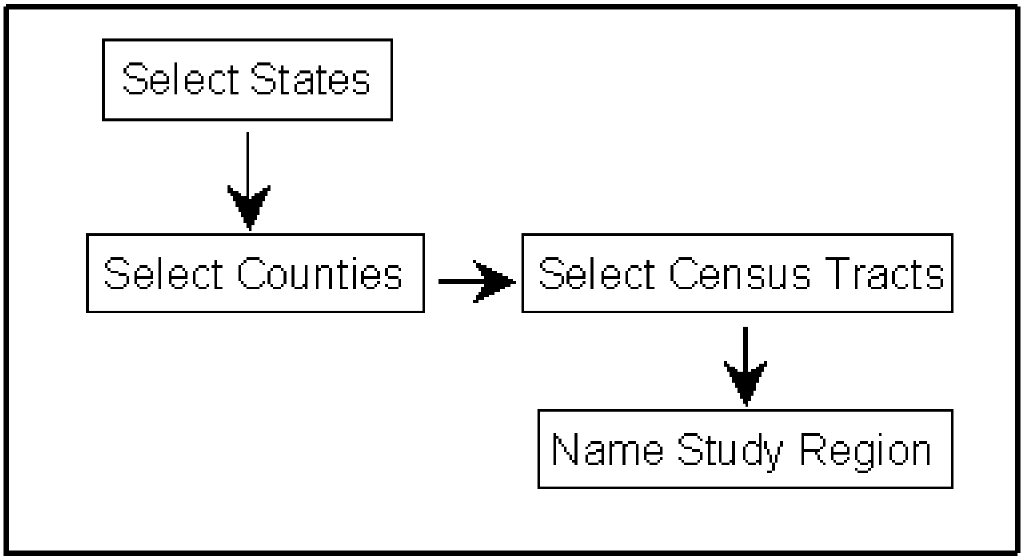


Figure 3.1 Steps needed to define the study region.

When using **HAZUS**, you will create a study region by the following sequence. From the **Study Region** window select **Create** and **New Region** as shown in Figure 3.2. In order to create a new study region the CD-ROM must be in the CD drive. The **Study Region** window will appear automatically when **HAZUS** is launched. The window also can be displayed by selecting the **File|Region** menu option.

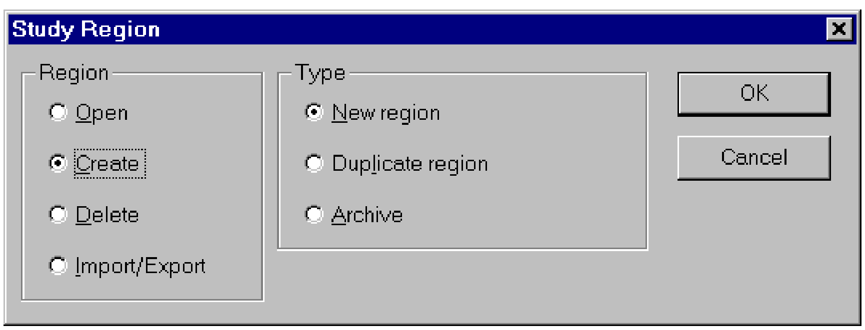


Figure 3.2 Study region window in HAZUS.

Next you will be prompted to select which states (including portions of states) are included in the study region. To select a state, click on the name of that state. To select multiple states, hold down the **Ctrl** key while you click on all of the states you wish to include. The user has selected Oregon in the example shown in Figure 3.3. It is important to make sure that you have enough disk space before you start the aggregation. The minimum recommended size is 1 GB. **HAZUS** displays the disk space available for aggregation as shown in Figure 3.3 (in this example, the available space is approximately 1.4 GB). When you have finished selecting the states, click on the **Next>** button.

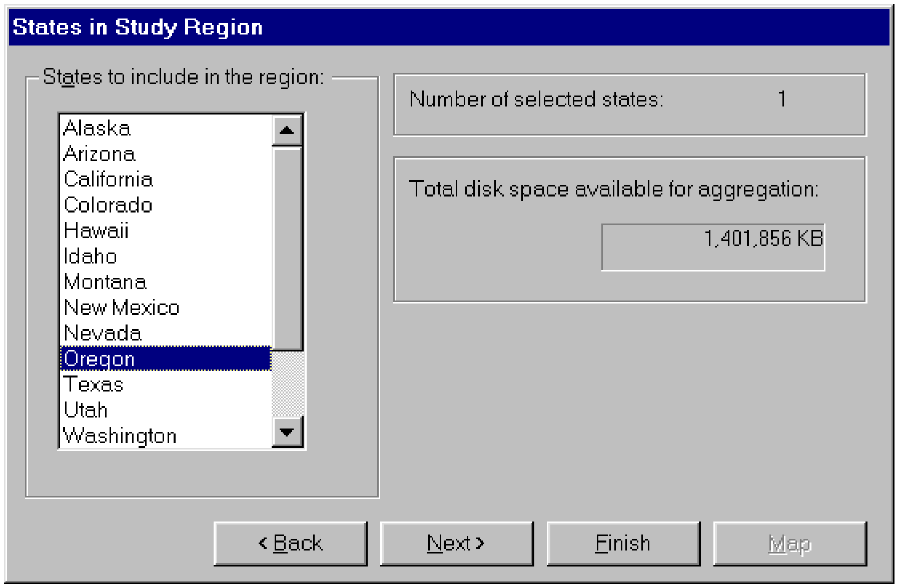


Figure 3.3 State selection window in HAZUS.

Once you have selected the states and clicked the **Next>** button, all of the counties in the selected states will be displayed. You can then select the counties you wish to include in the study region by clicking on the names of those counties. Multiple counties can be selected by holding down the **Ctrl** key and clicking on the desired counties as shown in Figure 3.4.

Alternatively you can click the **Map** button and choose the counties from a map of the state as shown in Figure 3.5. To select multiple counties, hold down the **Shift** key while clicking on the desired counties. When done, pull down the **Select** menu and choose **Selection Done**. This will return you to the window shown in Figure 3.3. Note that **Selection Done** is the only valid option from this window and you should not try to close the map using **File|Close Table** option.

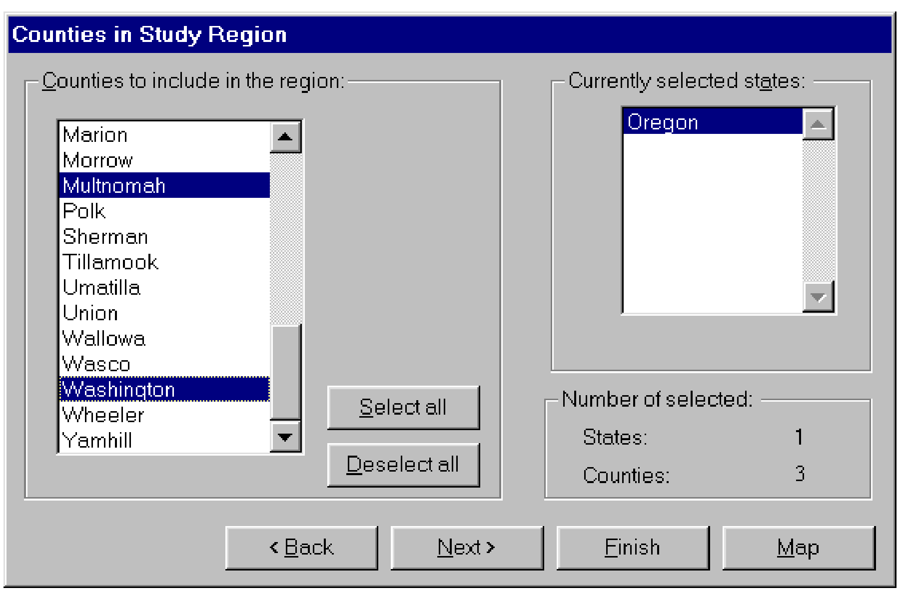


Figure 3.4 County selection window in HAZUS.

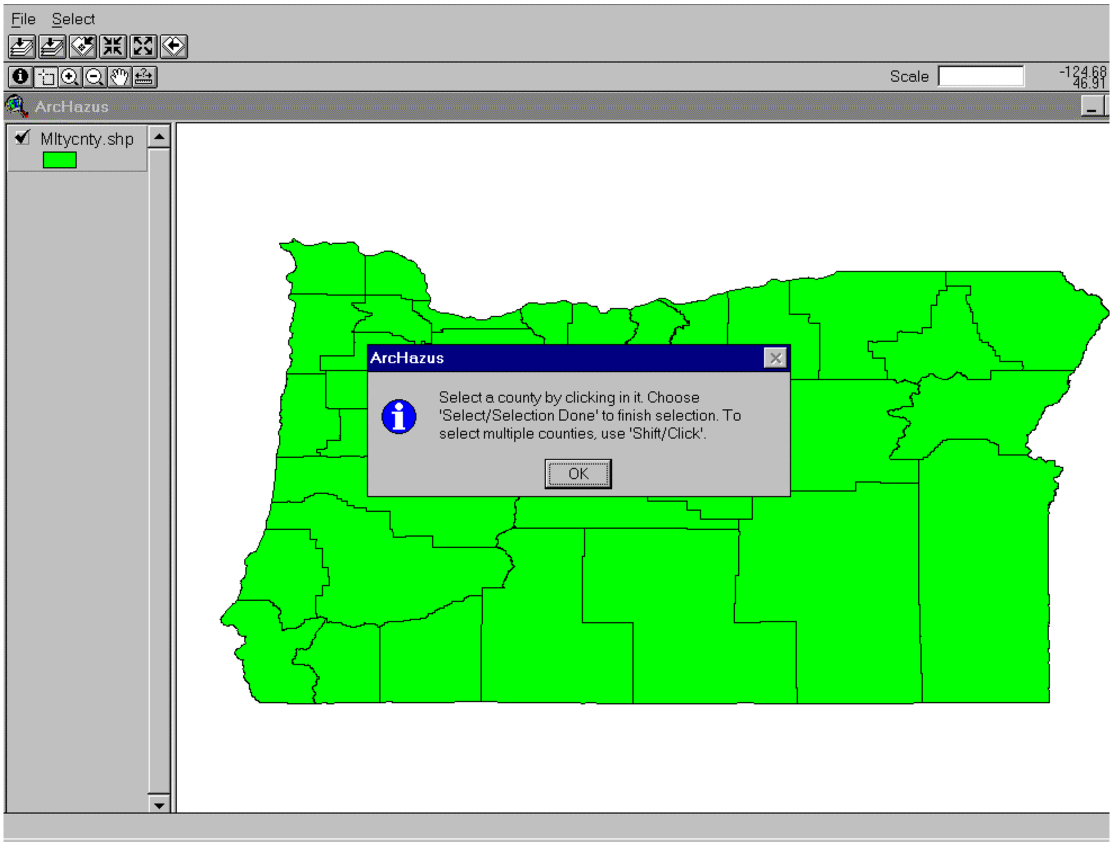


Figure 3.5 Selection of counties using the Map option.

Once you have selected the counties and clicked on the **Next>** button, you will be presented with all of the census tracts in the selected counties as shown in Figure 3.6. You can then select the census tracts that define the study region. At any point in this process you can undo your selections by using the **<Back** button.

At any point in state, county or census tract selection, you can click on **Finish** and you will have automatically selected everything within the previously selected entity. For example, if the user were to click **Finish** after he had selected Oregon in Figure 3.3, he would have selected all the counties in Oregon.

In this example the user has selected 234 census tracts from the three Oregon counties. The census tracts do not have to have continuous numbering nor do they need to be contiguous. As with the other windows you may graphically select census tracts by using the **Map** button. The selection of census tracts directly from the map is mostly helpful in the case of choosing census tracts that are in the vicinity of a city but not in a numerical sequence, or for the case when the location of a city is known while the census tract numbers around that city are not known.

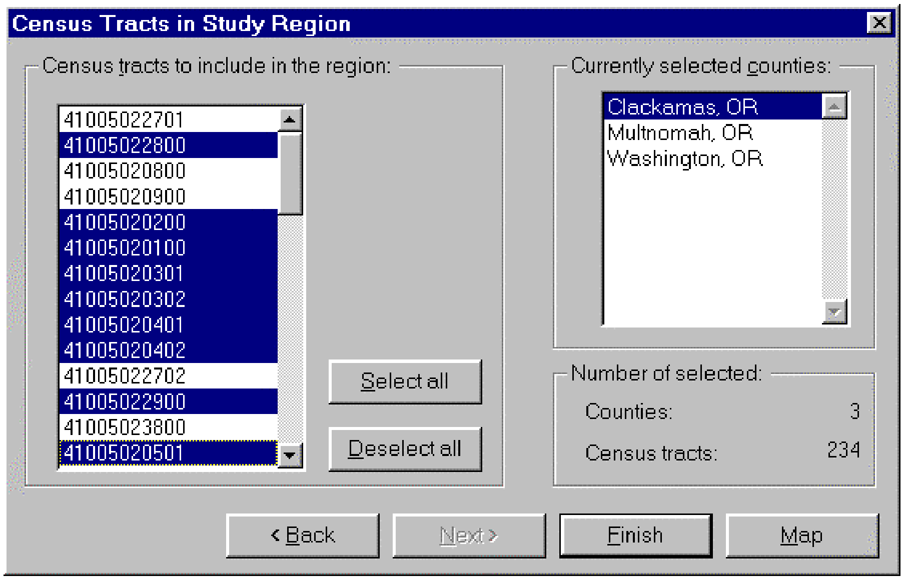


Figure 3.6 Census tract selection window in HAZUS.

When you have selected the census tracts, click on the **Finish** button and you will have the opportunity to name the study region and store it for future use (see Figure 3.7). The **Study Region description** is a more complete description of the study region that is used for display purposes in **HAZUS**. The Study region folder/directory is used to identify the directory (e.g. C:**HAZUS**\PRTLND) where all data and results are kept.

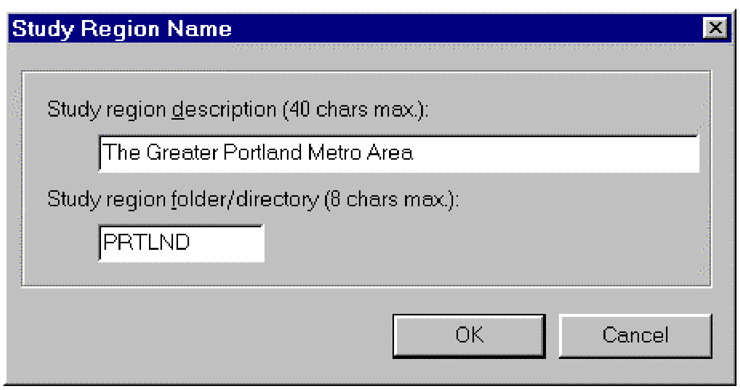


Figure 3.7 Study region name window in HAZUS.

After clicking on the **OK** button you will have to wait a few minutes while the default inventory data are downloaded from the CD-ROM to your hard drive. When that process is complete, a map of the study region, such as the one shown in Figure 3.8, will appear. Once a study region is created it can be retrieved and used for any number of analyses. Using the Open selection option shown in Figure 3.2 you can retrieve an existing region.

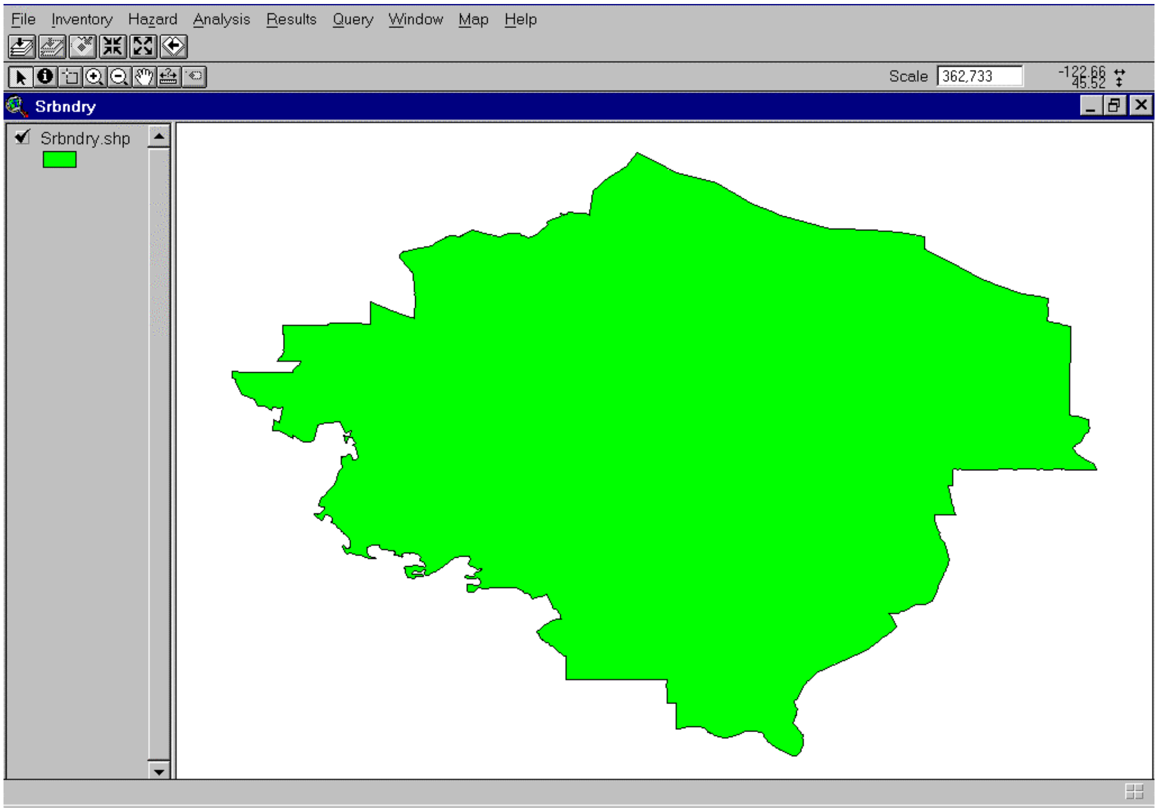


Figure 3.8 Map of a study region.

3.2 Defining a Scenario Earthquake

Before an analysis can be run, you must quantify the potential earth science hazards (PESH) that will serve as a basis for evaluating damage and losses. For an earthquake loss analysis, this involves identifying the size and location of the earthquake and estimating its associated ground motions and ground deformations due to ground failure. For this methodology, ground deformations due to liquefaction, landslides, and surface fault rupture can be included.

While there are a number of options available for defining PESH (see Section 9.1), the only method described in this section is defining a scenario earthquake using the arbitrary event option.

Click on the hazard definition menu (**Hazard**) as shown in Figure 3.9. Clicking on the **Scenario** option allows you to define the earthquake hazard using the window shown in Figure 3.10.

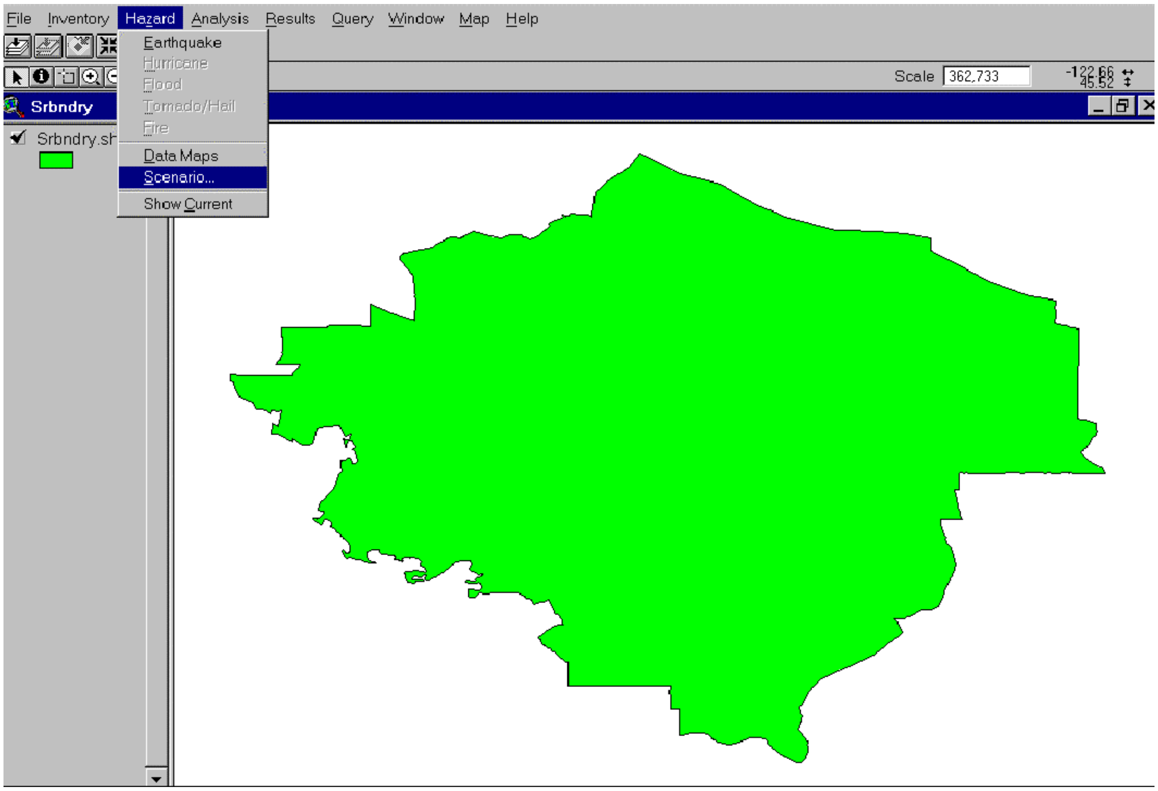


Figure 3.9 Hazard definition menu in HAZUS.

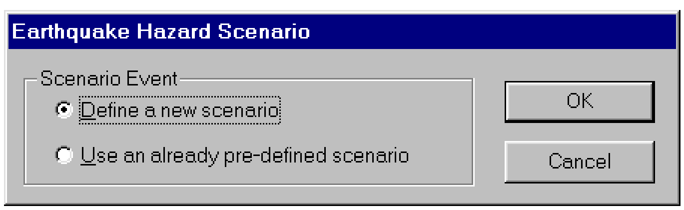


Figure 3.10 Earthquake Hazard Scenario window in HAZUS.

Choose **Define new scenario event** and the window shown in Figure 3.11 will appear. The **Open predefined scenario event** button can be used only if you have previously run a scenario for this region.

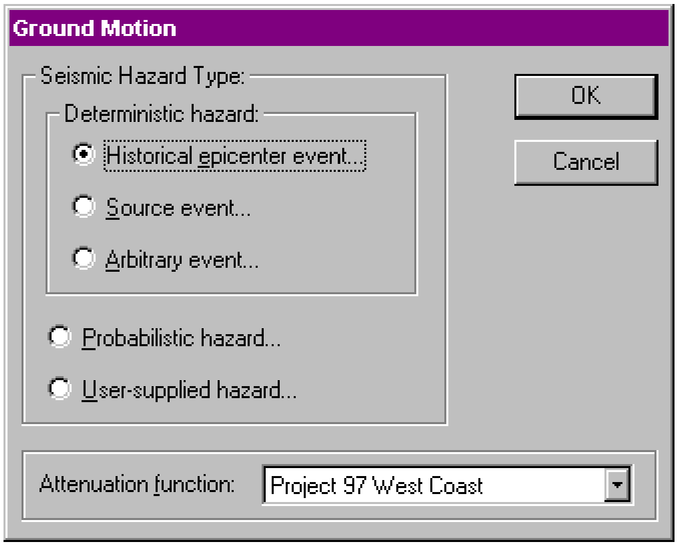


Figure 3.11 Ground motion definition window in HAZUS.

Next, click on **Arbitrary event…,** accept the default attenuation function *Project 97 West Coast*[3] and supply the parameters shown in the window in Figure 3.12. At a minimum, you need to supply the latitude and longitude of the event. Without any additional input from you, **HAZUS** will default to a 7.0 moment magnitude with a corresponding surface and subsurface rupture length, a depth of 0 kilometers, a fault rupture orientation of 0 degrees and a strike-slip/normal fault type. Entering data in the appropriate places will change the default values.

You can select the latitude and longitude from a map of the region by clicking on the **Map** option. You will be prompted to select a point in the study region by clicking on the screen. Once you have done this, **HAZUS** will return you to the window in Figure 3.12.

---

[3] HAZUS implements 7 attenuation functions for the Western U.S. regions, and 3 for the East Coast. The list showing in the combo-box will vary according to the study region aggregated.

For West Coast, the functions are:

- Project 97 West Coast,
- Project 97 Pacific Northwest
- Project 97 Hawaii
- Boore, Joyner & Fumal (1994)
- Sadigh et. al. (1993)
- Youngs et. al (1995)
- Munson & Thurber

For East Coast, they are: :

- Project 97 East Coast
- Frankel (1996)
- Toro, Abrahamson & Schneider (1994)

Chapter 5 of the technical manual describes in detail all of the functions listed above.

If you choose to change the magnitude and would like to have the surface and subsurface rupture lengths correspond to the new magnitude, you need to click on the **Override** boxes. When you have finished, click on the **OK** button.

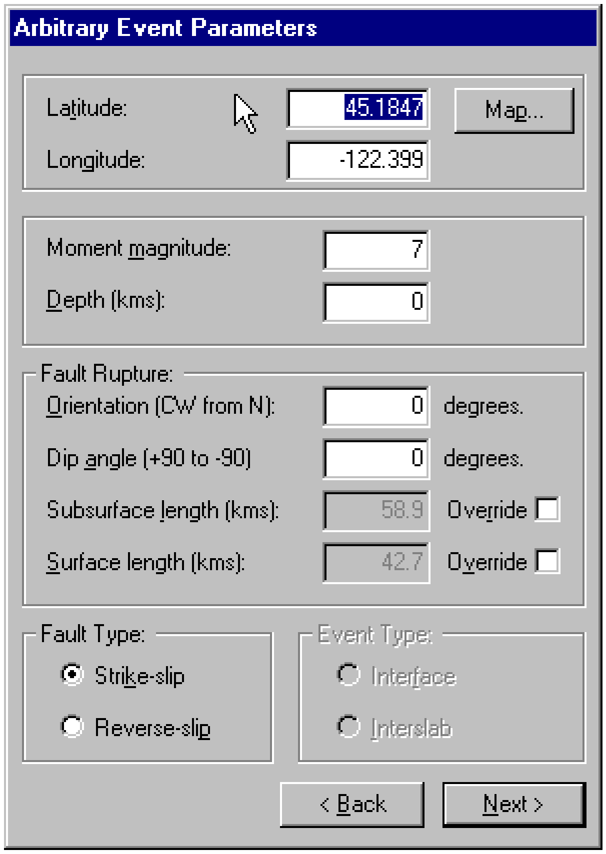


Figure 3.12 Window to define parameters for an arbitrary event.

3.3 Running an Analysis Using Default Data

If you opt to run your analysis with default data and parameters, the only information you will need to supply **HAZUS** is the definition of the study region and the size and location of the scenario earthquake. Defining the study region was discussed in Section 3.1 and definition of the scenario earthquake was outlined in Section 3.2. Once this information has been supplied the analysis can be run using the following steps:

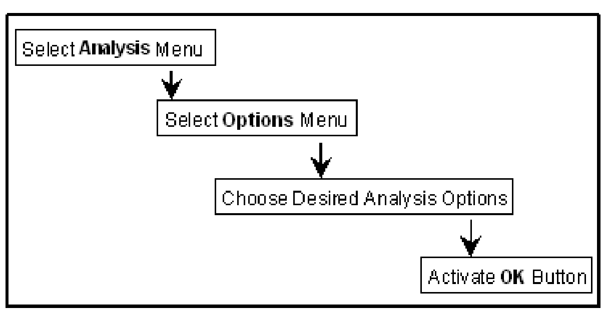


Figure 3.13 Running an analysis with HAZUS.

The **HAZUS** windows used to perform this sequence of steps are illustrated in Figures 3.14 to 3.19. Figure 3.14 shows the **Analysis** menu. This menu can be accessed after you have defined the study region and the scenario event. The map shown in Figure 3.14 is an outline of the study region that was created using the steps detailed in Section 3.1. There are several operations within the **Analysis** menu that can be initiated, such as modifying damage functions or restoration times. However, you can run an analysis using only default data and inventory, without modifying any parameters whatsoever. Choose **Run...** and the window in Figure 3.15 will appear. This window provides a number of analysis options that can be selected by clicking in the associated box.

All analysis options can be run at the same time or each can be run separately. If a study region is large (a few hundred to more than a thousand census tracts), a complete analysis can take several hours. It is suggested that you run the analysis options one at a time while you are developing and modifying scenarios, inventories, and model parameters. This allows you to review intermediate results and check to determine if the results look reasonable or serve your needs without waiting several hours to run a complete analysis. Once you are satisfied with inventories and model parameters, you may wish to perform additional analyses with all options running simultaneously.

If you wish to ask "what if" questions, individual options can be run repeatedly without performing a complete analysis. Once an option is run, all of the results from that option are saved until it is run again. For example, if a you want to know what would happen if costs of repairs were increased (keeping everything else the same), you would only have to run the **Direct social and economic loss** option again. **HAZUS** will use damage results from the previous analysis to estimate economic losses.

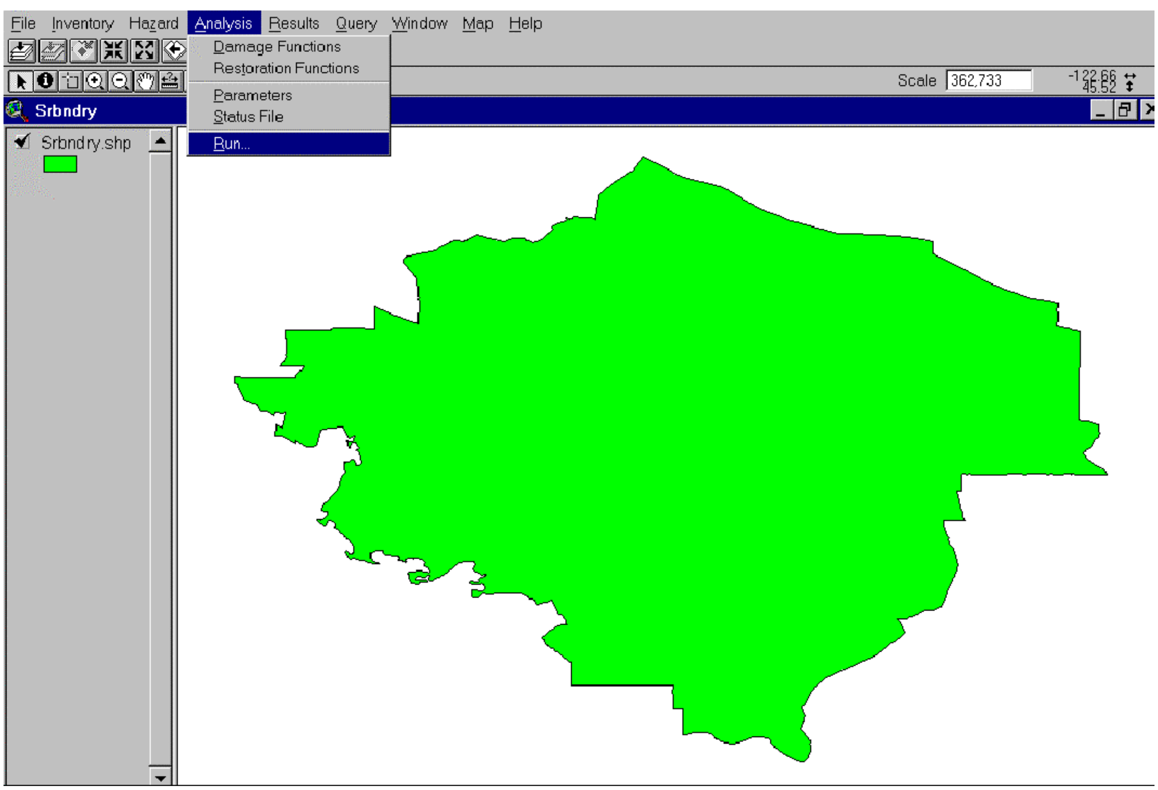


Figure 3.14 Accessing the analysis menu in HAZUS.

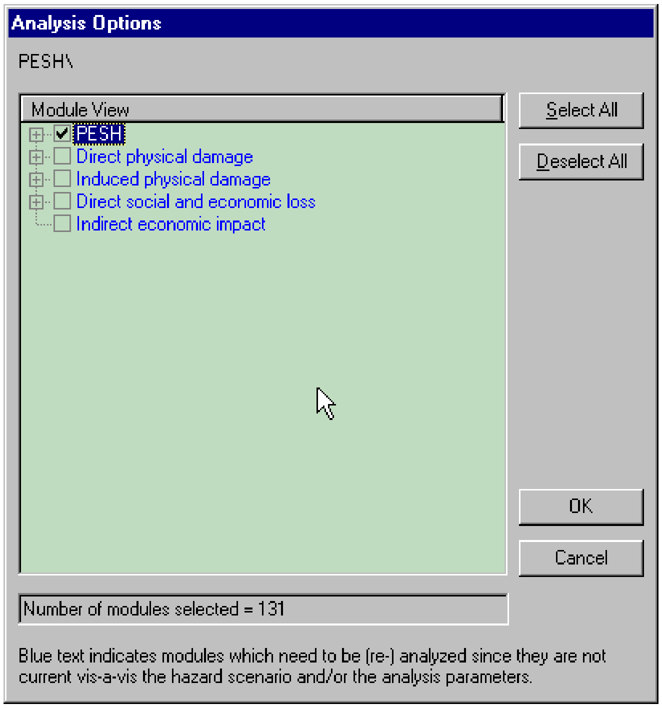


Figure 3.15 Analysis Options window in HAZUS.

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. When you select the **PESH** option from Figure 3.15, you will be presented with the window in Figure 3.16. This window allows you to select the type of ground motion output you wish to view (**By Census Tract** or **Contour Maps**) and to specify if you will include liquefaction, landslide and/or surface faulting in the analysis. When ground motion is mapped by census tract, a constant level of ground motion (the value of the ground motion at the centroid of the census tract) is displayed for each census tract. Contour maps provide a more detailed mapping of the ground motion and thus take a longer time to generate. Contour maps are for display purposes only and are not used in calculating damage and losses. Users may opt to not generate contour maps if they wish to shorten analysis time.

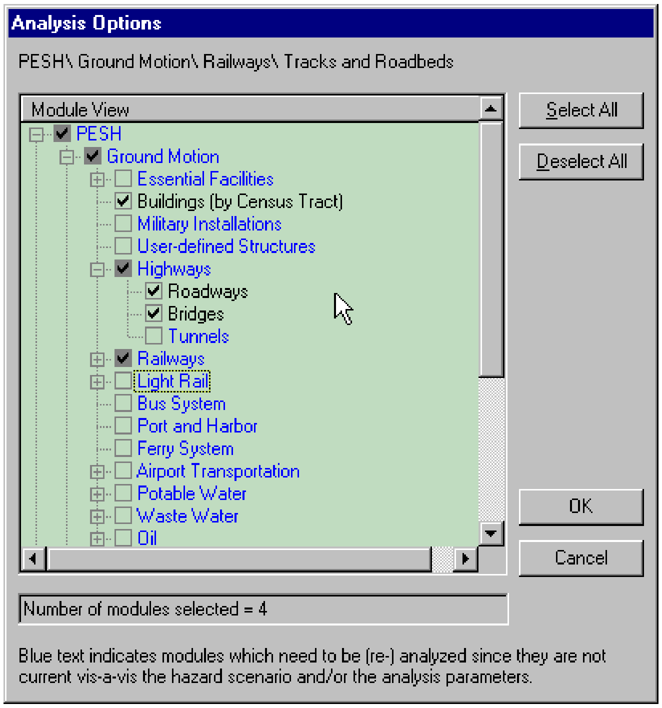


Figure 3.16 PESH analysis options window in HAZUS.

The Analysis Options window shown in Figure 3.15 provides you with the opportunity to specify exactly which damage and losses you want to estimate. For example if you select the **Direct physical damage** option in Figure 3.15, you may opt to estimate damage to general building stock, highways and railways by clicking on and highlighting those facilities as shown in Figure 3.17. You may specify **Debris** only from the **Induced Physical Damage** window shown in Figure 3.18 and **Casualties** from the direct social and economic loss window shown in Figure 3.19. Once all of the desired options have been specified, click on the **OK** button to run the analysis.

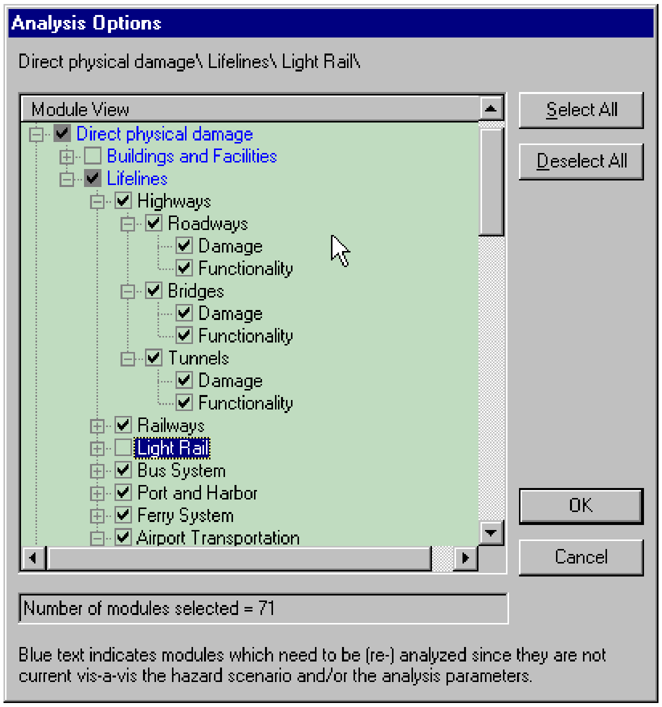


Figure 3.17 Direct physical damage analysis options window.

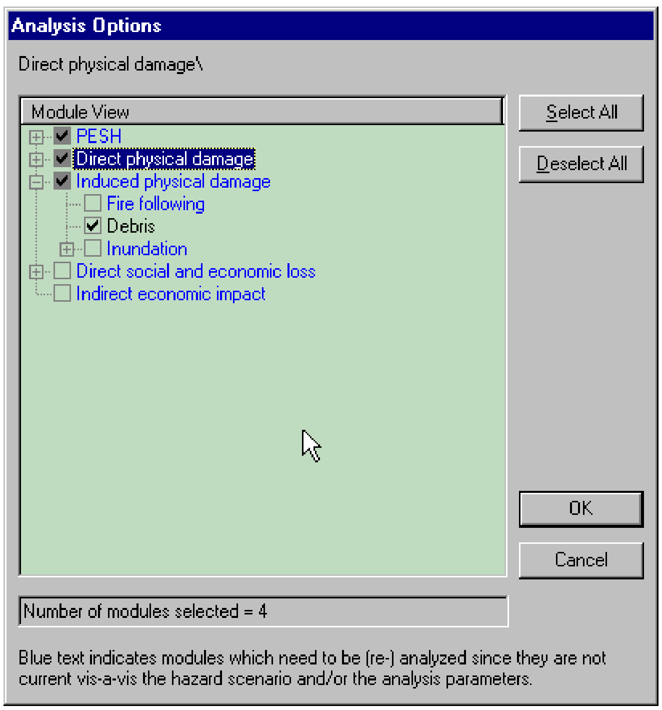


Figure 3.18 Induced physical damage analysis options window.

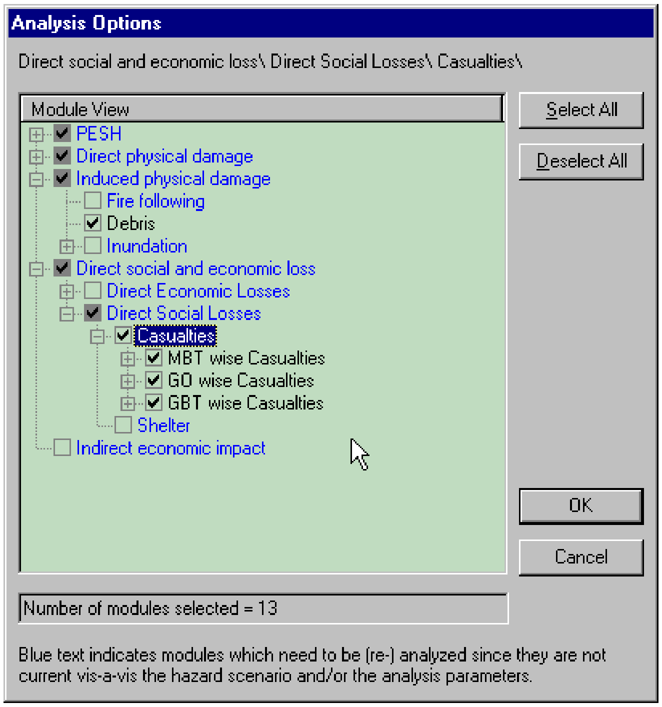


Figure 3.19 Direct social and economic loss options window.

3.4 Viewing Analysis Results

Each of the modules of **HAZUS** provides the user with a series of outputs. The outputs can be in a tabular or graphical form. Some of the modules yield intermediate results that are used as inputs to other modules. For example, the PESH (Potential Earth Science Hazards) module determines ground motion at different locations for a specified earthquake scenario. This information by itself may not be very useful for hazard mitigation and emergency planning. However, the results of the PESH module are used as an input to determine the damage to structures in the Direct Physical Damage module.

Analysis results are accessed from the **Results** menu as shown in Figure 3.20. Three types of output are available:

- Thematic map of results (Figures 3.21 and 3.22)
- Table of results by census tract (Figure 3.23)
- Summary table of results by county and for the whole region (Figure 3.24)

Thematic maps use colors or symbols to display results. For example in Figure 3.21, red might indicate 20% to 25% of the census tract is burned and green might indicate 0% to 4% is burned. Similarly in Figure 3.22, a *check mark* indicates a high probability of an airport terminal being functional and an *asterisk* indicates it is more likely to be non-functional. Results can be thematically mapped by using the **Map** button at the bottom of a table of results (see Figure 3.23). A variety of summary reports are available through the **Summary Reports** menu at the bottom of the **Results** menu shown in Figure 3.20. Displaying results is discussed in more detail in Chapter 10.

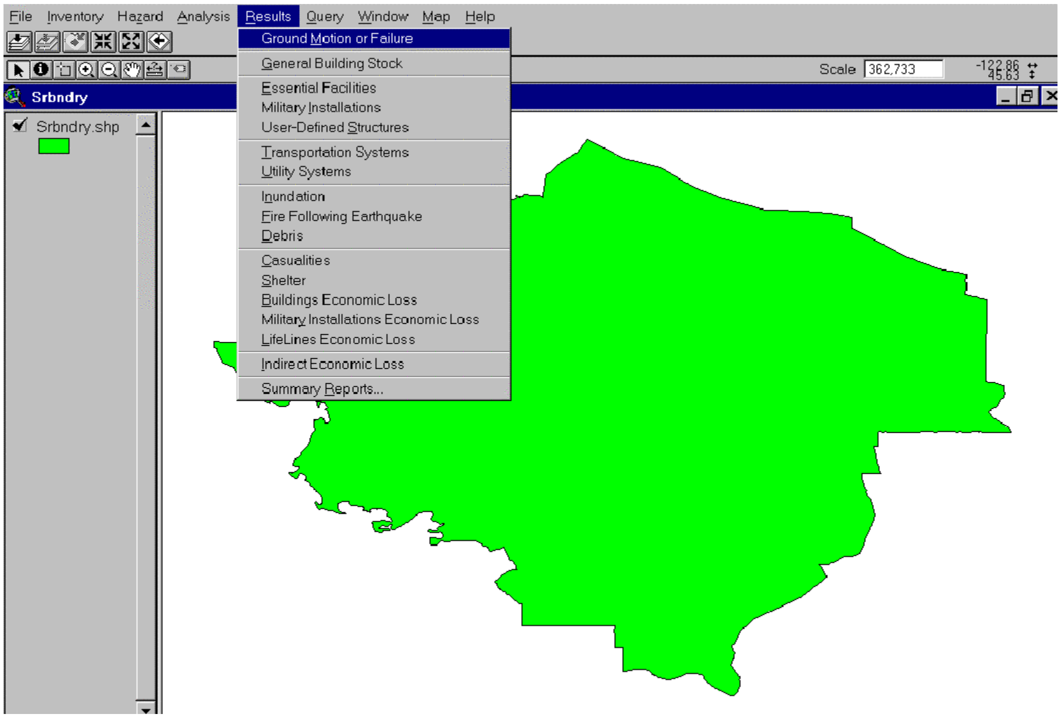


Figure 3.20 Accessing analysis results.

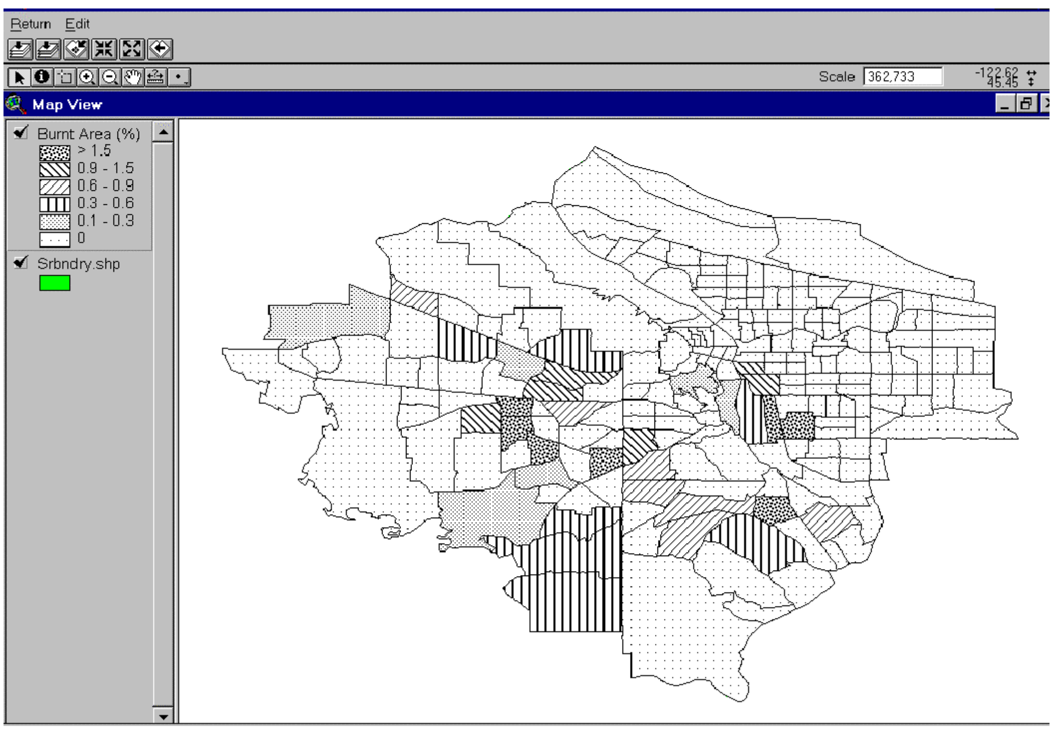


Figure 3.21 Sample thematic map: percent of each census tract burned.

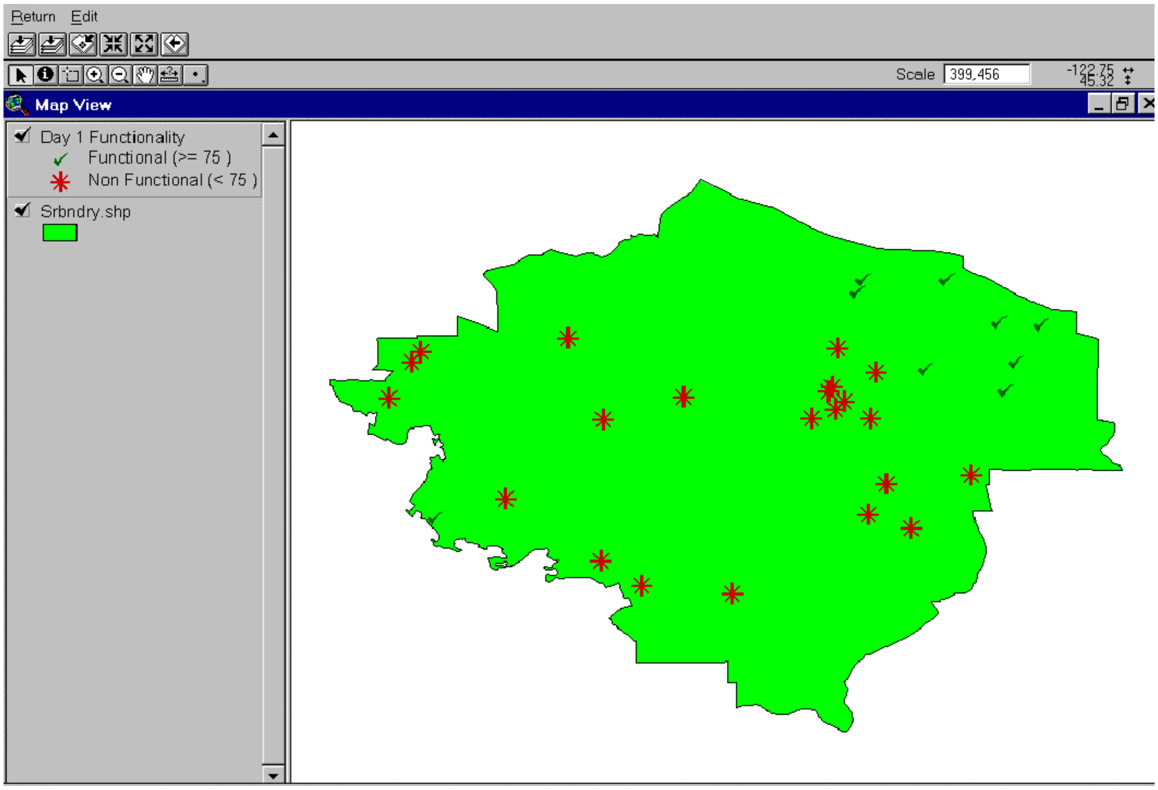
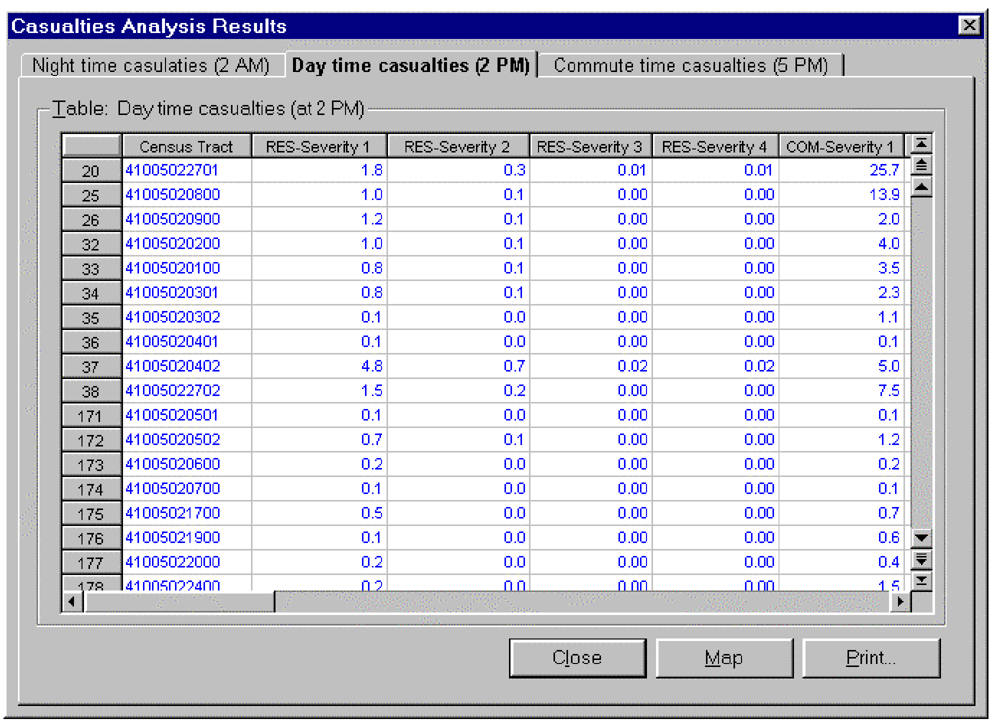


Figure 3.22 Sample thematic map: functionality of airport terminal buildings.


Casualties Analysis Results

Night time casulaties (2 AM) | Day time casualties (2 PM) | Commute time casualties (5 PM)

Table: Day time casualties (at 2 PM)

	Census Tract	RES-Severity 1	RES-Severity 2	RES-Severity 3	RES-Severity 4	COM-Severity 1
20	41005022701	1.8	0.3	0.01	0.01	25.7
25	41005020800	1.0	0.1	0.00	0.00	13.9
26	41005020900	1.2	0.1	0.00	0.00	2.0
32	41005020200	1.0	0.1	0.00	0.00	4.0
33	41005020100	0.8	0.1	0.00	0.00	3.5
34	41005020301	0.8	0.1	0.00	0.00	2.3
35	41005020302	0.1	0.0	0.00	0.00	1.1
36	41005020401	0.1	0.0	0.00	0.00	0.1
37	41005020402	4.8	0.7	0.02	0.02	5.0
38	41005022702	1.5	0.2	0.00	0.00	7.5
171	41005020501	0.1	0.0	0.00	0.00	0.1
172	41005020502	0.7	0.1	0.00	0.00	1.2
173	41005020600	0.2	0.0	0.00	0.00	0.2
174	41005020700	0.1	0.0	0.00	0.00	0.1
175	41005021700	0.5	0.0	0.00	0.00	0.7
176	41005021900	0.1	0.0	0.00	0.00	0.6
177	41005022000	0.2	0.0	0.00	0.00	0.4
178	41005022400	0.2	0.0	0.00	0.00	1.5

Close | Map | Print...

Figure 3.23 Sample table of results: residential casualties at 2 PM.

Building Damage By General Occupancy

Nov 25, 1997

	Square Footage (Thousand.sq.ft)	Damage State Probability (%)				
		None	Slight	Moderate	Extensive	Complete
Oregon						
Clackamas						
Residential	74.354	24.99	35.84	30.01	8.14	1.22
Commercial	17.628	21.00	20.87	33.73	19.73	4.68
Industrial	5.180	20.71	19.17	34.46	20.28	5.37
Others	3.716	24.96	27.72	30.90	13.52	2.90
Multnomah						
Residential	297.608	40.43	34.05	20.74	4.45	0.33
Commercial	103.199	29.93	22.63	30.35	14.74	2.35
Industrial	31.222	29.71	20.60	31.20	15.47	3.03
Others	10.894	35.41	26.67	25.99	10.12	1.80
Washington						
Residential	138.713	23.02	35.00	31.37	9.22	1.39
Commercial	35.843	17.94	19.28	34.43	22.36	6.00
Industrial	17.556	18.76	17.41	34.16	22.86	6.81
Others	4.481	21.56	26.26	32.36	16.00	3.81
Total State						
Residential	510.705	33.46	34.54	24.98	6.28	0.74
Commercial	156.669	26.18	21.67	31.66	17.04	3.45
Industrial	53.957	25.28	19.43	32.47	18.34	4.48
Others	19.091	30.13	26.78	28.44	12.16	2.49

Study Region : The Greater Portland Metro Area
Scenario : Portland Hills Event

Page : 1 of 1

Figure 3.24 Sample summary report: building damage by general occupancy.

3.5 Default Databases and Default Parameters

While most users will develop a local inventory that best reflects the characteristics of their region, such as building types and demographics, **HAZUS** is capable of producing crude estimates of losses based on a minimum of local input. Of course, the quality and uncertainty of the results will be affected by the detail and accuracy of the inventory and the economic and demographic data provided. The crude estimates would most likely be used only as initial estimates to determine where more detailed analyses would be warranted. This section describes the types of data that are supplied as defaults with **HAZUS**.

3.5.1 Default Databases

Default inventory databases provided with **HAZUS** are of two types. The first type is a national listing of <u>individual</u> facilities, such as dams, bridges, or locations where toxic materials are stored. These databases are modified versions of publicly available databases. The modifications that have been made have been to eliminate data elements that are not needed for the earthquake loss estimation methodology. An example of a default medical care facility database is shown in Figure 4.3. The second type of default database consists of data aggregated on a county or census tract scale. Examples are building stock square footage for each census tract and census data. These default databases are also derived from publicly available data, eliminating fields of data that are not needed for the methodology.

The databases are stored on the **HAZUS** CD-ROM. When you aggregate a region, **HAZUS** extracts only those portions of the databases that are relevant to your region. You can then access these region specific default databases and update them with improved information that you have obtained. Displaying and modifying inventories is discussed in Chapter 7.

Appendix D gives details about the structure of the default databases and their original sources. Following is a list of default inventory information currently supplied with **HAZUS**:

- **Demographic Data**
  - Population Distribution
  - Age, Ethnic, and Income Distribution
- **General Building Stock**
  - Square Footage of Occupancy Classes for Each Census Tract
- **Essential Facilities**
  - Medical Care Facilities
  - Emergency Response Facilities (fire stations, police stations, EOCs)
  - Schools
- **High Potential Loss Facilities**
  - Dams
  - Nuclear Power Plants
  - Military Installations
- **Facilities Containing Hazardous Materials**
- **Transportation Lifelines**
  - Highway Segments, Bridges and Tunnels
  - Railroad Tracks, Bridges, Tunnels and Facilities
  - Light Rail Tracks, Bridges, Tunnels and Facilities
  - Bus Facilities
  - Port Facilities
  - Ferry Facilities
  - Airports Facilities and Runways
- **Utility Lifelines**
  - Potable Water Facilities, Pipelines and Distribution Lines
  - Waste Water Facilities, Pipelines and Distribution Lines
  - Oil Facilities and Pipelines
  - Natural Gas Facilities, Pipelines and Distribution Lines
  - Electric Power Facilities and Distribution Lines
  - Communication Facilities and Distribution Lines

3.5.2 Default Parameters

In addition to default databases, the user is supplied with default parameters documented throughout the Technical Manual. In many cases these parameters are defined on a national basis without adjustments for regional variations. In other cases such as with repair costs, regional variations are included. Examples of default parameters are costs per square foot to repair a structure, percent of residences that are owner occupied, and casualty rates for specific building types experiencing different damage states. Default relationships between occupancy classes and building types are provided to infer building inventory characteristics. Fragility curves (used for estimating damage) with default means and variances are supplied for each model building type. The user can modify all of these parameters if better information is available. Modifying default parameters is discussed in Chapters 4 through 8.

3.5.3 Viewing Default Parameters

To view the default classes, use the **Analysis|Parameters|Default Classes** menu. This window gives you the option to view and change default classes for transportation lifelines, utility lifelines, essential facilities and high potential loss facilities. For example, for health care facilities the default occupancy is EFHM (hospital with 50 to 150 beds). If you want to change the default to EFHS (hospital with less than 50 beds), you would use this window.

Chapter 4. Data Needed for More Complete Loss Estimation Study

Figure 4.1 shows the steps that are typically performed in assessing and mitigating the impacts of a natural hazard such as an earthquake, hurricane or flood. In order to estimate regional losses resulting from a natural disaster, you need to have an understanding of both the size of the potential event (hazard identification) and the characteristics of the population and the environment that will be impacted (inventory collection). For example, a flood that occurs near a densely populated region will cause different types of losses than one that occurs in a mostly agricultural region. Similarly, the economic impacts of an earthquake in a highly industrialized region will be different from those in a region that predominantly supports a service economy. Thus, to reliably model the losses in your region, you will need to collect a wide variety of data so as to be able to characterize the buildings and lifelines, the population, and the structure of the local economy.

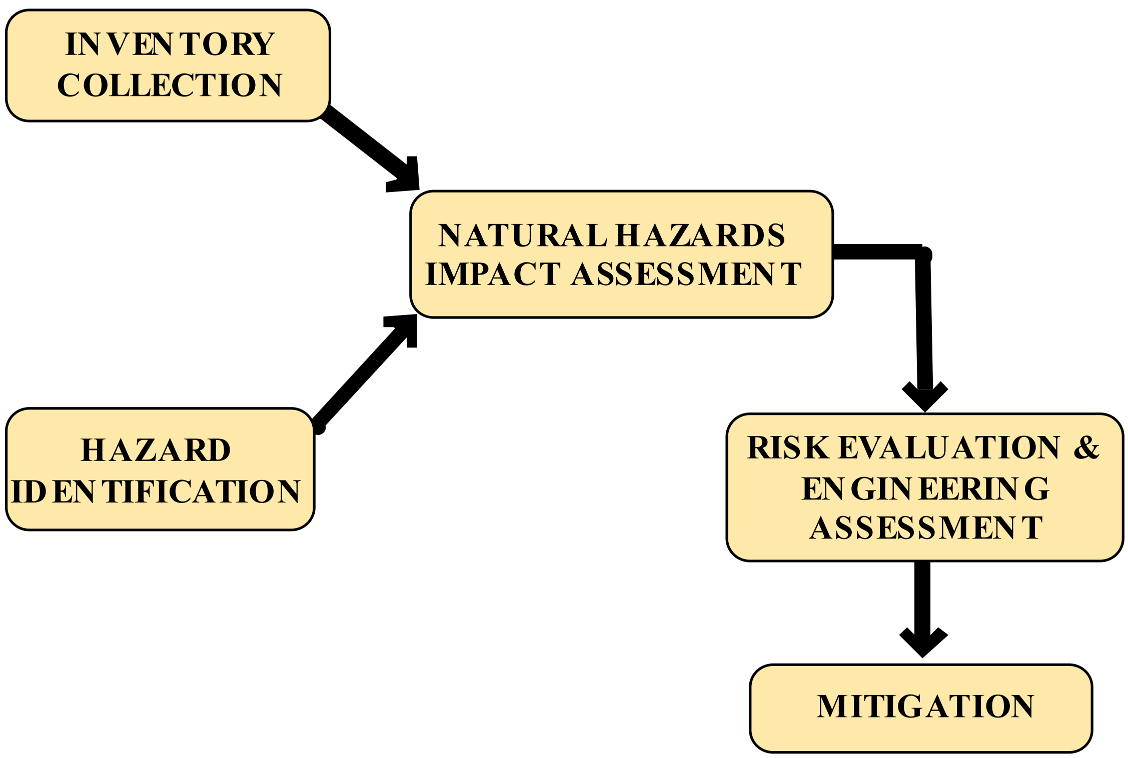
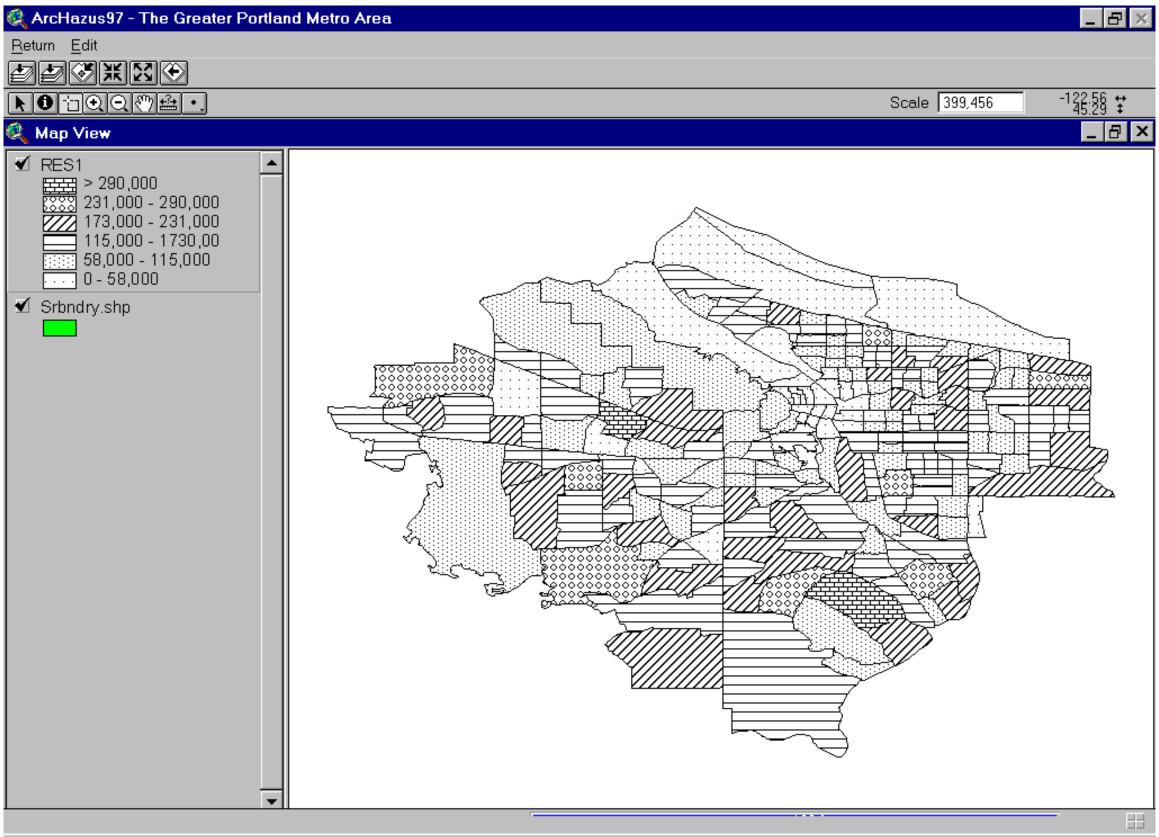


Figure 4.1 Steps in assessing and mitigating losses dues to natural hazards.

4.1 Developing a Regional Inventory

In developing a regional inventory, it is almost impossible from a cost point of view to individually identify and inventory each man-made structure. Some important structures such as hospitals, schools, emergency operation centers, fire stations, important bridges, and electrical power substations may be identified individually, but the majority of buildings in a region are grouped together collectively and identified by their total value or square footage. To permit modeling of spatial variation in types and occupancies of buildings, a region is built up from sub-regions, and the inventory is collected for each sub-region. In the earthquake loss estimation methodology, **census tracts** are used as the basic sub-region unit, and all regions are built up by aggregating census tracts. Thus for each census tract, your inventory might consist of the number of square feet of wood frame buildings, the number of square feet of unreinforced masonry buildings and so on for each building type. Figure 4.2 shows the inventory of single-family residential construction in a region. Note that the value of single-family residential construction is stored and displayed for each census tract in the region.



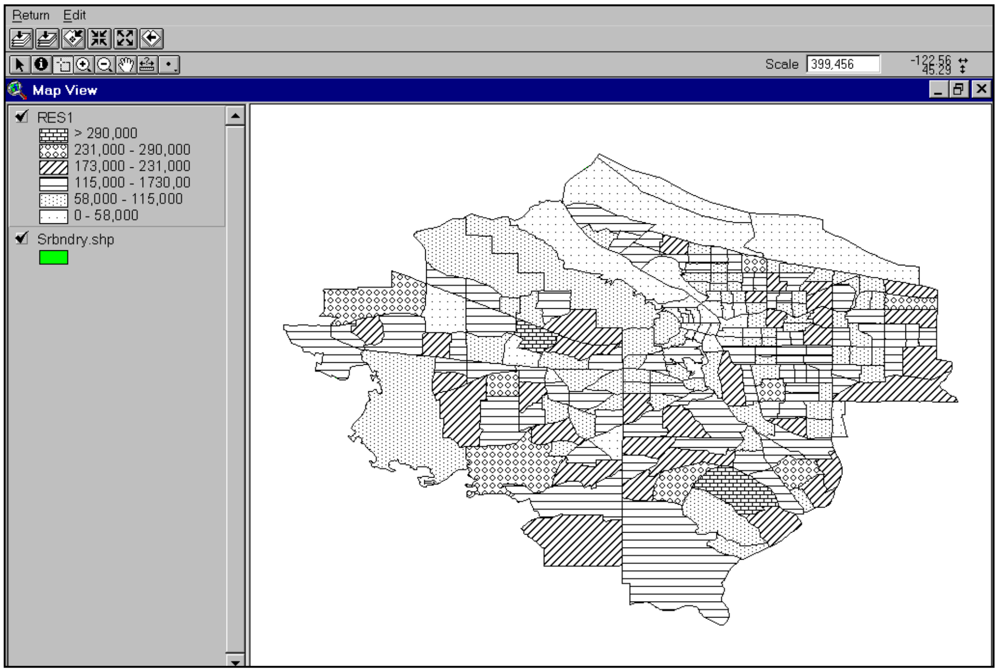


Figure 4.2 Value of single-family residential homes (RES1) by census tract.

In the methodology, the residential, commercial and industrial buildings that are not identified specifically are called the **general building stock**. General building stock is inventoried by calculating, for each census tract, the total square footage of groups of buildings with specific characteristics (i.e., calculating the total square footage of low-rise unreinforced masonry structures). Collecting even this "simplified" inventory can be problematic. There are rarely reliable and complete databases that provide the necessary information such as building size, building occupancy, building height and structural system that could be used to obtain total values for each census tract. Therefore, in general, inferences are made about large groups of buildings based on land use patterns, census information, business patterns, assessors' files, insurance files, etc. Inferences can take the form, "if this is a residential area, 50% of the buildings are single family wood structures and 50% are multi-family wood structures". While there are inaccuracies in the inventory of general building stock due to inferences that are made, the error tends to be random and can be accounted for in the probabilistic aspects of the methodology. Similar types of inferences are made with respect to lifeline systems (e.g., the number of miles of water supply pipe in a census tract may be inferred from the number of miles of streets).

In contrast to the inventory of general building stock which is maintained in terms of total value per census tract, facilities that have some special significance such as essential facilities or components of lifeline systems can be maintained in the database by individual location. Correspondingly losses for essential facilities and some lifeline components are computed for individual facilities, while losses for general building stock are calculated by census tract. While some inferences can be used for site-specific facilities when data are unavailable, often you will have better access to databases about these facilities than you will for general building stock. Sometimes there will be few enough of these facilities that you can actually go to the site and collect the required inventory information. Sources of inventory information and how to go about collecting it are discussed in Chapter 5.

4.2 Standardizing and Classifying Data

There are two issues that must be considered in the development of an inventory: classification of data, and collection and handling of data. Classification systems are essential to ensuring a uniform interpretation of data and results. As discussed earlier, it is almost impossible, from a cost point of view, to identify and individually inventory each building or component of each lifeline. Thus losses in a regional study are estimated based on general characteristics of buildings or lifeline components, and classification systems are a tool to group together structures or lifeline components that would be expected to behave similarly in a seismic event. For each of the types of data that must be collected to perform a loss study, a classification system has been defined in this methodology.

The building classification system used in this methodology has been developed to provide an ability to differentiate between buildings with substantially different damage and loss characteristics. In general, buildings behave differently due to the types of structural systems they have (i.e. wood versus steel), the codes to which they were designed, their heights, their shapes or footprints, and local construction practices. As a consequence of the variations in design, shape, height etc., no two buildings will behave exactly the same when subjected to an earthquake. Therefore, **model building types** are defined to represent the average characteristics of buildings in a class. Within any given building class there will be a great deal of variation. The damage and loss prediction models in this methodology are developed for model building types and the estimated performance is based upon the "average characteristics" of the total population of buildings within each class.

Table 4.1 provides a summary of the 36 model building types that have been defined in the methodology. Each model building type is defined by a short description of the related structural system. These short descriptions can be found in Appendix B. It can be seen in the table in Appendix B that there are 16 general model building types (shown in bold) with some building types being subdivided by height. In addition, the seismic design level, which reflects the relationship between design quality and extent of damage, can be used to further classify each model building type. Four design levels are defined in the methodology: High-Code, Moderate-Code, Low-Code and Pre-Code. For a detailed discussion of how the classification system was developed and the characteristics that were used to differentiate classes, see Chapters 3 and 5 of the Technical Manual.

General building stock is also classified based on occupancy. The occupancy classification is broken into **general occupancy** and **specific occupancy** classes. For the methodology, the general occupancy classification system consists of seven groups: residential, commercial, industrial, religion/non profit, government, education and lifelines. Specific occupancy consists of 28 classes. Occupancy classes are used to account for the fact that contributions to losses are from damage to both the structural system and non-structural elements, and the types and costs of non-structural elements are often governed by the occupancy of the building, e.g., in a warehouse there may be few expensive wall coverings, whereas a bank may have expensive lighting and wall finishes. If the structural systems of these two buildings experience the same amount of damage, the costs to repair the bank will be greater than the warehouse due to the more expensive finishes. Other issues related to occupancy may also be important, such as rental costs, number of employees, type of building contents and importance of function. Finally, a great deal of inventory information, such as county business patterns or census data, is only available by occupancy.

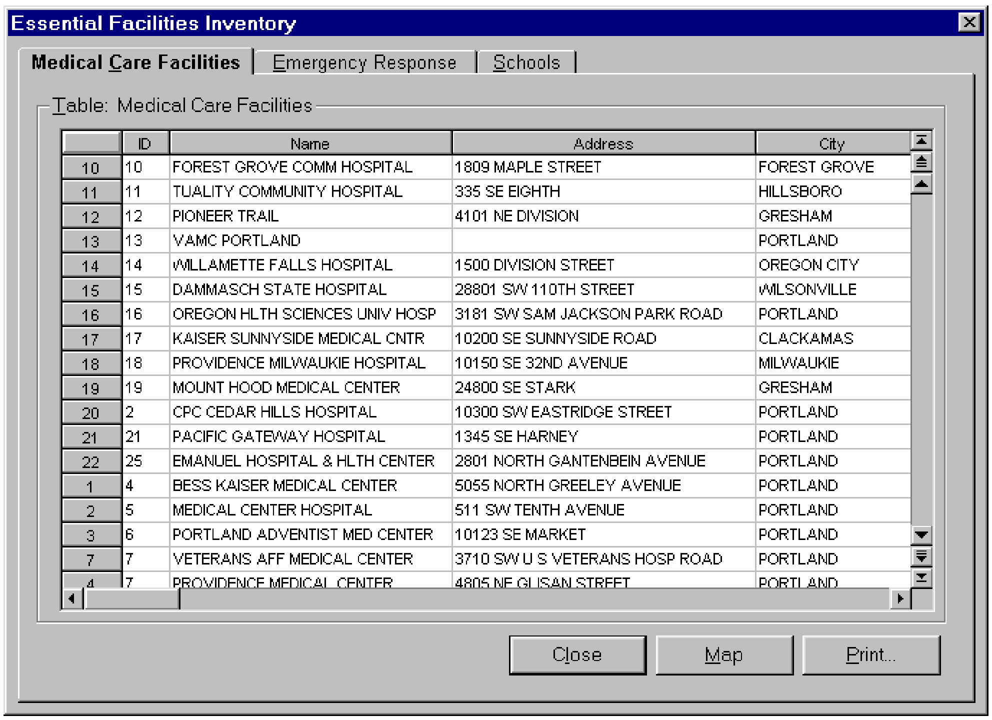
Classification systems developed for soils, model building types, building occupancies, essential facilities, high potential loss facilities, and lifelines are listed in Appendix A. Descriptions of the characteristics of lifeline components are found in Appendix C.

Table 4.1 Structural building classifications (Model Building Types)

No.	Label	Description	Height			
			Range		Typical	
			Name	Stories	Stories	Feet
1 2	W1 W2	Wood, Light Frame (≤ 5,000 sq. ft.) Wood, Commercial and Industrial (> 5,000 sq. ft.)		1 - 2 All	1 2	14 24
3 4 5	S1L S1M S1H	Steel Moment Frame	Low-Rise Mid-Rise High-Rise	1 - 3 4 - 7 8+	2 5 13	24 60 156
6 7 8	S2L S2M S2H	Steel Braced Frame	Low-Rise Mid-Rise High-Rise	1 - 3 4 - 7 8+	2 5 13	24 60 156
9	S3	Steel Light Frame		All	1	15
10 11 12	S4L S4M S4H	Steel Frame with Cast-in-Place Concrete Shear Walls	Low-Rise Mid-Rise High-Rise	1 - 3 4 - 7 8+	2 5 13	24 60 156
13 14 15	S5L S5M S5H	Steel Frame with Unreinforced Masonry Infill Walls	Low-Rise Mid-Rise High-Rise	1 - 3 4 - 7 8+	2 5 13	24 60 156
16 17 18	C1L C1M C1H	Concrete Moment Frame	Low-Rise Mid-Rise High-Rise	1 - 3 4 - 7 8+	2 5 12	20 50 120
19 20 21	C2L C2M C2H	Concrete Shear Walls	Low-Rise Mid-Rise High-Rise	1 - 3 4 - 7 8+	2 5 12	20 50 120
22 23 24	C3L C3M C3H	Concrete Frame with Unreinforced Masonry Infill Walls	Low-Rise Mid-Rise High-Rise	1 - 3 4 - 7 8+	2 5 12	20 50 120
25	PC1	Precast Concrete Tilt-Up Walls		All	1	15
26 27 28	PC2L PC2M PC2H	Precast Concrete Frames with Concrete Shear Walls	Low-Rise Mid-Rise High-Rise	1 - 3 4 - 7 8+	2 5 12	20 50 120
29 30	RM1L RM2M	Reinforced Masonry Bearing Walls with Wood or Metal Deck Diaphragms	Low-Rise Mid-Rise	1-3 4+	2 5	20 50
31 32 33	RM2L RM2M RM2H	Reinforced Masonry Bearing Walls with Precast Concrete Diaphragms	Low-Rise Mid-Rise High-Rise	1 - 3 4 - 7 8+	2 5 12	20 50 120
34 35	URML URMM	Unreinforced Masonry Bearing Walls	Low-Rise Mid-Rise	1 - 2 3+	1 3	15 35
36	MH	Mobile Homes		All	1	10

4.3 Inventory Databases

Once data have been collected, they can be accessed more easily and updated in the future if they are maintained in an orderly manner. Database formats have been developed for all of the data that you will collect to perform the loss study. An example of a database of medical care facilities as you would see it when using **HAZUS** is found in Figure 4.3. The database contains fields that allow you to store a variety of attributes about each facility. For example, in addition to the name, address and city of the medical facilities as shown in Figure 4.3, you have space to enter the zip code, the name and phone number of a contact at the facility, the class of facility (small, medium, large), the number of beds, the structural type and several other attributes. There is also a “comments” field that allows you to include any information that does not fit into other fields. Some of these fields are not shown in the figure but can be accessed if you scroll to the right. You will notice in this example that some of the facilities are missing information such as address. A missing address does not prevent a facility from being included in the database or in the analysis. In order to be included, only the latitude, longitude and county need be specified while other attributes can be inferred (with corresponding uncertainty).

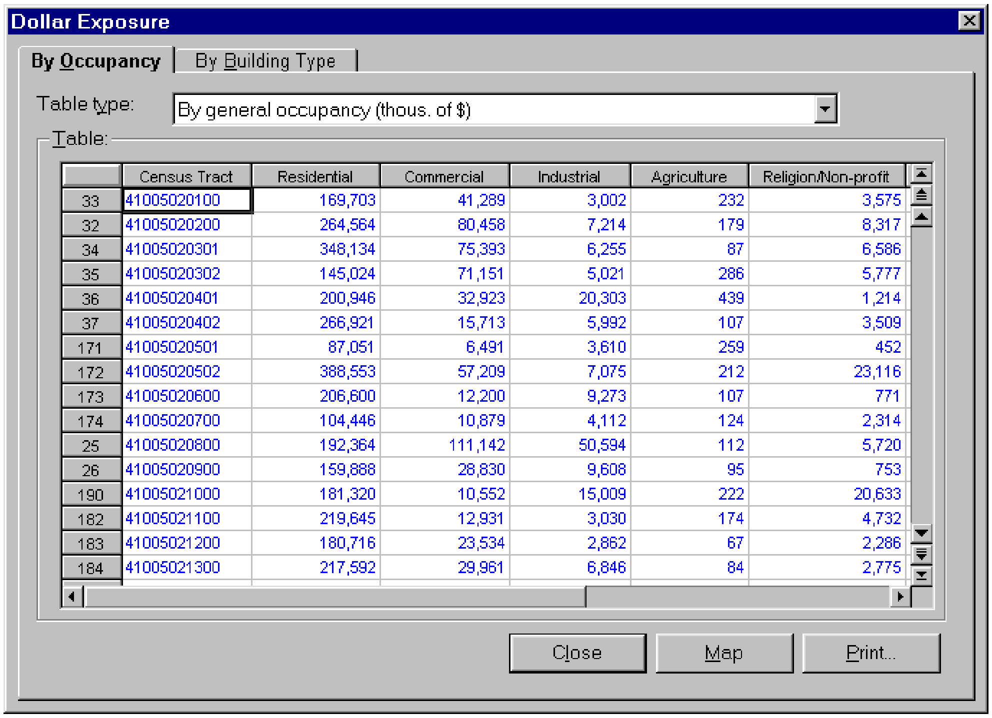


	ID	Name	Address	City
10	10	FOREST GROVE COMM HOSPITAL	1809 MAPLE STREET	FOREST GROVE
11	11	TUALITY COMMUNITY HOSPITAL	335 SE EIGHTH	HILLSBORO
12	12	PIONEER TRAIL	4101 NE DIVISION	GRESHAM
13	13	VAMC PORTLAND		PORTLAND
14	14	WILLAMETTE FALLS HOSPITAL	1500 DIVISION STREET	OREGON CITY
15	15	DAMMASCH STATE HOSPITAL	28801 SW 110TH STREET	WILSONVILLE
16	16	OREGON HLTH SCIENCES UNIV HOSP	3181 SW SAM JACKSON PARK ROAD	PORTLAND
17	17	KAISER SUNNYSIDE MEDICAL CNTR	10200 SE SUNNYSIDE ROAD	CLACKAMAS
18	18	PROVIDENCE MILWAUKIE HOSPITAL	10150 SE 32ND AVENUE	MILWAUKIE
19	19	MOUNT HOOD MEDICAL CENTER	24800 SE STARK	GRESHAM
20	2	CPC CEDAR HILLS HOSPITAL	10300 SW EASTRIDGE STREET	PORTLAND
21	21	PACIFIC GATEWAY HOSPITAL	1345 SE HARNEY	PORTLAND
22	25	EMANUEL HOSPITAL & HLTH CENTER	2801 NORTH GANTENBEIN AVENUE	PORTLAND
1	4	BESS KAISER MEDICAL CENTER	5055 NORTH GREELEY AVENUE	PORTLAND
2	5	MEDICAL CENTER HOSPITAL	511 SW TENTH AVENUE	PORTLAND
3	6	PORTLAND ADVENTIST MED CENTER	10123 SE MARKET	PORTLAND
7	7	VETERANS AFF MEDICAL CENTER	3710 SW U S VETERANS HOSP ROAD	PORTLAND
4	7	PROVIDENCE MEDICAL CENTER	4805 NE GLISAN STREET	PORTLAND

Figure 4.3 Database of medical care facilities.

Figure 4.4 shows an inventory database for general building stock. For general building stock, data are stored by census tract and for each census tract you will find the total monetary value for each of the seven general occupancy types: residential, commercial, industrial, agricultural, religious/non-profit, governmental and educational. For example, in census tract 41005020100, the value of residential construction is $169.7 million and for commercial construction is $41.3 million. You can also view the inventory in terms of each of the 28 specific occupancy types (RES1, RES2, RES3, etc.) by clicking on **By specific occupancy** in the **Table type:** box shown at the top of Figure 4.4.

You will find that data entry is in a familiar spreadsheet format to allow for easy entry and modification. Moving around in the database involves using the arrow keys at the bottom and to the right of the window. Discussion of how to display, print, modify and map your inventories is found in Chapter 7. All data are in a *.dbf format that can be read by Paradox, Dbase, Excel and a variety of other data management programs. The structures of all the databases that are maintained by **HAZUS** are found in Appendix E. A discussion of default databases is found in Section 3.5.



	Census Tract	Residential	Commercial	Industrial	Agriculture	Religion/Non-profit
33	41005020100	169,703	41,289	3,002	232	3,575
32	41005020200	264,564	80,458	7,214	179	8,317
34	41005020301	348,134	75,393	6,255	87	6,586
35	41005020302	145,024	71,151	5,021	286	5,777
36	41005020401	200,946	32,923	20,303	439	1,214
37	41005020402	266,921	15,713	5,992	107	3,509
171	41005020501	87,051	6,491	3,610	259	452
172	41005020502	388,553	57,209	7,075	212	23,116
173	41005020600	206,600	12,200	9,273	107	771
174	41005020700	104,446	10,879	4,112	124	2,314
25	41005020800	192,364	111,142	50,594	112	5,720
26	41005020900	159,888	28,830	9,608	95	753
190	41005021000	181,320	10,552	15,009	222	20,633
182	41005021100	219,645	12,931	3,030	174	4,732
183	41005021200	180,716	23,534	2,862	67	2,286
184	41005021300	217,592	29,961	6,846	84	2,775

Figure 4.4 Value of general building stock inventory.

4.4 Inventory Requirements

Each module in the earthquake loss estimation methodology requires a specific set of input data. The required data can take two forms. The first is inventory data such as the square footage of buildings of a specified type, the length of roadways or the population in the study region. These are used to estimate the amount of exposure or potential damage in the region. The second data type includes characteristics of the local economy that are important in estimating losses (e.g., rental rates, construction costs or regional unemployment rates). This section summarizes the inventory information that is needed to perform a loss study.

Table 4.2 lists the inventory required for each type of output that is provided in the methodology. You will find that there are varying degrees of difficulty in developing this inventory. For example, in your region excellent records may be available concerning the police and fire stations and schools. On the other hand you may find that it is difficult to obtain detailed information about some of the lifeline facilities. An issue that you will likely run into is that data you collect will have to be adjusted so that the inventory is classified according to the systems defined in the methodology. In some cases, you may find that you require a consultant to assist with the classification of data. Default values are provided for most of the input information (see Section 3.5). In Table 4.2, a star is placed next to those input requirements that do not have default values.

Table 4.2 Minimum inventory for the Earthquake Loss Estimation Methodology

Desired Output	Required Input
POTENTIAL EARTH SCIENCE HAZARDS (PESH)	
Intensities of ground shaking for scenario earthquake	Definition of scenario earthquake and attenuation functions, soil map
Permanent ground displacements	Liquefaction and landslide susceptibility maps
Liquefaction probability	Liquefaction susceptibility map
Landsliding probability	Landslide susceptibility map
GENERAL BUILDING STOCK	
Damage to general building stock - by occupancy or building type	Total square footage of each occupancy by census tract, occupancy to building type relationships
ESSENTIAL FACILITIES	
Damage and functionality of essential facilities	Location and building type of each facility
Loss of beds and estimated recovery time for hospitals	Number of beds at each facility
HIGH POTENTIAL LOSS FACILITIES	
Map of high potential loss facilities	Locations and types of facilities
Damage and loss for military installations	Location, building type, and value of military installations
TRANSPORTATION LIFELINES	
Damage to transportation components	Locations and classes of components
Restoration times of transportation components	Estimates of repair times for each level of damage
UTILITY LIFELINES	
Damage to utility components	Locations and classes of components
Restoration times of utility components	Estimates of repair times for each level of damage
INDUCED PHYSICAL DAMAGE	
Inundation exposure	Inundation map*
Number of ignitions and percentage of burned area by census tract	General building stock inventory, average speed of fire engines, and speed and direction of wind
Map of facilities containing hazardous materials	Inventory of facilities containing hazardous materials
Type and weight of debris	General building stock inventory and estimates of type and unit weight of debris

Table 4.2 (cont.) Minimum inventory for the Earthquake Loss Estimation Methodology

Desired Output	Required Input
DIRECT SOCIAL LOSSES	
Number of displaced households	Number of households per census tract
Number of people requiring temporary shelter	Population including ethnicity, age, income
Casualties in four categories of severity based on event at three different times of day	Population distribution at three times of day
ECONOMIC LOSSES	
Structural and nonstructural cost of repair or replacement	Cost per square foot to repair damage by structural type and occupancy for each level of damage
Loss of contents	Contents value as percentage of replacement value by occupancy
Business inventory damage or loss	Annual gross sales in $ per square foot
Relocation costs	Rental costs per month per square foot by occupancy
Business income loss	Income in $ per square foot per month by occupancy
Employee wage Loss	Wages in $ per square foot per month by occupancy
Loss of rental income	Rental costs per month per square foot by occupancy
Cost of damage to transportation components	Costs of repair/replacement of components
Cost of damage to utility components	Costs of repair/replacement of components
INDIRECT ECONOMIC LOSSES	
Long-term economic effects on the region	Unemployment rates, input/output model parameters

4.5 Relationship Between Building Types and Occupancy Classes

As discussed earlier, contributions to the loss estimates come from damage to both the structural system and the non-structural elements. Thus in order to estimate losses, the structural system must be known or inferred for all of the buildings in the inventory. Since much of the inventory information that is available is based on occupancy classes, inferences must be made to convert occupancy class inventory to model building types. The relationship between structural type and occupancy class will vary on a regional basis. For example, in California, the occupancy RES1 (single family dwelling) can be 95% W1 (wood, light frame) and 5% URML (unreinforced masonry bearing wall, low rise). In a city on the east coast, the relationship can be 40% W1, 50% URML and 10% RM1L (reinforced masonry bearing wall with wood or metal deck diaphragm, low rise).

In most cases, structures in a study region or census tract have been built at different times. As a result, some structures might have been built before 1950, some between 1950 and 1970 and others after 1970. An exception can be a large development that occurred over a short period in which most structures would have about the same age. Since construction practices change over time, so does the mix of structural types. For example, Table 4.3 shows a typical mix of low-rise model building types for west coast construction for occupancy class COM1 (retail trade). Looking at the building type S5L (low rise steel frame with unreinforced masonry infill walls) it can be seen that before

1950, 20% of stores were built using this structural system, whereas after 1970 none were.

Table 4.3 Distribution of floor area for occupancy COM1, Low-Rise West Coast Construction

Age	Model Building Type													
	2	**3**	**6**	**9**	**10**	**13**	**16**	**19**	**22**	**25**	**26**	**29**	**31**	**34**
	W2	S1L	S2L	S3	S4L	S5L	C1L	C2L	C3L	PC1	PC2L	RM1L	RM2L	URML
Pre-1950	22%	2%		6%	3%	20%		17%	1%			6%		23%
1950 to 1970	34%	3%	1%	3%	2%	4%		13%	5%	10%	1%	18%	2%	4%
Post-1970	26%	9%	1%	2%	1%		6%	10%	1%	15%	5%	21%	3%	

While the relationship shown in Table 4.3 can be developed from data collected locally, **HAZUS** provides default mappings of specific occupancy classes to model building types. Three general mapping schemes have been defined and assigned depending upon whether a state is in the Western U. S., the Mid-West or the Eastern U. S. Table 3C.1 of the *Technical Manual* provides the regional classification for each state. Default mappings will be the same for regions that are created anywhere within a particular state. It will be up to you to modify these defaults to reflect characteristics that are specific to your local region.

In addition to geographical location, the distributions can also depend on when the buildings were constructed and whether they are low, medium or high-rise structures. Age is important because it affects the types of structures that exist in a region. For example, if most of the buildings in a region were built after 1970, there will be very few unreinforced masonry structures. An example of how age and height information affects the mix of building types is shown as follows:

Suppose you determined the following information:

All of the buildings in a census tract are low-rise
50% of the buildings were built before 1950
30% of the buildings were built between 1950 and 1970
20% of the buildings were built after 1970.

A new occupancy mapping can be calculated by combining the different mapping schemes presented in Table 4.3. The new occupancy mapping for COM1 would be determined by multiplying the first row of Table 4.3 by 0.5, the second row by 0.3, the third row by 0.2 and then summing. To calculate the modified occupancy mapping for the building type W2, the calculation would be:

$$0.5 \times 22\% + 0.3 \times 34\% + 0.2 \times 26\% = 26\%$$

The resulting occupancy mapping is shown in Table 4.4. Similar calculations would occur if you were also to include a mix of building heights.

Table 4.4 Modified occupancy mapping for COM1 to include age mix

Specific Occupancy Class	Model Building Type													
	2	**3**	**6**	**9**	**10**	**13**	**16**	**19**	**22**	**25**	**26**	**29**	**31**	**34**
	W2	S1L	S2L	S3	S4L	S5L	C1L	C2L	C3L	PC1	PC2L	RM1L	RM2L	URML
COM1	26%	4%	1%	4%	2%	11%	1%	15%	2%	6%	1%	13%	1%	13%

Modifying occupancy to model building type relationships in **HAZUS** is discussed in Chapter 7. Developing custom mapping schemes using local data and experts is discussed in Chapter 5. Developing mapping schemes using tax assessor or property records is discussed in Chapter 8.

Chapter 5. Collecting Inventory Data

A limiting factor in performing a loss estimation study is the cost and quality of the inventory. Collection of inventory is without question the most costly part of performing the study. Crude estimates of damage do not require extensive inventory data and can be performed on a modest budget. As the damage estimates become more precise, the need for inventory information increases, as does the cost to obtain this information. Since many municipalities have limited bud gets for performing an earthquake loss estimation study, HAZUS accommodates different users with different levels of resources. It should be understood, however, that the uncertainty of the loss estimates increases with less detailed inventory, and that there are uncertainties associated with modules other than inventory. For example, even with a perfectly accurate inventory of soils and buildings in the study area, **HAZUS** or any other loss estimation methodology cannot infallibly predict damage and associated losses.

Inventory information will come from and/or be collected in databases compatible with the GIS technology. Once collected and entered into the database, the data will also be available to users for other applications. For example, data collected for an earthquake loss estimation model in San Bernardino County, California is now being used for city planning purposes.

5.1 Sources of Information

As discussed in Chapter 3, the use of default parameters and default inventory in performing a loss study introduces a great deal of uncertainty. Loss studies performed with only default data may be best for preliminary assessments to determine where more information is needed. For example, if the analysis using only default information suggests that the scenario earthquake will cause a great deal of damage in a particular part of your community, you may want to collect more detailed inventory for that area to have a better understanding of the types of structures, the essential facilities and businesses that will be affected. Similarly, your default analysis may indicate that components of your electrical system are vulnerable. Based on this outcome, you may wish to perform walk-downs of the substations to see how they are really configured. In short, it is likely that you will want to augment and update the default data that are supplied with **HAZUS**.

Regional building inventories can be built up from a variety of sources including federal government, state government, local government and private sector databases. These databases may be useful for obtaining facility-specific information. Following are examples of sources of inventory data that can be accessed to enhance the **HAZUS** building data.

- Locations of government facilities such as military installations and government offices
- Databases of hazardous buildings such as the California Safety Commission database of unreinforced masonry buildings
- Tax assessor's files
- School district or university system facilities
- Databases of fire stations or police stations
- Databases of historical buildings
- Databases of churches and other religious facilities
- Postal facilities (ATC-26, 1992)
- Hospitals (The AHA Guide of the American Hospital Association; ATC-23A, 1991A)
- Public and private utility facility databases
- Department of transportation bridge inventory
- Dun and Bradstreet database of business establishments
- Insurance Services Office's files of large buildings that is used for fire assessment real estate databases

It should be kept in mind that each of these databases includes only a portion of the building stock, and none is complete. For example, the tax assessor's files do not include untaxed properties such as government buildings, public works and tax-exempt private properties. School district databases probably will not include private schools. A good discussion of available databases is found in ATC-13 (1985) and Vasudevan et al. (1992), although some of the databases discussed in these two references are specific to California.

Another possible source of inventory information is previous loss or hazard studies. An example is "Earthquake Hazard Mitigation of Transportation Facilities" (Allen et al., 1988), which contains a listing of all "seismically significant" points along priority routes surrounding the New Madrid Seismic Zone. This listing includes dams, pipelines, high fills, cut slopes, signs, tanks, mines, buildings subject to collapse, faults and bridges. This type of list could certainly be used as a starting point for developing a complete lifeline inventory. Unfortunately many regional loss studies do not contain a listing (either hard copy or electronic) of the inventory that was used.

The following sections contain more detailed information about sources of information for specific modules of the earthquake loss estimation methodology.

5.1.1 Potential Earth Science Hazards (PESH)

5.1.1.1 Soil Maps

In order to account for the effects of local soil conditions for estimating ground motion and landslide and liquefaction potential, you need to enter a soil map into **HAZUS**. High-resolution (1:24,000 or greater) or lower resolution (1:250,000) geologic maps are generally available from geologists or regional U. S. Geological Survey offices, state geological agencies, regional planning agencies or local government agencies. There are a variety of schemes available for classifying soils. The geologic maps typically identify the age, depositional environment, and material type for a particular mapped geologic unit. You will require the services of a geologist or geotechnical engineer to convert the classification system on your map to the one used in this methodology (see Table A.1 in Appendix A).

If a previous regional loss study has been conducted, you may find that the study contains soil maps. Once again, for use with **HAZUS** you may need to convert the classification to the one described in Table A.1.

5.1.1.2 Liquefaction Susceptibility

Liquefaction susceptibility maps, which may be utilized in the hazard analysis, have been produced for a few selected regions, i.e., greater San Francisco region (ABAG, 1980); San Diego (Power, et. al., 1982); Los Angeles (Tinsley, et. al., 1985); San Jose (Power, et. al., 1991); Seattle (Grant, et. al., 1991); among others. Applied Technology Council published a summary of available regional liquefaction hazard maps (Power and Holtzer, 1996).

If no liquefaction susceptibility maps are available, and liquefaction is a potential hazard, a geologist or geotechnical engineer will be required to develop one. The level of effort required depends on the size of the region and the desired resolution of the contours. A crude map with a great deal of uncertainty can be developed in one week using the procedure outlined in Chapter 4 of the *Technical Manual*. An experienced geotechnical engineer with knowledge of the region can develop a simple map in about one month. A detailed map can require a separate study that could take several months to years. Digitizing a map can take a day to a week depending on the size and complexity of the region.

5.1.1.3 Landslide Susceptibility

If no landslide susceptibility maps are available, and landslides are potential hazards, a geologist or geotechnical engineer will be required to develop one. The level of effort required depends on the size of the region, and the desired resolution of the contours.

5.1.2 General Building Stock

Developing the inventory for general building stock most likely will require combining information from several sources. As mentioned earlier, there is no complete single source of general building stock information. In addition, you will find that the quality and format of the information varies dramatically from county to county. Furthermore, since general building stock inventory is not normally compiled by counting individual buildings, but instead is developed using various assumptions and inferences, you may find that you need input from local engineers and building officials to ensure that you have captured unique aspects of the region.

5.1.2.1 County Tax Assessor Files

County Tax Assessor files may or may not be a source of general building stock information. Since Tax Assessor files are kept for the purposes of collecting property taxes, they may contain little or no useful structural information. The quality of the data varies widely from county to county. The most useful data will contain occupancy, structural type, square footage, height, and age. Generally, the files contain good information on the use (occupancy) of the building, since tax rates often depend on building use; therefore, either a land use code and/or a specific occupancy of the building is included. Ideally, if good information is available, you can use the Building Data Import Tool (BIT) described in Chapter 8 to develop region-specific occupancy to model building type relationships. However, several problems generally occur:

- Many Tax Assessor files do not contain building square footage information. In some counties, square footage is not recorded at all. In other cases, it is only sometimes recorded. You should ask the Tax Assessor before you buy the records as to what percentage of the records contain square footage information.
- Many Tax Assessor files contain square footage information that may be difficult to interpret. For example, a property that is owned by several owners (such as an office building) may appear several times in the files. Perhaps Owner #1 owns two floors of the building and Owner #2 owns eight floors. The Tax Assessor's records may not reflect the fact that Owner #1 owns 20% of the Building and Owner #2 owns 80%. In fact, sometimes both property entries will show the total building square footage instead of Owner #1 with 20% of the square footage and Owner #2 with 80%. Without going through the files record by record, this is difficult to fix.
- Since some occupants that do not pay taxes (e.g., schools, churches, and government buildings) are not usually well represented in the Tax Assessor's files. Often these types of properties include an entry and an Assessor's Parcel Number, but omit assessed value, square footage, structural type, height or age.
- Structural type may not be recorded at all in the files. You need to ask the Tax Assessor what percentage of the records has structural information before you buy the files.
- Similar comments about missing data can be made about age and height.
- Some or all of the properties in the Tax Assessor's files may contain no address information. In some counties, the Assessor's Parcel Number is the only identifier in the database. While this can be mapped to location, it is not an easy task. The file may contain a mailing address of the owner, but this is not a reliable address to locate properties. In other cases, selected properties are missing addresses. Address information is important because you can use addresses to see how the types and occupancies of buildings vary geographically.
- Perhaps one of the most difficult problems is that, in many cases, the Tax Assessors use a system of classifying structures that is difficult to map to the model building types defined in Table A.2. For example, there may only be five building types, such as steel frame, wood frame, fire resistant, masonry and other. It is difficult from this very simple classification system to determine whether masonry structures are reinforced or unreinforced. Similarly, it is impossible to distinguish braced steel frames from moment resisting steel frames. Fire resistant construction could include a variety of structural types consisting of concrete or masonry. In these cases you will need to use local experts to help define the mix of construction.

5.1.2.2 Commercial Sources of Property Data

There are a variety of on-line services that maintain databases of real property that are designed to assist realtors and other commercial enterprises in gathering property sales data and owner information, and to assist in generating mailing lists and labels. The databases are developed from County Tax Assessor's files and updated as properties are sold or as other information becomes available.

You can subscribe to one of these services and download records over a telephone line, or you can order CDs of selected counties and use software supplied by the service to extract the records on your own computer. It seems that different services tend to focus their efforts in different parts of the United States. Therefore, one service may not maintain a database on the county you wish to study while another service may. Typical costs for a county are $300 to $1000, depending on its size. Addresses and phone numbers of several on-line services are listed below. (Note: While these are California addresses, they carry data from around the country. There may be local offices for these companies.) If one of these services does not have the counties in your study region you may find that there is a service in your own community that maintains these types of records. Local real estate agencies or the local Board of Realtors would probably know about this. Alternatively, you could try calling local Tax Assessors and see if they have sold their data to this type of service.

Some of the Commercial Sources of Property Data are:

Experian Property Data (formally known as TRW)
3610 Central Avenue
Riverside, CA 92506
(800) 345-7334

Transamerica Information Management (offer a program called MetroScan)
1860 Howe Avenue, Suite 455
Sacramento, CA 98525
(800) 866-2783

DataQuick Information Services
9171 Towne Centre Drive, #404
San Diego, CA 92122
(800) 950-9171

The commercially available databases contain the same type of problems found in the County Assessor's data since they were obtained from them. Perhaps one of the main advantages of the commercially available data is that you can get some technical support in trying to put the data into databases. The software they provide enables you to look at individual properties or to sort properties in a variety of ways such as by zip code, or by census tract, or by age, or by occupancy to name a few. On the other hand, assessor's data are often stored on 9-track tape and little instruction is provided about how to extract the data.

One note of caution: The software that commercial services provide is limited in that you cannot extract the entire county at once. You are limited to extracting a certain number of records (for example 9000) at a time. A large county such as Los Angeles contains over two million records. Thus extracting all of the records for the county can be a tedious task, sometimes taking several days.

5.1.3 Occupancy to Model Building Type Relationships

Developing occupancy to model building type mapping schemes that accurately reflect your study region will require combining available data with input from local experts. The Building Data Inventory Tool (BIT) discussed in Chapter 8 has a utility that develops occupancy to model building type mapping schemes from the assessor's files or other commercially available property data. Collecting supplemental information about local building practices through the use of a questionnaire and/or a workshop is recommended.

A questionnaire that was used to collect region specific information for developing some of the default mapping schemes in **HAZUS** is found in Appendix F. This questionnaire was used in a one-day workshop that was attended by about ten individuals with significant experience with local construction that included design engineers, building officials and a university professor. Workshop participants were presented with preliminary occupancy to model building type relationships that were developed from County Assessor's files. Using the questionnaire to focus on the workshop, participants modified preliminary schemes based on their own experience. The advantage of using a workshop instead of sending the questionnaires out was that participants were able to discuss their different opinions and come to a consensus on a reasonable representation of local practices.

5.1.4 Essential Facilities

Essential facilities, to a great degree, are owned or licensed by government agencies. Consequently, lists of these facilities often have been compiled for a region. Therefore, the time associated with collecting inventory on essential facilities may be relatively small; perhaps a day or two, if no building type information is collected and default occupancy to building type mappings are used. However, more detailed building type information may require a site visit for each facility.

Some essential facilities are subject to special design and construction considerations that may help these structures perform better than the typical building when subjected to an earthquake. Data you collect with respect to special seismic design and construction considerations may be useful later on in identifying whether structures are high-code, moderate-code or low-code design. The criteria for determining how essential facilities fit in these categories are summarized in Table 5.1. An additional bias can also be defined for essential facilities to reflect the potential for different damage and losses based on the vintage of the design code. This is described in Section 6.7.1 of the *Technical Manual*.

Table 5.1 Suggested seismic design levels for essential facilities

Seismic Design Level (I = 1.5)	Seismic Zone (1994 Uniform Building Code)	Map Area (1994 NEHRP Provisions)
High-Code	4	7
Moderate-Code	2B	5
Low-Code	1	3

5.1.4.1 Medical Care Facilities

Sources of inventory information for medical care facilities include the yellow pages of the telephone book, city and county emergency response offices, the American Hospital Association and previous loss studies. The default medical facilities database included with **HAZUS** was developed from a FEMA database and contains the number of beds for many of the facilities. Determining the number of beds for other facilities may require the user to contact facilities on an individual basis. In some cases, county guides, such as the McCormack Guides in California, provide a listing of all health care facilities, their addresses, phone numbers and the number of beds. The State Department of Public Health in California (and its equivalent in other states) licenses health care facilities and may publish a directory of licensed facilities.

5.1.4.2 Fire Stations, Police Stations and Emergency Operations Centers

Locations of fire stations, police stations and emergency operations centers can be obtained from city and county emergency response offices. In addition, many city maps show locations of police and fire stations. Determining the number of fire trucks may require the user to contact an administrator in the fire department.

5.1.4.3 Schools

Locations of public schools and their enrollments can be obtained from district offices. The Board of Education in some states compiles a directory of all schools (public and private) in the state with names, addresses, phone numbers and enrollments. The yellow pages of the phone book can be used as an initial listing. Regional governments may compile directories of local educational institutions (including colleges and universities).

5.1.5 High Potential Loss Facilities

While High Potential Loss Facilities include nuclear power plants, dams and military installations, default data are currently provided only for nuclear power plants and dams.

5.1.5.1 Nuclear Power Plants

HAZUS does not include damage and loss estimates for nuclear power plants. These structures are so complex that estimating losses would require a dedicated study; therefore, **HAZUS** restricts the treatment of these facilities to mapping them in the study region. Since a default database is included with **HAZUS,** you will only have to add those nuclear power plants that are not listed in the default database. Utilities that operate these facilities will have information on their locations, though they may not be willing to share it. Local, state and Federal regulatory agencies should also have inventories of power plants (nuclear as well as fossil fuel plants).

5.1.5.2 Dams

The methodology does not include damage and loss estimates for dams. The default dam database provided with **HAZUS** is a modified version of the NATDAM database supplied by the National Inventory of Dams. It contains over 80,000 entries and includes most of the dams of any significance in a study region along with a great deal of descriptive information about each dam. The criteria for inclusion in the database are found in Table 5.2 and the list of fields is found in Section 2.2 of Appendix E. The default classes that are included in this database were assigned by converting the rather complex classification system used by NATDAM to the twelve classes used in this methodology. Cities, counties, states, the Army Corps of Engineers, the U.S. Soil Conservation Service, other federal agencies, water districts, flood control districts, or private parties may own dams or levees. Thus obtaining more detailed information on dams may require contacting a number of different sources. In addition to the above-mentioned agencies, you may wish to contact the State Office of Emergency Services, local emergency services, fire protection services, or regulatory agencies.

Table 5.2 Criteria for inclusion in the NATDAM database

Characteristic	Criterion	Excluded
Dam Height	Dam height greater than 25 feet	Dam height < 6 feet, regardless of reservoir capacity
Reservoir Size	Reservoir impoundment capacity greater than 50 acre-feet	Reservoir impoundment capacity less than 15 acre-feet maximum capacity regardless of dam height
Hazard	Any dam that poses a significant threat to human life or property in the event of its failure	N/A

5.1.5.3 Levees

Users are responsible for developing their own inventory of levees since **HAZUS** doesn't supply default levee inventory. Levees are defined in terms of endpoints of levee segments (latitude and longitude). There are a number of fields defined in the levee database structure (see Appendix E, Section 2.2) including:

- Levee design basis (for example 100 year flood)
- Levee crest elevation
- Water elevation during most of the year
- Levee owner/operator

Since some levees are designed only to provide protection during flooding, they may be dry during most of the year. These levees do not pose a significant inundation hazard.

5.1.5.4 Military Installations

The methodology includes the capability to estimate damage and loss for facilities on military bases that can be modeled as one of the 36 model building types. Locations of military installations can be obtained from maps or Topologically Integrated Geographic Encoding and Referencing (TIGER) files. These sources give locations of installations but no breakdown as to the number or type of structures. FEMA maintains databases of major Army, Navy and Air Force installations, although they are not included in **HAZUS**.

5.1.6 User-Defined Structures

User-defined structures are those structures, other than essential facilities or high potential loss facilities, which the user may wish to analyze on a site-specific basis. For example, you may wish to identify all of the unreinforced masonry buildings in the community or all of the pharmacies. You can collect data about these types of structures using the same sources you would use for general building stock or essential facilities, namely: specific databases that may be available to you through some agency, commercial sources of property data, the phone book, interviews with owners and site visits.

5.1.7 Lifelines

Developing a lifeline inventory or improving the inventories supplied with **HAZUS** most likely will require the cooperation of local utilities or government agencies that operate and maintain the systems. It is difficult to estimate how much time will be required to collect and organize lifeline information because it depends on the size of the region, the level of detail required, the quality of existing data and the degree of cooperation from agencies within the region.

Previous loss estimation or hazard studies may be sources of information on all types of lifelines. For example, the planning scenarios developed by the California Division of Mines and Geology (CDMG) provide detailed inventories of lifelines and essential facilities (See Davis et al., 1982). In the Davis study, addresses and the number of beds for all hospital facilities are provided. A limitation of the CDMG planning scenarios is that the inventory is only for the area around the epicenter of the scenario earthquake. Another example of a previous loss study is the study performed for the Portland, Oregon water and sewer systems (Kennedy/ Jenks/Chilton et al., 1989). It should be noted that a detailed lifeline study such as the one performed for Portland might provide information in addition to component inventory. This study contains values of facilities and loss curves (based on MMI) for some components. A source of loss studies that have been performed is FEMA Report 249 (FEMA, 1994).

In some communities, government agencies such as the Association of Bay Area Governments in the San Francisco area and Metro in Portland, have been studying hazard mitigation policies and procedures for quite some time. In some cases their studies have involved developing inventories of local lifeline and essential facilities.

5.1.7.1 Transportation Lifelines

The default databases of highways and bridges included with **HAZUS** were created from data obtained from Federal Highway Administration (FHWA) and the Census Bureau's TIGER files. You may find that the locations of these lifeline components contain inaccuracies; however, the locations can easily be modified based on more accurate information obtained by the user. Street maps are an excellent source for locating streets and highways. Although they provide no information about the width of streets or the average daily traffic, they do generally give the route number and usually classify the roads according to some simple scheme such as freeways, expressways, main highways, and surface streets. A potential drawback, however, is that to use street maps, you must digitize them.

Some cities and counties have invested in GIS systems and may already have computerized databases that you can use. You may find that the GIS files have to be converted into a format that is compatible with ArcView (see Section 6.1). To obtain cost and structural information about roads, bridges and tunnels that is not included in the default inventory, local and state transportation agencies maintain lists of bridges and tunnels and may also have detailed information about their design, construction and configuration. You may find that you need to perform a survey to collect cost per mile data for roads (surveys are discussed in Section 5.2.)

To obtain information about traffic on road segments you may wish to consult the default bridge database included with **HAZUS**. This database, obtained from the FHWA includes average daily traffic counts. As a first step you can assume that the average daily traffic on a bridge is the same as that on a highway leading to that bridge. Alternatively, the public works departments or the city, county, state or the federal agencies that own and operate the roads likely have performed studies with respect to the daily traffic and capacities of the roads.

The Federal Railway Administration maintains a database of all railways. It is unclear as to whether you will be able to access such a database. Rail companies that operate in a region maintain lists of rail yards and other rail facilities. These sources should be able to provide structural information as well as cost data.

Light rail, ferry and bus inventory information may be obtained from the agencies operating these systems. Maps of the light rail system can be digitized or scanned and entered into the GIS database to inventory track segments.

While the locations of ports and airports are provided in the default inventories, no information is provided about the types of buildings, cranes, tanks, etc. that are at these facilities. The Federal Aviation Administration maintains a database of airports along with information about the number of runways and the average daily traffic. It is unclear if you will be able to access this information. Facility maps may be obtained from the agencies that operate these ports and harbors. However, it is likely that a meeting or phone call with the owner will be required to get structural and cost information.

5.1.7.2 Utilities Lifelines

Developing a lifeline inventory or improving the default inventories supplied with **HAZUS** generally requires the cooperation of local utilities or government agencies that operate and maintain the systems. In some cases utilities and government agencies are already maintaining databases on GIS systems or in CAD systems. However, the data may have to be converted to a format that is compatible with the ArcView GIS software.

More than one supplier may supply water to a region. Suppliers may be either government owned or they may be private companies. Systems may already be mapped in a GIS or CAD system. In this case, the data files may need to be converted to an ArcView format. If the water system is not maintained in a GIS, a map of the pipe network can be digitized or scanned for input into **HAZUS**. Similar comments apply to wastewater systems.

A rather crude analysis of water and wastewater systems can be performed by knowing the number of kilometers of different types of pipes for each census tract. Owners of these systems can typically provide this information.

Oil and gas systems consist of not only the pipelines but also refineries, tank farms, pumping plants and compressor stations. In addition to inventories available from suppliers, databases of hazardous waste sites can serve as a locator of fuel storage facilities.

5.1.8 Inundation

Sources of existing inundation studies due to dam failure, levee failure or tsunami include state and federal agencies that regulate dams, dam or lake owners, the State Office of Emergency Services (OES), the U.S. Geological Survey (USGS), etc. The availability of such studies may be limited.

If inundation maps are available, they may be digitized and entered into **HAZUS** (see Section 9.5). Digitizing a map for display may take a day to a week. If an inundation map is not available, development of an inundation map for a particular earthquake scenario requires an analysis of the response of the dam to the earthquake and the involvement of a hydrologist to define the extent of flooding. This is a detailed study requiring up to several months.

5.1.9 Fire Following Earthquake

Aside from the locations of fire stations, and the number of trucks that should be available from fire departments or regional emergency response organizations, there is little inventory information available to investigate fire following earthquake. Typical wind speeds and wind directions can be obtained from the weather service, and average fire engine speeds should be available from the fire department.

5.1.10 Hazardous Materials

Due to the considerations of limiting the methodology to those hazardous materials whose release could have regional consequences, the default database contains only those chemicals that are considered highly toxic, flammable or highly explosive. In addition, it is limited to those facilities where large quantities of these materials are stored. The (Environmental Protection Agency) EPA compiles an annual inventory of manufacturing facilities that release toxic chemicals into the air, water and ground. This inventory focuses on 305 chemicals that may cause chronic health problems and serious environmental effects. The default database was built from the 1993 EPA Toxic Release Inventory (TRI) database of hazardous materials sites. The latest version of the TRI database may be obtained from the EPA. You may opt to use only the information contained in the default database provided with **HAZUS**. This database, however, is limited and you are urged to collect additional inventory for a better representation of the types of chemicals stored in your study region.

The ease with which information regarding hazardous materials storage and usage is available varies from jurisdiction to jurisdiction. Some jurisdictions have this information available in the form of a computer database/printout, whereas other jurisdictions do not. Most likely the format of the database will vary from place to place, and even if hazardous materials inventories are easy to get, there will be some effort required to combine databases from several cities in a region.

At the present time, users and handlers of hazardous materials have to meet two primary reporting requirements. One is the requirement mandated by the Uniform Fire Code, and the other is required by SARA Title III (Superfund Amendments and Reauthorization Act of 1986, Title III). The reporting requirements for each of these are rather different. The Uniform Fire Code is very comprehensive in its coverage. It covers materials that pose any physical or health hazard. The SARA Title III reporting requirements, on the other hand, are restricted to 360 hazardous materials that are known to be particularly toxic. These chemicals have been termed Acutely Hazardous Materials (AHM). For either of these reporting specifications, based upon the hazard posed by each material, there are minimum (threshold) hazardous material quantities below that the user/handler may store without a permit. The information contained in the application for a permit is a matter of public record, and the agency granting the permit is able to provide that information to the community, if deemed necessary. The hazardous materials that are covered under SARA Title III, including their Chemical Abstracts Service (CAS) registry numbers, and the threshold quantities for reporting purposes, are listed in Appendix G.

The user should contact the local Fire Department in the case of cities, or the County Health Department in the case of unincorporated areas, to obtain a list of facilities that have obtained permits to store, handle or use hazardous materials. It appears that most jurisdictions within the United States require all users and handlers of hazardous materials to obtain permits from the proper local authority.

The user should also be cognizant of the dynamic nature of hazardous materials data. This will be particularly true of areas that are undergoing economic and industrial growth. For best results, it is strongly recommended that the data be periodically updated, with the update interval being dependent on the rate of growth of the region.

5.1.11 Demographics

Population statistics are used in estimating several different losses such as casualties, displaced households and shelter needs. Population location, as well as ethnicity, income level, age and home ownership is needed to make these estimates. The 1990 Census data are included with **HAZUS**. Population migration patterns, based on place of employment, were developed from Dun and Bradstreet data as described in Section 3.6 of the Technical Manual. The user may be able to obtain updated information from the Census Bureau or from a regional planning agency.

5.1.12 Direct Economic Loss Parameters

Direct economic losses begin with the cost of repair and replacement of damaged or destroyed buildings. However, building damage results in a number of consequential losses that are defined as direct economic losses. 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
- Cost 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 expense (for businesses and institutions)
- Capital-related income loss (a measure of the loss of services or sales)
- Wage loss (consistent with income loss)
- Rental income loss (to building owners)

Damage to lifeline and transportation systems causes direct economic losses analogous to those caused by building damage. In this methodology, direct economic loss for lifelines and transportation systems are limited to the cost of repairing damage to the systems and business losses due to cessation of electrical power supply. A large part of the data required to estimate direct economic losses is concerned with the cost of repair and replacement, the value of lost inventory, wages and rent. Many of these types of economic parameters are documented by government agencies.

5.1.12.1 County Business Patterns

County Business Patterns is an annual series published by the United States Census Bureau that presents state and county-level employment, annual payrolls, total number of establishments, and establishments by employee size. The data are tabulated by industry as defined by the Standard Industrial Classification (SIC) Code. Most economic divisions are covered, which include agricultural services, mining, construction, manufacturing, transportation, public utilities, wholesale trade, retail trade, finance, insurance, real estate and services.

The data generally represents the types of employment covered by the Federal Insurance Contributions Act (FICA). Data for employees of establishments totally exempt from FICA are excluded, such as self-employed persons, domestic service employees, railroad employees, agricultural production employees and most government employees.

County Business Patterns is the only complete source of sub-national data based on the four digit SIC system. The series, therefore, is useful in making basic economic studies of small areas (counties), for analyzing the industrial structure of regions, and as a benchmark for statistical series, surveys and other economic databases. The data can serve a variety of business uses as well as being used by government agencies for administration and planning.

County Business Patterns data are extracted from the Standard Statistical Establishment List, a file of known single- and multi-establishment companies maintained and updated by the Bureau of the Census every year. The Annual Company Organization provides individual establishment data for multi-location firms. Data for single-location firms are obtained from various programs conducted by the Census Bureau as well as from administrative records of the Internal Revenue Service (Census Bureau, 1991).

5.1.12.2 Means Square Foot Costs

The default replacement costs supplied with the methodology (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 model, and a breakdown is provided that shows the cost and percentages of each building system or component. The methodology also allows the user to adjust costs for location of the structure (i.e., San Francisco versus Dallas). A description of how to estimate costs from the Means publication is found in Sections 15.2.1.1 and 15.2.1.2 of 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 Section 15.2.1.3 of the *Technical Manual*.

For **HAZUS**, selected Means models have been chosen from the more than 70 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.

5.1.12.3 Dun and Bradstreet

Dun and Bradstreet is an organization that tracks all businesses that are incorporated. Dun and Bradstreet maintains data on the type of business, the number of employees, the square footage of the business, the annual sales and a variety of other information. The default square footage for the occupancy classes and for all the census tracts was created from the 2 and 4 digit (Standard Industrial Classification) SIC 1995-1996 Dun and Bradstreet data. This mapping scheme is listed in Table 3.20 of the *Technical Manual*. Dun and Bradstreet will provide aggregated information for a specific region on total number of employees, total annual sales and total square footage by census tract. They can also provide information on specific businesses. Dun and Bradstreet has multiple offices in the United States and can be located using the local telephone directory assistance.

5.1.12.4 Capital-Related Income

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.

5.1.13 Indirect Economic Loss Parameters

To estimate long-term economic losses (indirect economic losses), you need to supply the variables summarized in Table 5.3. Other inputs will need to be estimated as described below.

Estimates of Supplemental Imports, Inventories (Supplies), Inventories (Demand), and New Export Markets are perhaps the most difficult parameters to estimate. If you have had an earthquake in your region, you will need both pre-quake and post-quake estimates in order to calculate percents as defined in Table 5.3. There are County Development Corporations (CDC) that can provide estimates of local economic activities. However, it is likely you will have to develop estimates of these parameters through discussions with individuals in the local community. One option is to perform a telephone survey. Another option is to create a panel of individuals from all of the sectors in the local community, ask them these same questions and reach some sort of consensus.

Table 5.3 User supplied inputs for indirect economic module

Variable	Definition	Units[a]	Default Value
Current Level of Employment	The number of people gainfully employed, by place of work (not residence).	Employed persons	Region-specific[b]
Current Level of Income	Total personal income for the study region.	Million dollars	Region-specific[b]
Composition of the Economy (Level I only)	1. Primarily manufacturing 2. Primarily service, secondarily manufacturing. 3. Primarily service secondarily trade.	1, 2, or 3	1
Supplemental Imports	In the event of a shortage, the amount of a good/service that was supplied from within the region that can be imported from elsewhere.	Percent of current annual imports (by industry)	Defaults for "distinct region"[c]
Inventories (Supplies)	In the event of a shortage, the amount of a good that was supplied from within a region that can be drawn from inventories within the region.	Percent of current annual sales (by industry)	0 (for all industries)
Inventories (Demand)	In the event of a surplus, the amount of a good placed in inventory for future sale.	Percent of current annual sales (by industry)	0 (for all industries)
New Export Markets	In the event of a surplus, the amount of a good which was once sold within the region that is now exported elsewhere.	Percent of current annual exports (by industry)	Defaults for "distinct region"[c]
Percent Rebuilding	The percent of damaged structures that are repaired or replaced	Percent	95%
Unemployment Rate	The pre-event unemployment rate as reported by the U.S. Bureau of Labor Statistics	Percent	6%
Outside Aid/Insurance	The percentage of reconstruction expenditures that will be financed by Federal/State aid (grants) and insurance payouts.	Percent	50%
Interest Rate	Current market interest rate for commercial loans.	Percent	5%
Restoration of function	The percent of total annual production capacity that is lost due to direct physical damage, taking into account reconstruction progress.	Percent (by industry, by year for 5 years)	Defaults for "moderate-major" event[c]
Rebuilding (buildings)	The percent of total building repair and reconstruction that takes place in a specific year.	Percent (by year for 5 years)	70% (yr. 1), 30% (yr. 2)
Rebuilding (lifelines)	The percent of total transportation and utility lifeline repair and reconstruction that takes place in a specific year.	Percent (by year for 5 years)	90% (yr. 1), 10% (yr. 2)
Stimulus	The amount of reconstruction stimulus anticipated in addition to buildings and lifelines repair and reconstruction.	Percent (by industry, by year for 5 years)	0% (for all)

NOTES:

(a) Percent data should be entered as percentage points, e.g. 60 for 60%.
(b) **HAZUS** provides a default value for the counties in the study region.

(c) See Section 16.5.2.2 of the *Technical Manual*.

5.1.13.1 Current Level of Employment

You can usually obtain data about current levels of employment from the CDC or the U.S. Bureau of Labor Statistics. The U.S. Bureau of Labor Statistics can be contacted at:

Bureau of Labor Statistics
2 Massachusetts Ave., N.E.
Washington, D.C. 20212
Phone: 202-606-7800
Fax: 202-606-7797

5.1.13.2 Current Level of Income

You can usually obtain data about current levels of income from the County Development Corporation or from the U.S. Bureau of Labor Statistics.

5.1.13.3 Composition of the Economy

Information about the composition of the economy may be obtained through the County Development Corporation, Chamber of Commerce, County Commissioner's Office or the Mayor's office of the largest city in the county.

5.1.13.4 Percent Rebuilding

The percent of destroyed property that is reconstructed will depend on the health of the economy of the region when the earthquake occurs. If there are many vacant properties, there are places for displaced companies and households to move. Thus it is likely that not all of the damaged and destroyed properties will be rebuilt. On the other hand, if the economy is booming and the vacancy rate was very low, then there will be a great deal of competition for space. In this case you can expect that most of the damage will be repaired. There is no source of data that will directly tell you the percent of destroyed property that will be reconstructed. As suggested above you might use vacancy rates to get a feel for the extra building capacity in your region. However, you will probably want to run the analysis using several values to see how the analysis changes. Reasonable values rebuilding estimates would be in the range of 95% to 100%.

5.1.13.5 Unemployment Rates

You can obtain pre-event unemployment rates from the U.S. Bureau of Labor Statistics.

5.1.13.6 Outside Aid and Insurance Payouts

Many state governments have an Insurance Commissioner who will most likely have compiled insurance payout statistics for previous disasters in the region. If you have not had a disaster in your region, you may have to contact someone from some other location in the country to ask about payouts resulting from a natural disaster in that region. In the absence of data, you can run the model twice, once with outside aid set to 100% and once with outside aid set to 0%. This will provide you with lower and upper bounds on the indirect economic impacts.

For state aid statistics, contact the state governor's chief economist at the Office of the Governor.

For federal aid statistics contact FEMA either at the main office (in address below) or at a regional office (see Table 5.4):

Federal Emergency Management Agency
500 C. Street S.W., Federal Center Plaza
Washington, D.C. 20472
Phone: 202-646-4600
Fax: 202-646-2531

Table 5.4 Addresses of regional offices of FEMA

FEMA Region	Address		Phone
Region 1	JW McCormack POCH Room 442	Boston, MA 02109	617-223-9540
Region 2	26 Federal Plaza Room 1337	New York, NY 10278	212-225-7209
Region 3	105 S 7th St. Liberty Square Bldg. 2nd floor	Philadelphia, PA 19106	215-931-5608
Region 4	3003 Chamblee-Tucker Road	Atlanta, GA 30341	770-220-5200
Region 5	175 W Jackson Blvd. 4th floor	Chicago, IL 60604	312-408-5501
Region 6	800 N Loop 288	Denton, TX 76201	817-898-5104
Region 7	2323 Grand Blvd. Suite 900	Kansas City, MO 64106	816-283-7061
Region 8	Denver Federal Center, Building 710, P. O. Box 25267	Denver, CO 80225	303-235-4812
Region 9	Presidio Bldg. 105	San Francisco, CA 94129	415-923-7100
Region 10	130 228th St. SW Federal Regional Center	Bothell, WA 98021	206-487-4604

5.1.13.7 Interest Rate

The current market interest rate for commercial loans should be available from a bank, a local newspaper or the Board of Realtors.

5.2 Collecting Inventory Data

It should be understood that many available databases do not contain all of the information that is needed to perform a loss study. For example, they may contain street addresses, the size of the facility, or the value of the facility, but may not contain information about structural type or age. A discussion of inferring missing attributes in inventory databases is found in King and Kiremidjian (1994). Databases may be out of date and may not contain all of the facilities in the region. Another problem the user can encounter is that databases may be in a paper rather than electronic format, making them difficult or impossible to use. Combining multiple databases can also be problematic.

Issues such as double counting facilities and eliminating unnecessary information need to be addressed (King and Kiremidjian, 1994).

In general, the majority of the building inventory used in the regional loss estimation will not be collected or kept on a facility-by-facility basis. Resource limitations make it difficult to collect such detailed information. Management and storage of such a large amount of information, while possible, is beyond the state-of-practice for many municipalities and government agencies. Maintaining facility-specific databases will be most useful for important or hazardous facilities such as hospitals, fire stations, emergency operation centers, facilities storing hazardous materials, and high occupancy facilities, to name a few. Procedures exist for supplementing facility-specific databases with area-specific inventory information. An example of an area specific inventory is the number of square feet of commercial space in a census tract or zip code. These area-specific inventories are often based on economic or land use information that is augmented using inference techniques. For example, the user may have available the number of commercial establishments in a region. Assuming an average size (in square feet) per establishment, the user can infer the total square footage of that occupancy. Similarly, a land use map may be converted to building square footage by multiplying land use area by percent of area covered by buildings (see Section 5.2.2 on Land Use Data).

Techniques for developing inventories by using sidewalk surveys, land use data and aerial photography are briefly discussed below.

5.2.1 Sidewalk/Windshield Survey

5.2.1.1 What's Needed:

- Data Collection Sheet
- Map
- Clip Board
- Camera (optional)
- Pre-field Planning
- Your Feet or an Automobile

A sidewalk survey is a technique that can be used to rapidly inventory and identify characteristics of buildings without entering or performing any engineering analyses of the structure. Essentially, most of the inventory collection is done from the sidewalk or the street. An individual uses a pre-defined data collection sheet, a map and possibly a camera and walks or drives through an area to identify buildings and specified characteristics. A critical aspect of the sidewalk survey is the data collection sheet. An example of a data collection sheet is found in Figure 5.1. This particular data sheet was used for ranking buildings for potential seismic hazards and a scoring system is also included. However, the data sheet could be modified for the needs of the particular region being evaluated.

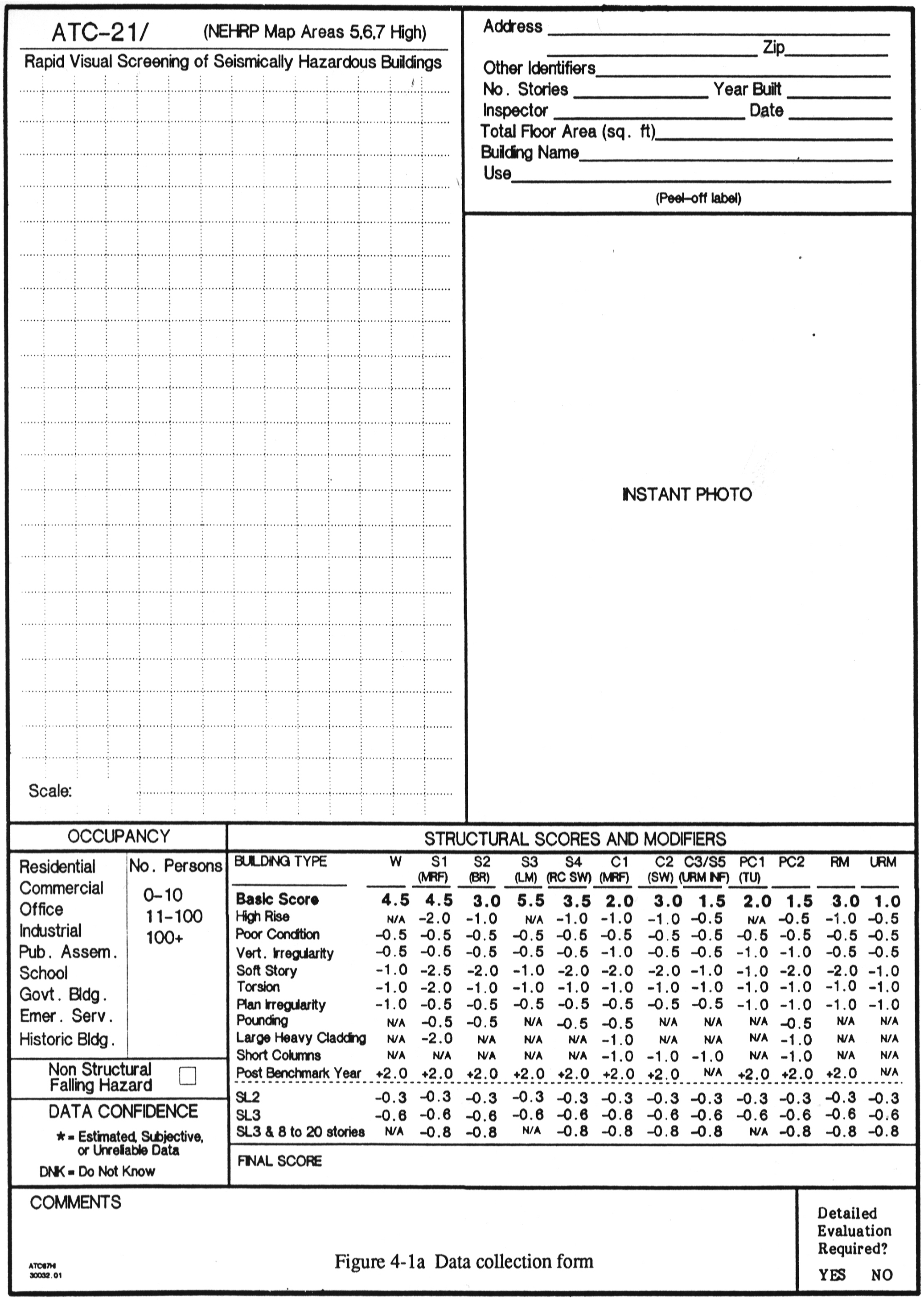
5.2.1.2 How the Information is used:

- Develop Inventories of Specific Building Types or Occupancy Classes
- Develop or Check Inferencing Rules
- Check Accuracy of Available Inventories

Sidewalk surveys have been performed in a number of cities. In Oakland (Arnold and Eisner, 1984) and Redlands California (County of San Bernardino, 1987), studies were performed to identify unreinforced masonry or other "seismically suspicious" buildings. In Portland Oregon, a sidewalk survey was used to collect building inventory (about 9000 buildings) for all commercial occupancies in the downtown and surrounding areas. An excellent overview of studies that have been performed using sidewalk surveys or rapid visual screening techniques is found in FEMA 155 (1988).

A sidewalk survey can be used to develop or check inference rules that are used to characterize that region. An example of such rules might be that 90% of all low-rise residential buildings are wood frame and 10% are unreinforced masonry. Data collected in a residential portion of the study region can be compared with the rule to check validity. Similarly, different areas within a region will have different building and occupancy patterns depending on when structures were built, zoning laws and land use. Sampling of different areas within the study region can be used to identify these variations.

Finally, the user may have access to previously collected inventories such as tax assessors files. A sidewalk survey can be used to determine if structural information in the assessors file are accurate.



ATC-21/ (NEHRP Map Areas 5,6,7 High)

Rapid Visual Screening of Seismically Hazardous Buildings

Address ____________ Zip ____

Other Identifiers ____________

No. Stories ______ Year Built ______

Inspector ______ Date ______

Total Floor Area (sq. ft) ______

Building Name ______

Use ______

(Peel-off label)

INSTANT PHOTO

Scale:

OCCUPANCY	
Residential Commercial Office Industrial Pub. Assem. School Govt. Bldg. Emer. Serv. Historic Bldg.	No. Persons 0–10 11–100 100+

Non Structural Falling Hazard ☐

DATA CONFIDENCE

* = Estimated, Subjective, or Unreliable Data

DNK = Do Not Know

STRUCTURAL SCORES AND MODIFIERS

BUILDING TYPE	W	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	C1 (MRF)	C2 (SW)	C3/S5 (URM INF)	PC1 (TU)	PC2	RM	URM
Basic Score	**4.5**	**4.5**	**3.0**	**5.5**	**3.5**	**2.0**	**3.0**	**1.5**	**2.0**	**1.5**	**3.0**	**1.0**
High Rise	N/A	-2.0	-1.0	N/A	-1.0	-1.0	-1.0	-0.5	N/A	-0.5	-1.0	-0.5
Poor Condition	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Vert. Irregularity	-0.5	-0.5	-0.5	-0.5	-0.5	-1.0	-0.5	-0.5	-1.0	-1.0	-0.5	-0.5
Soft Story	-1.0	-2.5	-2.0	-1.0	-2.0	-2.0	-2.0	-1.0	-1.0	-2.0	-2.0	-1.0
Torsion	-1.0	-2.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
Plan Irregularity	-1.0	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-1.0	-1.0	-1.0	-1.0
Pounding	N/A	-0.5	-0.5	N/A	-0.5	-0.5	N/A	N/A	N/A	-0.5	N/A	N/A
Large Heavy Cladding	N/A	-2.0	N/A	N/A	N/A	-1.0	N/A	N/A	N/A	-1.0	N/A	N/A
Short Columns	N/A	N/A	N/A	N/A	N/A	-1.0	-1.0	-1.0	N/A	-1.0	N/A	N/A
Post Benchmark Year	+2.0	+2.0	+2.0	+2.0	+2.0	+2.0	+2.0	N/A	+2.0	+2.0	+2.0	N/A
SL2	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3
SL3	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6
SL3 & 8 to 20 stories	N/A	-0.8	-0.8	N/A	-0.8	-0.8	-0.8	-0.8	N/A	-0.8	-0.8	-0.8
FINAL SCORE												

COMMENTS

Detailed Evaluation Required? YES NO

ATC87M 30032.01

Figure 4-1a Data collection form

54 RSP Method and the Data Collection Form ATC-21

Figure 5.1 Example of a data collection sheet for sidewalk survey from FEMA 154 (1988).

5.2.1.3 Steps Followed to Perform a Sidewalk Survey

- Define survey objectives
- Develop survey data sheet
- Identify area where survey is to be performed
- Examine map of survey area looking at density of building construction, and other characteristics that would affect how the area is surveyed
- Perform pre-field data collection (e.g. building age)

Train individuals who will perform survey

As discussed earlier, a sidewalk survey can be performed for a variety of purposes. Examples of survey objectives are:

- Inventory building stock according to occupancy
- Inventory building stock according to model building type
- Identify specific occupancies (e.g. # of buildings on a school campus)
- Identify specific model building types (e.g. unreinforced masonry)
- Identify characteristics of the building stock (e.g. age, height)
- Identify potential seismic hazards (e.g. unbraced parapets, overhangs, unusual geometry)

The design of the survey data sheet will depend on the objectives that are defined. As discussed in FEMA 154, the survey data sheet should include a minimum amount of information as listed below:

- Complete address or other identifier of building (i.e. tax assessor's parcel number)
- Name of surveyor
- Number of stories
- Estimate of building plan dimensions

The above minimum information is needed so that the survey can be updated or used again at a later time. It is also useful for directing any survey related questions to the surveyor. It is also useful to have:

- Sketch of building plan
- Photo of building

A good data sheet will be in a check off format so that 1) all buildings will be in the same format, and 2) the inspector will not forget to mark certain information. One suggestion is to develop data labels from some pre-existing database such as Assessor's files or building department files with street addresses, building type and other information that may be determined before going into the field. Using an Assessor's map to mark down relevant information can also be useful.

Identifying structural types from the street can be extremely difficult. Structural frames and walls are often covered with finishes that mask their characteristics. However, building practices can be associated with certain eras, architectural styles or occupancies. This will likely vary by region. FEMA 154 devotes a whole chapter to inferring model building type from architectural styles. Training of surveyors should include instruction in building practices of the region and characteristics that might be used to identify certain building types. Surveyors should train together on the same group of buildings to improve consistency in survey results.

5.2.2 Land Use Data

Land use data can be combined with a series of inferences to develop a building inventory. This approach has been used in many previous loss studies and is described in some detail in Scawthorn and Gates (1983) and ABAG (1986). Land Use data provides information about the location and area of different land use categories in a region. Several steps are required to convert the land use areas to building inventory:

- Land use must be converted to building type
- Land use area must be converted to square feet of building

To convert land use to building type, inferencing rules about the proportion of model building types in each land use category must be developed. An example of these inferences taken from a loss study for Los Angeles County (Scawthorn and Gates, 1983) is shown in Table 5.5. From this table it can be inferred that if the land use is General Commercial (Code 129) then 23% of the land has 1 to 4 story concrete block construction, 9 % has 1 to 2 story tilt-up, 58% has 1 to 2 story wood, 2% has unreinforced masonry and 8% has reinforced masonry. This table was developed based on interviews with experienced engineers and personnel from local building departments. (Note: Using the standardized model building types developed in this methodology, concrete block would be classified as reinforced or unreinforced masonry. You will need to discuss with a local building official or other expert whether or not the concrete block construction contains reinforcing.)

To estimate square footage of each building type, one needs to make inferences about the ratio of building square footage to total land. An example of this type of inference is found in Table 5.6. This table, also taken from Scawthorn and Gates (1983), was developed with the help of real estate consulting services, the local school district, and experienced engineers. Table 5.6 shows that for land containing high-rise apartments (Code 119), the square footage of the apartment is equal to 184% of the land area, whereas for single family dwellings (Code 112), the square footage of these dwellings is only 18% of the land area. For example, if 4 acres of land contain high-rise apartments and 3 acres contained single-family dwellings, the following inventory results:

4 acres x 43,560 sq. ft/acre x 1.84 bldg. sq. ft/sq. ft = 320,600 sq. ft high rise apartments
3 acres x 43,560 sq. ft/acre x 0.18 bldg. sq. ft/sq. ft = 23,522 sq. ft single family residences

These numbers can then be proportioned among building types using the inferences in Table 5.5. The results are shown in Table 5.7.

Table 5.5 Land Use to Building Type Conversion - Proportion by Percent
(from Scawthorn and Gates, 1983)

CODE	LAND USE CATEGORY	BUILDING TYPE - STRUCTURAL MATERIAL AND NUMBER OF FLOORS												
		CONC. BLOCK 1-4	TILT-UP 1-2	WOOD 1-2	WOOD 3-4	CONCRETE 1-2	STEEL 1-2	CONCRETE 3-4	STEEL 3-4	CONCRETE 5-19	STEEL 5-19	URM**	REINFORCED MASONRY	STEEL ≥20
111	ESTATE	3		85								4	8	
112	SINGLE FAMILY			87								5	8	
113	DUPLEX / ROW HOUSING			84								11	5	
114	LOW RISE APARTMENTS / CONDOMINIUMS			84								11	5	
115	MEDIUM RISE APARTMENTS / CONDOMINIUMS			75								13	12	
116	RURAL CLUSTERED			89								6	8	
117	RURAL DISPERSED			96								7	4	
118	MOBILE HOMES / TRAILER PARKS	4		92									4	
119	HIGH RISE APARTMENTS / CONDOMINIUMS									69	21		10	
121	MAJOR OFFICE USE	12		10	3	38	7		5		10	3	12	
122*	MAJOR OFFICE USE -- 8 OR MORE FLOORS													
123	REGIONAL SHOPPING CENTER	13	27	4		44		3					9	
124	NEIGHBORHOOD SHOPPING CENTER	13	7	72								1	7	
125	STRIP/ ROADSIDE COMMERCIAL	6		82								6	6	
127	COMMERCIAL RECREATION	18	3	62		6	2						9	
128	HOTEL / MOTEL	16		61	8							3	12	
129	GENERAL COMMERCIAL	23	9	58								2	8	
132	OIL AND GAS EXTRACTIVE	6				3	91							
133	RESEARCH AND DEVELOPMENT	24	18	9		24	18							
134	MOTION PICTURE	27	15	49									7	
135	MANUFACTURING AND ASSEMBLY	15	34	35		7							9	
136	PETROLEUM REFINING / PROCESSING	10	9			4	46	12	13			1	5	
138	MAJOR METALS	5	5			25	65							
139	WHOLESALING AND WAREHOUSING	19	45	5		13	10			3		1	5	
141	AIRPORT	14	15	27		10	15	10				16	8	
142	RAILROAD	7		33		28	11					7	5	
144	HARBOR FACILITIES	4		32		24	28						5	
150	ELECTRIC POWER FACILITIES	10	5			50	25						10	
152	LIQUID WASTE DISPOSAL FACILITIES	25				50	25							
156	COMMUNICATION FACILITIES	32	5	10		40			4		3		6	
160	SPECIALIZED USE INSTITUTION	22		40		19	4	4	4				7	
161	GOVERNMENT OFFICES AND FACILITIES	21		50	3	12						4	10	
162	EMERGENCY RESPONSE FACILITIES	27		27		28							18	
163	MAJOR HEALTH CARE FACILITIES	6		17		47		10	5				15	
164	ELEMENTARY SCHOOL	7		49		16	15						13	
165	JUNIOR HIGH SCHOOL	13		29		37	3						18	
166	HIGH SCHOOL	13		19		38	6	7					17	
167	COLLEGE / UNIVERSITY / OTHER SCHOOL	16	3	5		48	7	4					17	
168	TRADE SCHOOL	16		27		32	3					1	21	
169	RELIGIOUS FACILITIES	16		42		21	3					2	16	

* Code 122 was distributed amongst building types concrete, 5-19; steel, 5-19; and steel ≥ 20 using a method described in Section 2.4.1.3.1.
Land Use Code 122 was the only one with any of its total area assigned to the steel ≥ 20 building type.

** All of the area assigned to Unreinforced Masonry (URM) was distributed according to a method described in Section 2.4.1.3.2.

Table 5.6 Site coverage for different land use categories (from Scawthorn and Gates, 1983)

CODE	LAND USE CATEGORY	FLOOR AREA RATIO (%)
111	ESTATE	23
112	SINGLE FAMILY	18
113	DUPLEX / ROW HOUSING	25
114	LOW RISE APARTMENTS / CONDOMINIUMS	48
115	MEDIUM RISE APARTMENTS / CONDOMINIUMS	100
116	RURAL CLUSTERED	4
117	RURAL DISPERSED	5
118	MOBILE HOMES / TRAILER PARKS	25
119	HIGH RISE APARTMENTS / CONDOMINIUMS	184
121	MAJOR OFFICE USE	80
122*	MAJOR OFFICE USE -- 8 OR MORE FLOORS	200
123	REGIONAL SHOPPING CENTER	30
124	NEIGHBORHOOD SHOPPING CENTER	28
125	STRIP/ ROADSIDE COMMERCIAL	40
127	COMMERCIAL RECREATION	35
128	HOTEL / MOTEL	70
129	GENERAL COMMERCIAL	35
132	OIL AND GAS EXTRACTIVE	2
133	RESEARCH AND DEVELOPMENT	35
134	MOTION PICTURE	20
135	MANUFACTURING AND ASSEMBLY	65
136	PETROLEUM REFINING / PROCESSING	5
138	MAJOR METALS	50
139	WHOLESALING AND WAREHOUSING	60
141	AIRPORT	5
142	RAILROAD	5
144	HARBOR FACILITIES	30
150	ELECTRIC POWER FACILITIES	10
152	LIQUID WASTE FACILITIES	2
156	COMMUNICATION FACILITIES	5
160	SPECIALIZED USE INSTITUTION	15
161	GOVERNMENT OFFICES AND FACILITIES	60
162	EMERGENCY RESPONSE FACILITIES	50
163	MAJOR HEALTH CARE FACILITIES	80
164	ELEMENTARY SCHOOL	25
165	JUNIOR HIGH SCHOOL	23
166	HIGH SCHOOL	33
167	COLLEGE / UNIVERSITY / OTHER SCHOOL	25
168	TRADE SCHOOL	30
169	RELIGIOUS FACILITIES	30

*The amount of area in Land Use Code 122 was distributed according to a method described in Section 2.4.1.3.1 and this Floor Area Ratio was used only as a check against the estimate.

Table 5.7 Square footage of each building type for study region

	Wood (1-2 stories)	Unreinforced Masonry	Reinforced Masonry	Concrete (5-19 stories)	Steel (5-19 stories)
High Rise Apartments	-	-	32,060	221,214	67,326
Single Family Residential	20,464	1,176	1,882	-	-

Land use information can be obtained from Land Use and Land Cover maps and digital data available from the USGS or from maps developed by local counties and cites. It should be understood that the resolution of USGS maps (1/100,000 or 1/250,000 scale) might not be adequate. Furthermore, these maps are based on aerial photography from the mid-1970s and have not been updated. As a result they will not contain newer developments. An index of available maps and digital data can be obtained from the USGS. Some municipalities maintain their own land use maps or computerized land use databases. A few select regions may maintain land use in a GIS.

5.2.3 Aerial Photography

Aerial photography may be most useful for developing land use maps in areas where they do not exist. A great deal of research has been done on how to convert aerial photographs to land use maps (Gauchet and Schodek, 1984; Johnson, 1986; Jones et al., 1987). The effort involved is significant and therefore other methods of collecting inventory may be more appropriate.

5.2.4 Discussions with Local Engineers and Building Officials

Valuable information, particularly on age and type of construction, can be collected from discussions with engineers, building officials and inspectors. Past experience has shown that the best data collection occurs if interviews are conducted in an organized and consistent manner. In a loss study by the Association of Bay Area Governments (ABAG, 1986) typical interviews lasted 1 to 3 hours and involved filling out a form such as the one shown in Figure 5.2. It was discovered in the interview process that building officials who had been working and living in the region for a number of years could provide much more information than those who were new to the region. In addition, building officials could provide little information about facilities for which they have no jurisdiction - these included public schools, hospitals, state colleges and universities, state penitentiaries and federal military installations.

To develop the occupancy to model building type relationships used in this methodology, several one-day workshops were performed around the country. These workshops were comprised of building officials, engineers and academics. Appendix F contains an example of a questionnaire that was used to better understand the characteristics of the regional building stock.

Figure 5.2 Association of Bay Area Governments (ABAG) survey

TABLE B-1-
PERCENTAGE OF SELECTED BUILDING TYPES
WITHIN LAND USE CLASSIFICATIONS

IS TRACT SPLIT?______________ TRACT POPULATION:________________

CENSUS TRACT NO.____________________ OTHER JURISDICTIONS: TRACT POPULATION IN
JURISDICTION:________________________ ____________________________ JURISDICTION:________________
____________________________ TRACT EMPLOYMENT:________________

LAND USE	WOOD FRAME (%)	LIGHT METAL (%)	MASONRY (%)	CONCRETE AND STEEL (%)	PRE-CAST CONCRETE (%)	MOBILE HOME-TYPE (%)
11 RESIDENTIAL (111) 1 or less Du/hectare (112) 2-8 Du/hectare (113) 9 or more Du/hectare (114) Mobile Home Parks						
12 COMMERCIAL & SERVICES (121) Retail & Wholesale (122) Commercial Outdoor Recreation (123) Education (1231) Elementary & Secondary (1232) Colleges & Universities (1233) Stadium (124) Hospitals, Rehab. Centers, Other Public Facilities (125) Military Installations (126) Other Public Institutions and Facilities (1261) Stadium (1262) Church (127) Research Centers (128) Office (129) Hotels						
13 INDUSTRIAL (131) Heavy Industrial (132) Light Industrial						
14 TRANSPORTATION UTILITIES (141) Highways (142) Railways (143) Airports (144) Ports (145) Power Lines (146) Sewage treatment plants						
15 COMMERCIAL AND INDUSTRIAL						
16 MIXED URBAN OR BUILT-UP LAND (161) Transitional (162) Mixed use in buildings						
17 OTHER URBAN OR BUILT-UP (171) Extensive recreation (1711) Golf Courses (1712) Racetracks (172) Cemeteries (173) Parks (174) Open space-urban						
NON URBAN (233) Greenhouses (55) Sedimentation ponds (75) Mines, quarries and gravel pits (761) Sanitary land fills						

Comments:

Chapter 6. Entering and Managing Data in HAZUS

HAZUS contains a variety of default parameters and databases. You can run a loss estimation analysis using only default data (Chapter 3), but your results will be subject to a great deal of uncertainty. If you wish to reduce the uncertainty associated with your results, you can augment or replace the default information with improved data collected for your region of study. You will find that **HAZUS** contains spreadsheets for entering data and several additional utilities that were developed to assist in organizing your inventory data. The following sections provide information on importing data, entering data through **HAZUS** windows, and managing the data.

As has been discussed in earlier sections, it is very likely that data obtained from different sources will not be in the same format. Furthermore, the data may contain a different number of fields than the databases defined in **HAZUS**. This will require putting the data in the correct format to ensure compatibility with **HAZUS** databases. An import database utility has been developed to help you convert databases to the **HAZUS** format (Section 6.2.1).

6.1 Importing GIS and Graphic Files

Many municipalities and lifeline operators are currently using a GIS to maintain databases of their facilities. There are a number of formats that **HAZUS** can accept for graphic or geographic data. Some can be opened without converting to another format, while others will require conversion.

6.1.1 Opening ArcInfo Files in ArcView

ArcInfo coverage files (*.e00) can be opened directly in ArcView. To open an ArcInfo file in ArcView, you start by making the View window active. Choose the **Add Theme** option from the **View** menu. Make sure that the **Data Source Types:** is pointed to **Feature Data Source**. Select the desired coverage file and click the **OK** button (Figure 6.1).

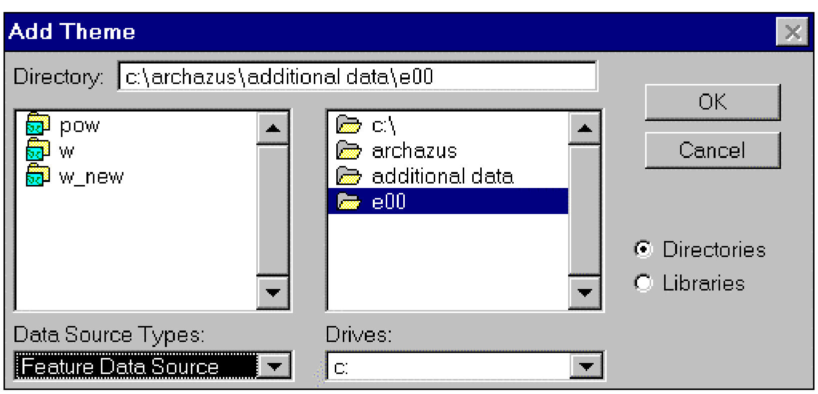


Figure 6.1 Opening ArcInfo files in ArcView.

6.1.2 Importing MapInfo Files in ArcView

MapInfo files cannot be opened directly in ArcView. A special import utility that converts MapInfo (*.mif) files to ArcView(*.shp) files is generally packaged with the

ArcView software and is installed automatically on your system when ArcView is installed.

6.1.3 Opening Atlas GIS Files in ArcView

Atlas GIS exports ArcInfo (*.e00) files that can be directly opened in ArcView as described in Section 6.1.1.

6.1.4 Opening AutoCAD (*.dxf) Files in ArcView

A special ArcView extension can be purchased separately from ESRI that will allow the conversion of AutoCAD (*.dxf) files to ArcView (*.shp) files.

6.1.5 Digitized Maps

ArcInfo has the ability to read and display a variety of image formats. These formats include: *.bsq, *.jpg (when the JPEG Image extension that comes with ArcView is loaded), *.tif, *.gis, and *.bil.

To add an image to a view, click the **Add Theme** button. In the dialog box that appears (shown in Figure 6.2), choose **Image Data Source** from the **Data Source Types** and navigate to the directory that contains the image you want to add. Select the image file and click the **OK** button. Check the box next to the theme's name in the table of contents of the **Map View** window to be able to see the image. It is important to understand that scanned images can be displayed in **HAZUS** but cannot be used for analysis.

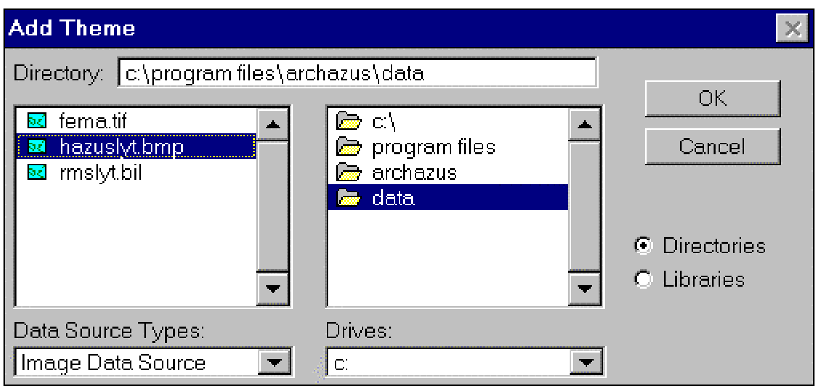


Figure 6.2 Opening an Image file in ArcView.

6.2 Opening Database Files into HAZUS

In some cases, the user can acquire inventory information databases from local agencies in electronic files. To open such file in **HAZUS**, they must be in a (*.dbf) format. Other formats will require to you to use a database manager external to **HAZUS** for converting the file to a (*.dbf) format. These types of files are discussed in Sections 6.2.3 through 6.2.6.

6.2.1 The Import Database Utility

A database import utility has been developed to assist you in converting an electronic database to the appropriate format for **HAZUS**. Clicking on the right mouse button accesses this import utility. The Database Management Tools menu, shown in Figure

6.3, will appear. Select the **Import database** and the dialog box shown in Figure 6.4 will appear. Click on the name of the file you want to import and click the **OK** button.

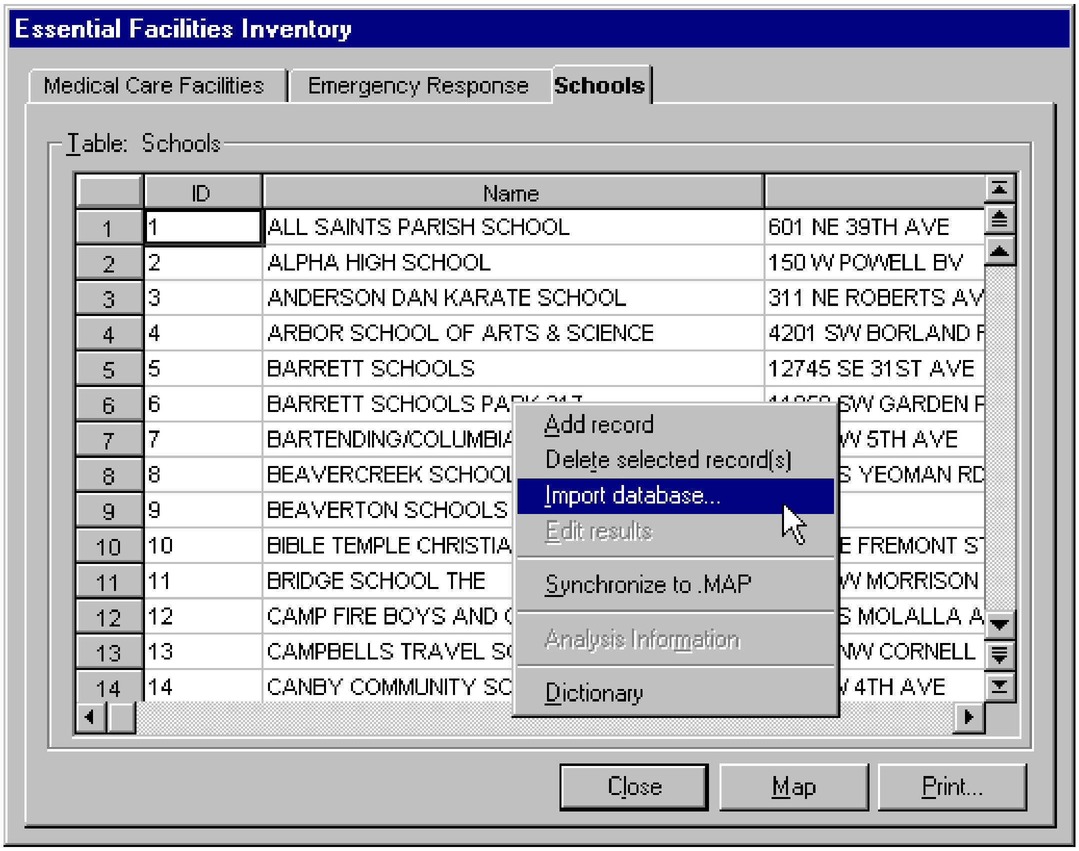


Figure 6.3 Accessing the database menu.

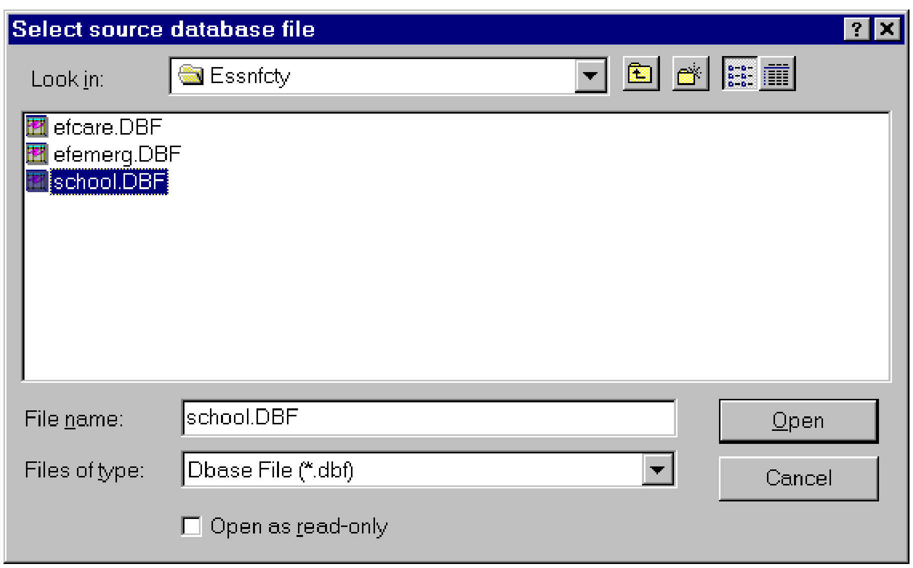


Figure 6.4 Window used to identify the location of a database to be imported.

The mapping window shown in Figure 6.5 is used to map the fields in your database (the source) to the fields used in the **HAZUS** database (the target database). The Database

Dictionary in Appendix E contains the names and structures of all of the databases that are used by **HAZUS**. From the Database Dictionary you can determine the names of the target fields. The Database Dictionary, in an abbreviated, form is available interactively in **HAZUS**. To access the Dictionary, click on the right mouse button, and using the menu shown in Figure 6.3, click on **Dictionary**. An example of the Database Dictionary is shown in Figure 6.6.

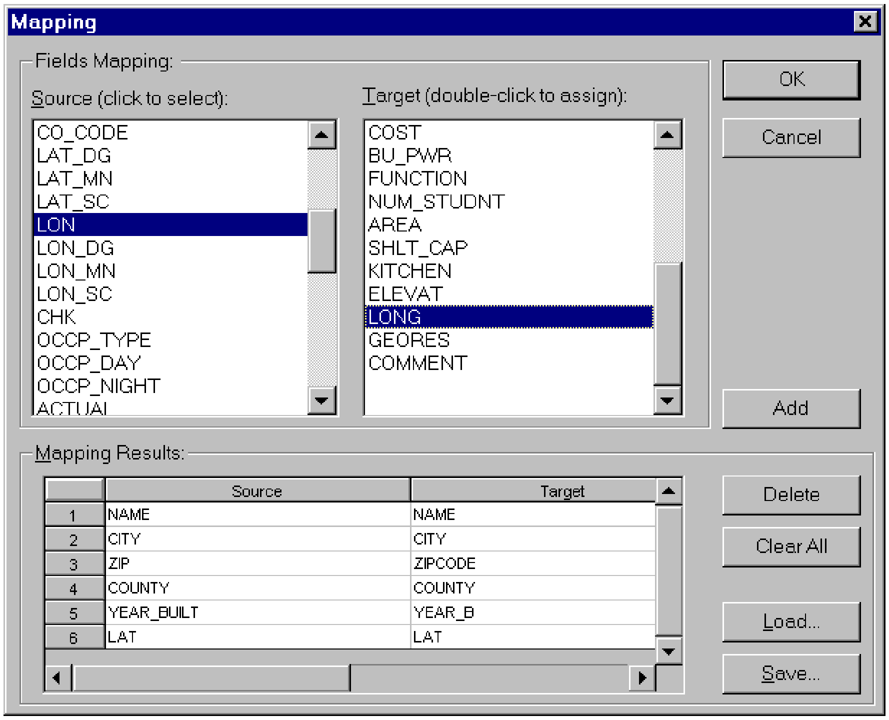


Figure 6.5 Mapping the fields of your data file to the HAZUS data structure, when importing a site-specific database.

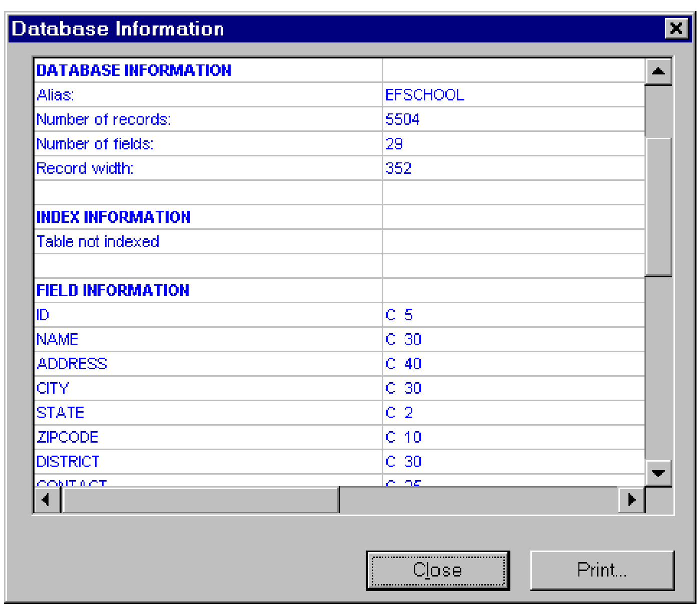


Figure 6.6 Interactive database dictionary.

The fields from the **Source** menu do not have to be in the same order nor do they have to have the same names as the fields in the **Target** menu. For example, in Figure 6.5, the year the school was built is in a field called "YEAR_BUILT" in the **Source** file, whereas the field that contains this information is in the "YEAR_B" field in the **Target** file. To define the desired mapping, simply click on a field name from the **Source** menu (e.g. LON) and the corresponding field name from the **Target** menu (e.g. LONG) and then click on the **Add** button. After performing these steps, the mapping you have defined will disappear from the **Source** and **Target** menus and will appear in the **Mapping Results** box at the bottom of the window. If you make a mistake, click the **Delete** button, and the last mapping pair you have defined will be undone. In this example, the user has already defined six relationships and is in the process of defining a seventh. When you have completed defining all of the information, click on the **OK** button, wait a few seconds, and your imported database will be displayed in **HAZUS**. NOTE: You do not have to map all of the fields from the **Source** menu. However, any fields you do not map will not be imported into the **Target** database.

It is possible to have several databases with the same format. To save the mapping that you have defined so that it can be reapplied to other files, click the **Save** button in Figure 6.5 and the dialog box shown in Figure 6.7 will appear. Enter a name for the mapping scheme and click the **OK** button. To retrieve the saved mapping, click on the **Load** button in Figure 6.5.

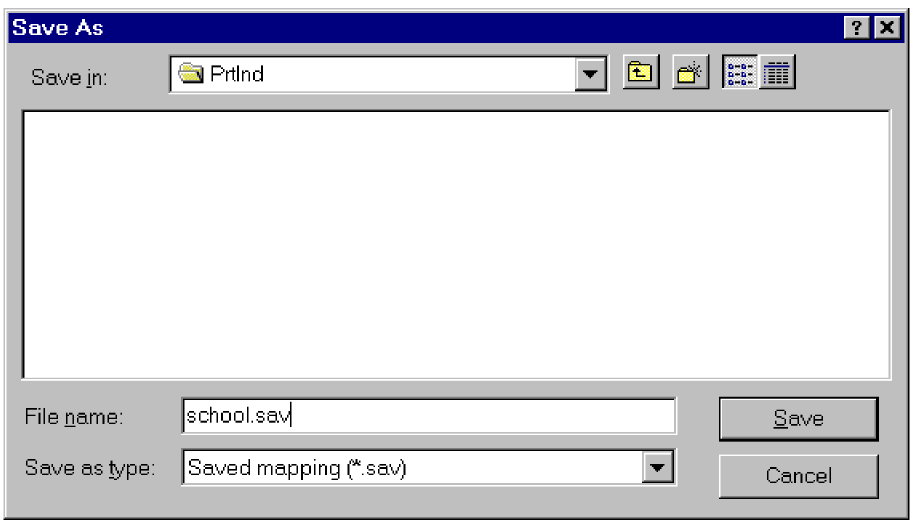


Figure 6.7 Saving a database mapping scheme.

6.2.2 Instructions for Opening dBASE (*.dbf) Files in ArcView

Files in a (*.dbf) format can be directly opened into ArcView. To open a (*.dbf) file in ArcView, select **Add Table** from the **Project** menu, shown in Figure 6.8, and an **Add Table** dialog box will appear as shown in Figure 6.9.

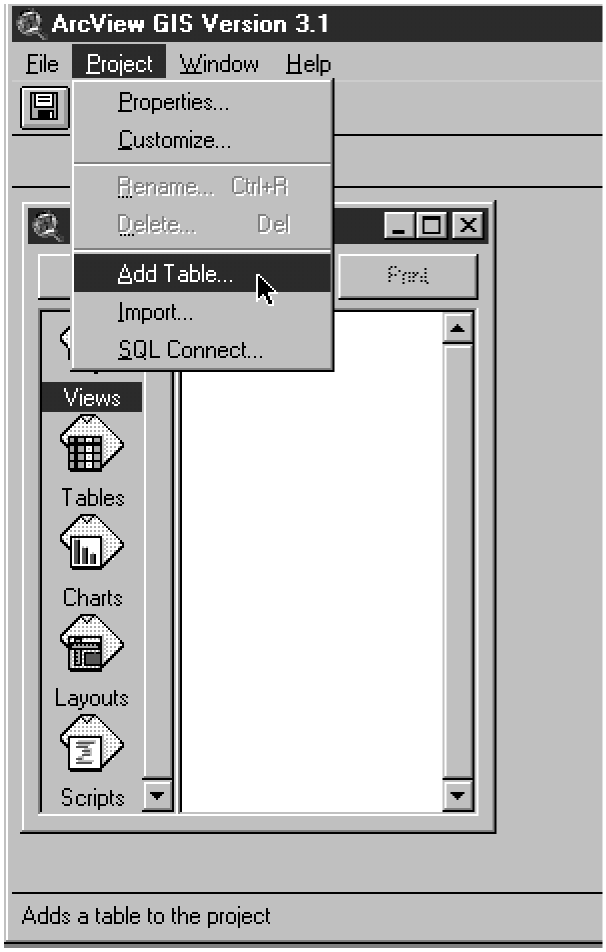


Figure 6.8 Project menu in ArcView.

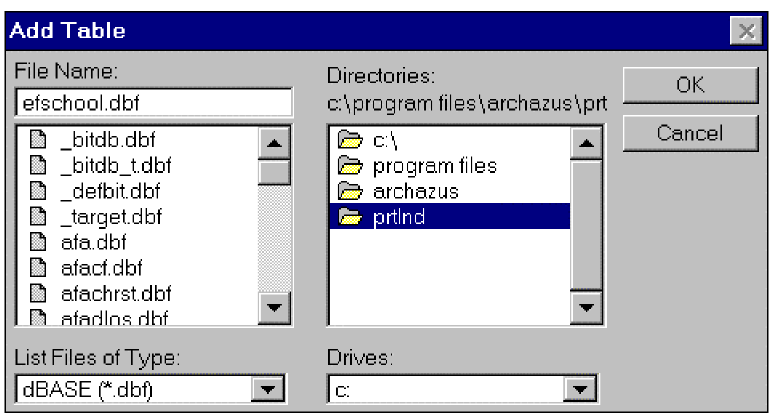


Figure 6.9 Opening a table in ArcView.

Choose **dBASE (*.dbf)** from the **List Files of Type:** box in the lower left corner of the **Add Table** dialog box. Select the drive and directory that contains your file the select the file to be opened. Click the **OK** button.

6.2.3 Opening Excel (*.xls) Files in ArcView

ArcView can read dBASE, INFO (INFO is the database built into ArcInfo software), and tab- or comma-delimited text files. If you have inventory information saved in an Excel spreadsheet (*.xls), you will need to convert it to a (*.dbf) format. To convert the file, use the following steps:

1) Open the file in Excel. Be sure that all of the columns in the spreadsheet are wide enough so that all of the data in each column is showing. Anything that is hidden behind another column will be truncated when you save the file in a (*.dbf) format.
2) Highlight all the columns and rows that you would like to include in the (*.dbf) format file.
3) From the **File** menu, select **Save As**.
4) Select the drive and directory that the file should be saved to. From the **Save as type:** menu, select the file type. As illustrated in Figure 6.9, you should select dBASE DBF.

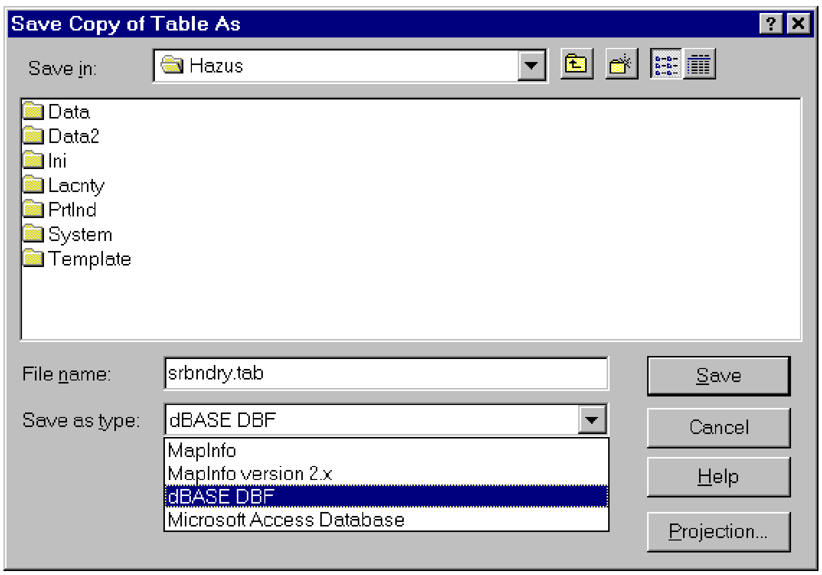


Figure 6.10 Saving an Excel file in a dBASE format.

5) Click on the Save button.

6.2.4 Instructions for Importing Paradox (*.db) Files into ArcView

Paradox files (*.db) cannot be opened directly in ArcView. To open a (*.db) file, you must open the file in Paradox and convert it from (*.db) to (*.dbf) file type. Now you can open the (*.dbf) file directly in ArcView as explained in Section 6.2.2.

6.2.5 Instructions for Opening ASCII Delimited Files in ArcView

Files in an ASCII Tab or Comma Delimited format can be opened directly in ArcView. To open a Tab- or Comma Delimited file, select Add Table from the Project menu (Figure 6.8). Choose Delimited Text (*.txt) from the List Files of Type: box in the lower left corner of the Add Table dialog box. Select the drive and directory that contains your files. Select the file to be opened. Click the OK button.

6.2.6 Instructions for Importing ASCII Fixed Length Files into ArcView

ASCII Fixed Length Field Files cannot be directly opened in or imported into ArcView. An external program should be used to convert such a file into an ASCII Tab or Comma delimited or dBASE file format. Use the procedures discussed in the previous sections to open the files.

6.3 Adding Records to Site Specific Databases

When you are collecting information about essential facilities, high potential loss facilities, lifeline components and facilities storing hazardous materials, you will be collecting and storing the data on a site-by-site basis. Therefore, your databases will contain sets of records in which each record refers to a particular site. When you identify a new site, you will need to add a new record.

When you need to add a record to a database, you go to **Inventory|(**database category)**|Inventory data**. Clicking on the right mouse button while the mouse is positioned in the inventory table accesses the database management tools. This provides you with several utilities for managing your inventory databases. From this menu you can add, or delete records. You can also import a database that contains a complete set of sites of interest to you (Section 6.2.1 To add records, place the cursor on the top of data-sheet and use the right mouse click to access the **Add record** option. The pop-up menu shown in Figure 6.11 will appear. This particular example refers to medical care facilities, but the same steps would be followed for all of the site-specific databases mentioned above. The only exception is that you cannot use this procedure to add lifeline components that are represented as lines instead of points (e.g. highway segments, railway segments, pipeline segments).

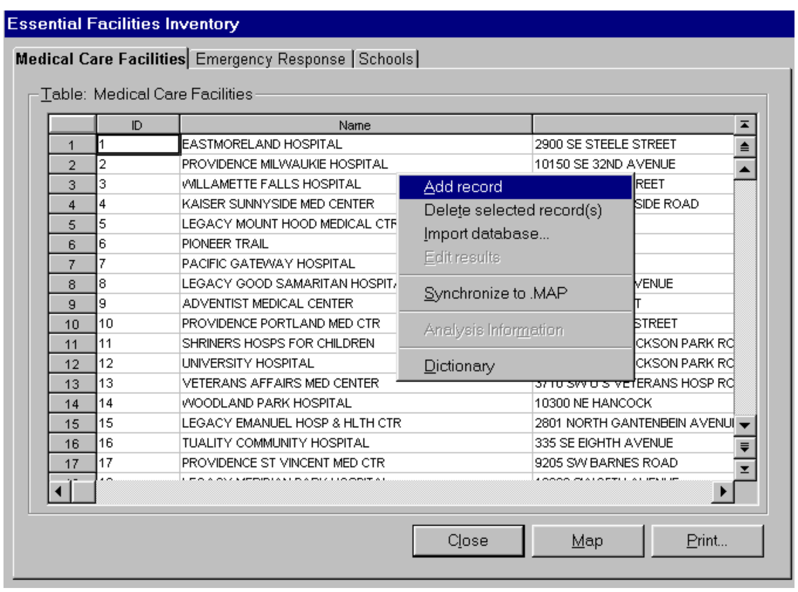


Figure 6.11 The Add Record option

For this example, assume you wish to add two records, you would need to do (right-mouse click)|**Add Record** twice. Every time you add a record, you will be prompt with a "Save" window dialogue. The medical care facility database has 27 fields for storing data; however, only a few of these fields are required for defining a record. The required fields for each database are specified in Appendix E. It is recommended that you give each record an ID number, although the database will accept your entries without ID numbers. ID numbers are used for reporting results. Therefore, if you have a several records without ID numbers you will not be able to associate results with a particular facility.

The one essential datum element required to define a facility is its location. The only way to define a location of a facility in **HAZUS** is to type the longitude and latitude of the facility. If you don't know the longitude and latitude of the facility, you would need to use a geocoder[4] to get the longitude and latitude of the location and then add it to the database in **HAZUS**.

Once you have defined a location, click on the **Close** button and the database will be saved. Alternatively, you can map the database using the **Map** button or switch to another database by clicking on the tabs at the top of the window (for example, click on Schools). In any of these cases the dialog box shown in Figure 6.13 allow you to confirm the database changes.

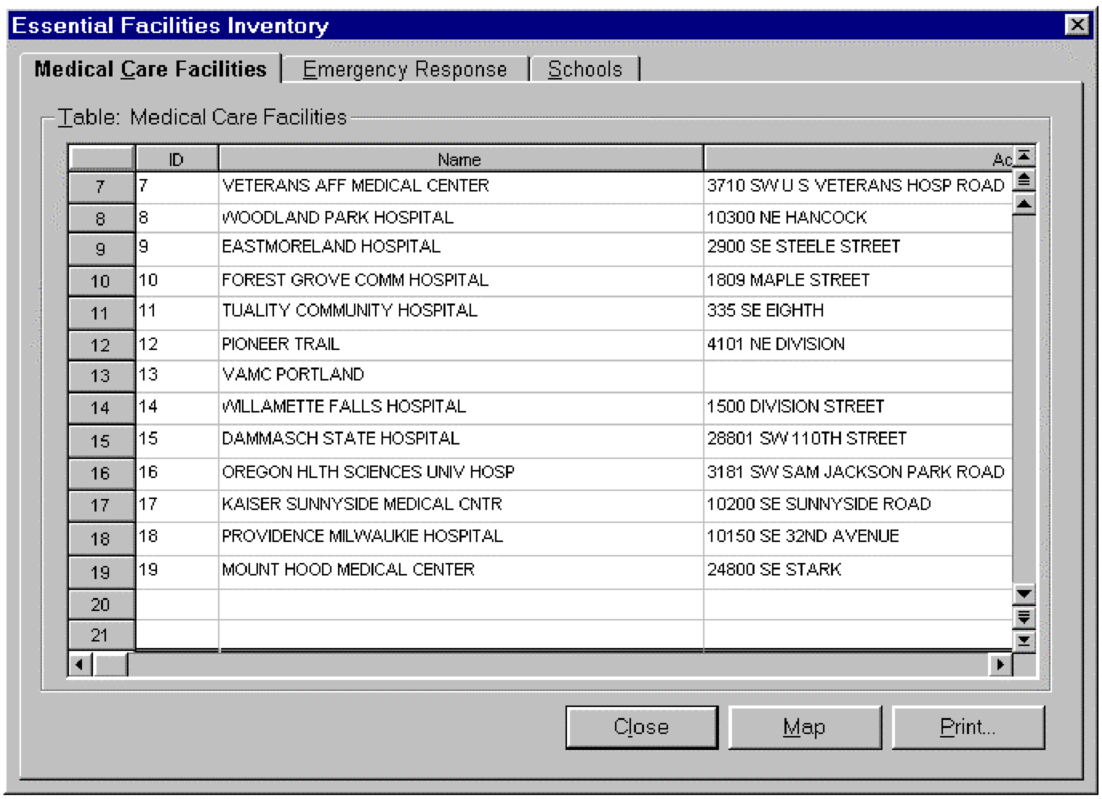


Figure 6.12 Modified medical care facilities database after adding two records.

[4] The geocoding process is performed outside HAZUS. Any commercial geocoder application can be used.

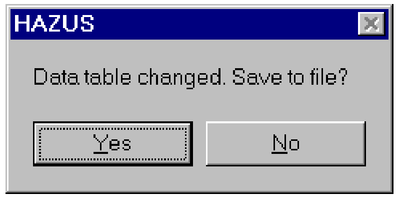


Figure 6.13 Confirmation window when data have been changed.

6.3.1 Errors When Adding Records

HAZUS is very strict about enforcing the rule that *all inventory data points must fall within the study region boundary*. If you define facility locations that are outside the study region, **HAZUS** deletes them and displays the dialog show in Figure 6.14.

Figure 6.14 Error message when adding records with sites located outside the study region.

6.4 Deleting Records from Site Specific Databases

Select the record to be deleted from a database by clicking on the record number on the left side of the record. To highlight the records shown in Figure 6.15, click on the number 5 and 6. When the records have been selected, use the right mouse button to display the database management options and select **Delete selected record(s)…**. The dialog box shown in Figure 6.16 will appear. When you click **Yes**, the records are deleted.

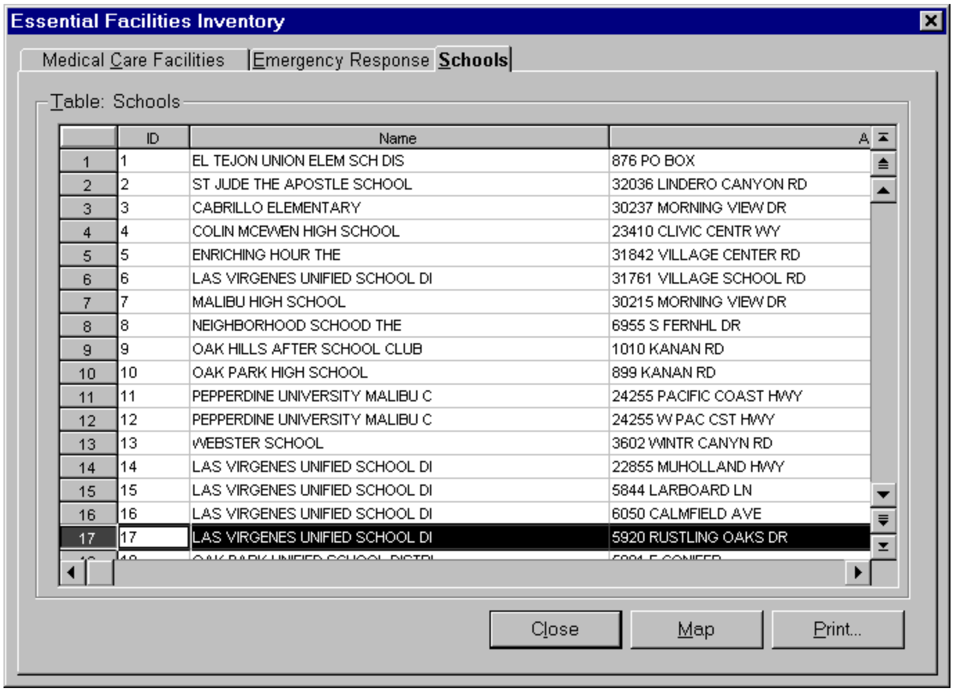


Figure 6.15 Selecting a record to delete from a database.

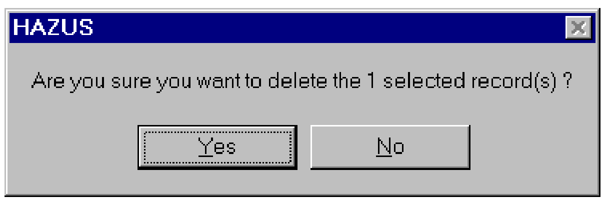


Figure 6.16 Confirmation window for deleting a record.

6.5 Editing Records

Data within a record can be edited by double clicking on the spreadsheet cell containing the data and then highlighting the text to be modified. To highlight the text, hold the left button of the mouse down while dragging it over the text. Release the mouse and start typing. The new typing entry will replace the highlighted text.

Alternatively, a facility can be moved by selecting **Edit|Start Editing** from the map window (i.e. the window that appears after you map a database). Once you are in an edit mode, double click on the location to be moved and a box will appear around the symbol as shown in Figure 6.17. With your mouse button held down, drag and drop the facility symbol from its old location to the desired new location. To delete a location, click on **Edit|Start Editing**, double click on the location to be deleted and click on **Edit|Delete Features** (as shown in Figure 6.17).

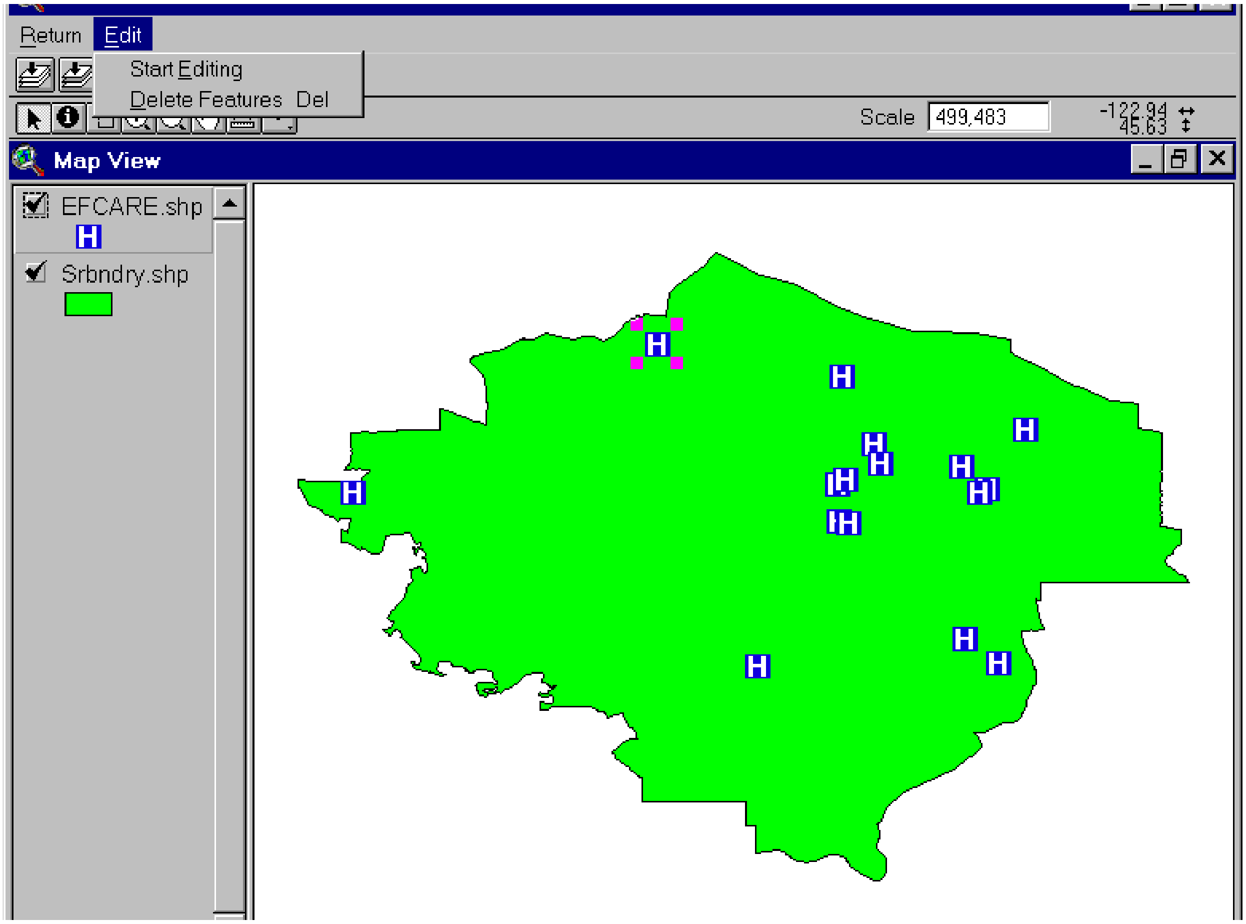


Figure 6.17 Editing Window

You also have the option of moving or deleting more than one record at a time. To do so, click on each location, one at a time, while holding the shift key down. Once all the locations have been selected, release the shift key and follow the above steps for deleting or moving a record. It is also possible to access the **Start Editing** and **Delete Features** menus by positioning your cursor over the map and clicking the right mouse button. When you have finished, click on the **Return|Return to Table** menu. You will be asked to confirm your changes as shown in Figure 6.18.

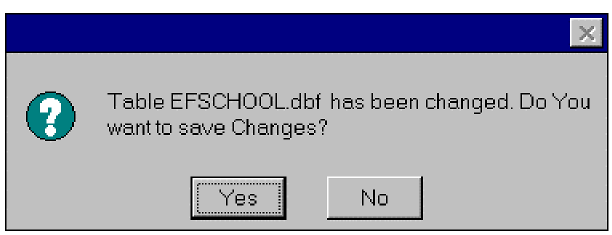


Figure 6.18 Confirmation window for modifying a site-specific database in the map window.

6.5.1 Synchronizing Databases with Mapping Coordinates

There are two databases that contain your data: a (*.dbf) file and a (*.shp) file. The (*.dbf) file contains the database as you see it in the spreadsheet. The (*.shp) file contains the coordinates of the points used to display the points on a map. If you modify data in the latitude and longitude cells of a record in the spreadsheet, you need to "Synchronize" the databases so that the spreadsheet and mapped database are displaying the same information. Synchronizing, which is done with the **Synchronize to .MAP** option as shown in Figure 6.3, will update the (*.shp) file so that the mapping coordinates agree with the spreadsheet.

When data is modified using the map window (Section 6.4), it is automatically synchronized.

6.6 Lifelines

6.6.1 Adding Lifeline Segments

Lifeline segments must be created using ArcView tools. To add lifeline segments you must be familiar with the basic functions of ArcView.

6.6.2 Adding Highway Bridges

Adding highway bridges is done using the procedure discussed in Section 6.2. To access the database, use the **Inventory|Transportation Systems|Inventory Data** menu. **HAZUS** assumes a default bridge class of HBW5 (Concrete Construction, Simply Supported, Multiple Column Bent, Built before 1990 and Constructed outside of California - see Table A.6 in Appendix A) if no bridge class is supplied.

6.7 Specifying Hazard Maps

Simplified hazard maps are generated during the creation of the study region. These files are named SOILDEF, LQFDEF, and LNDDEF and are located in the study region directory. These crude hazard maps are based on default soil maps and the census tract boundaries and can be modified by a user that has a general understanding of spatial distribution of the hazards. If digital information is available from experts or other state agencies, the expert-generated maps should replace the simplified maps.

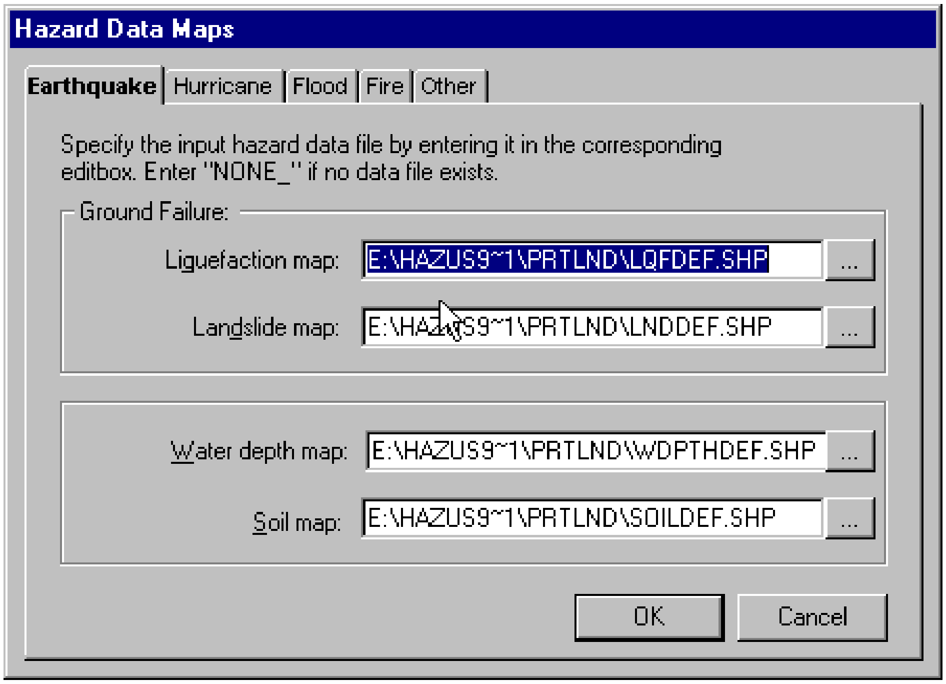


Figure 6.28 Specifying hazard maps in HAZUS.

Soil, liquefaction susceptibility and landslide susceptibility maps are specified in the window shown in Figure 6.28. This window is accessed from the **Hazard|DataMaps** menu. In this example, the default maps generated by **HAZUS** during the creation of the study region are specified. To change the name of a file, either type the path name in the provided box, or click on the button to the right of the box. This button will access the standard "Open" window as shown in Figure 6.29. It is now possible to move around the directories to find the needed file. Note: Map files in ArcView are identified by the .shp extension.

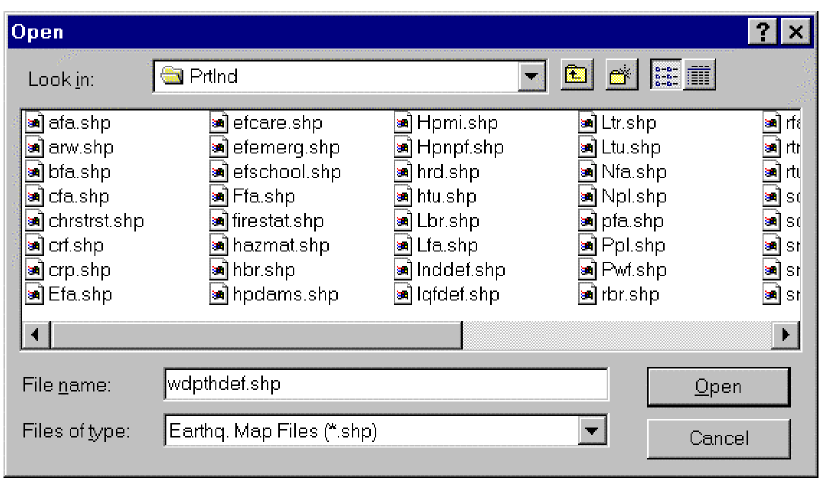


Figure 6.29 File open window listing (*.shp) files.

6.7.1 Modifying Census Tract Centroid Hazard Values

For the general building stock, **HAZUS** uses a simplified analysis procedure that aggregates the data and locates the aggregated data at the centroid of the census tract. In some cases, the soil or susceptibility class determined for the centroid does not represent the average value for the census tract. **HAZUS** was designed with a capability to modify the values based on your observation and understanding. In the following example, the census tract centroid soil information for a study region is modified. The liquefaction and landslide maps can also be changed using the same approach. This procedure can only be completed after a PESH analysis has been run at least once.

1. Display the soil map using **Map|Earthquake|Soil Type** and the window shown in Figure 6.30 will appear. Select the "Show hazard values…". Click **OK** and a census tract map with the shaded hazard values will appear as shown in Figure 6.31. In this case, the user is displaying the default soil map, so all of the census tracts are soil class D.

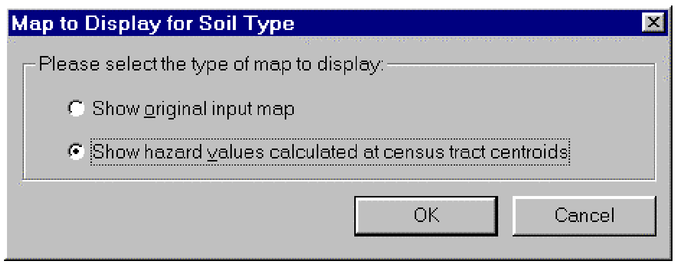


Figure 6.30 Map to Display for Soil Type Dialog.

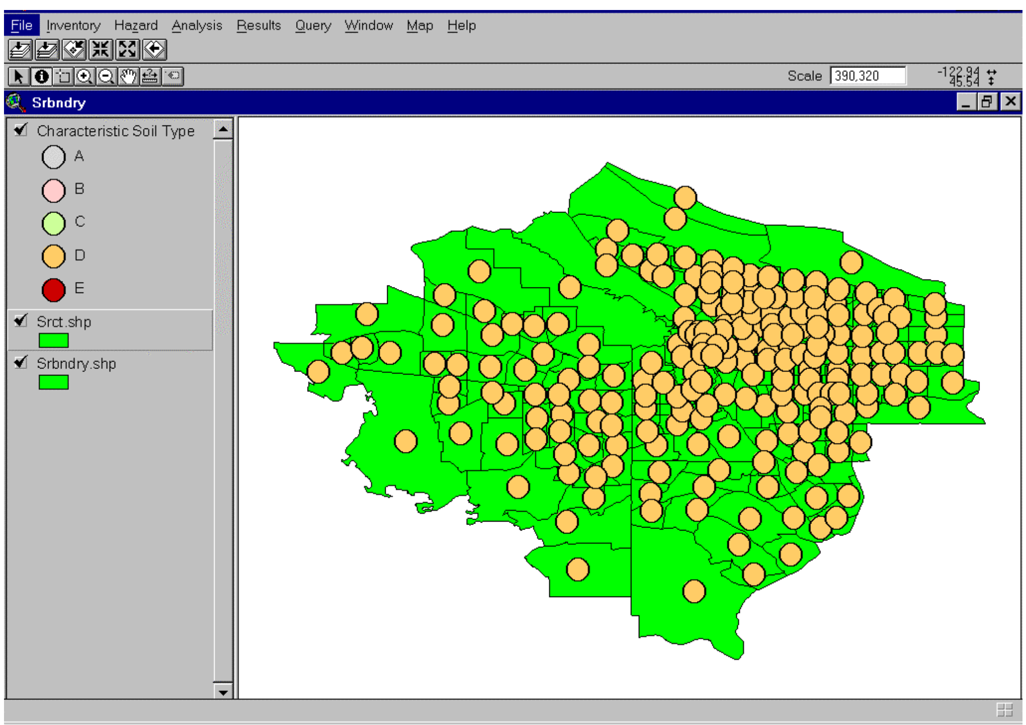


Figure 6.31 Soil map with census tract centroid values.

With the [i] button (i.e., "Info Tool" button), click on the census tract to be changed. A dialog window displaying information related to the currently active layer will appear. In this case they are three layers in the map:

- chrstrst: characteristic soil map
- SRCT: census tract boundaries
- srbndry: study region boundary (which is not accessible)

By making any of the chrstrst layers active and clicking on the button, Figure 6.32 will appear displaying more information related to the particular location you had selected in the active layer:

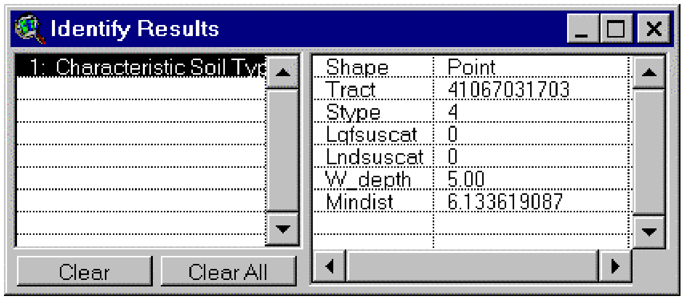


Figure 6.32 Identify Results window showing details information of a selected location.

Note that you can switch between the layers and select different locations in the active layer with the Info Tool button and have a list of location information displayed at one time as shown in Figure 6.33. You can switch between any of the locations on the list and view more information related to the particular location you have selected.

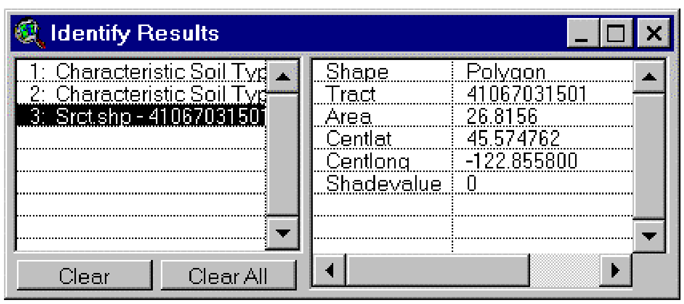


Figure 6.33 The Identify Results window showing a list of locations.

Chapter 7. Displaying, Modifying and Mapping Inventories

Chapter 6 discussed how to enter data and import databases. Once your data is entered into **HAZUS**, you have a number of options available for displaying and modifying the data.

7.1 Editing a Database

Data within a database can be edited by double clicking on the spreadsheet cell containing the data you want to change. Highlight the text you wish to modify and your typing will replace the highlighted text.

7.2 Printing Out a Database

All databases can be printed out using the **Print** button at the bottom of the window.

7.3 Modifying Occupancy to Model Building Type Relationships

From the **Inventory|General Building Stock|Occupancy Mapping...** menu a spreadsheet, such as the one shown in Figure 7.1, will appear. In this particular example the default mapping is for a low seismic region as shown in the Design Level list box in the upper left corner of the window. If the region you are studying happens to be moderate or high seismic, the spreadsheet will be populated differently and the Design Level list box will indicate a moderate or high design level.

The design level designation is tied to the damageability of a structure reflected in the damage functions (fragility curves). Fragility curves are discussed in Chapter 9 of this manual and in the *Technical Manual*. The design levels correspond to map areas in the document *NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings* (FEMA, 1991a). High seismic design corresponds to map area 7, moderate seismic design to map areas 5 and 6, and low seismic design to map areas 1 through 4.

Each row of the spreadsheet represents an occupancy class and each column represents a model building type. For this example, low-rise construction (RES3) consists of 73% W1, 2% S3, 3% S4L, 6% C2L, 1% C3L, 1% PC2L, 9% RM1L and 5% MH (see Table 3A.4 of the Technical Manual). Many of the model building types are not visible in Figure 7.1, but can be seen by scrolling to the right on your screen. The sum of the model building type percentages for each occupancy is found in column 2 of the spreadsheet, entitled “Total”.

It should be noted that three default occupancy-to-model-building-type mapping schemes have been developed (West Coast, Mid-West and East Coast) and are found in Appendix 3A of the Technical Manual for general building stock and Appendix 3B for essential facilities. Appendix 3C summarizes which of these three groups is identified with each of the fifty states. Finally, it should be noted that at the present time the mapping schemes for Pre-1950, 1950-1970, and post-1970 differ only in the West Coast region.

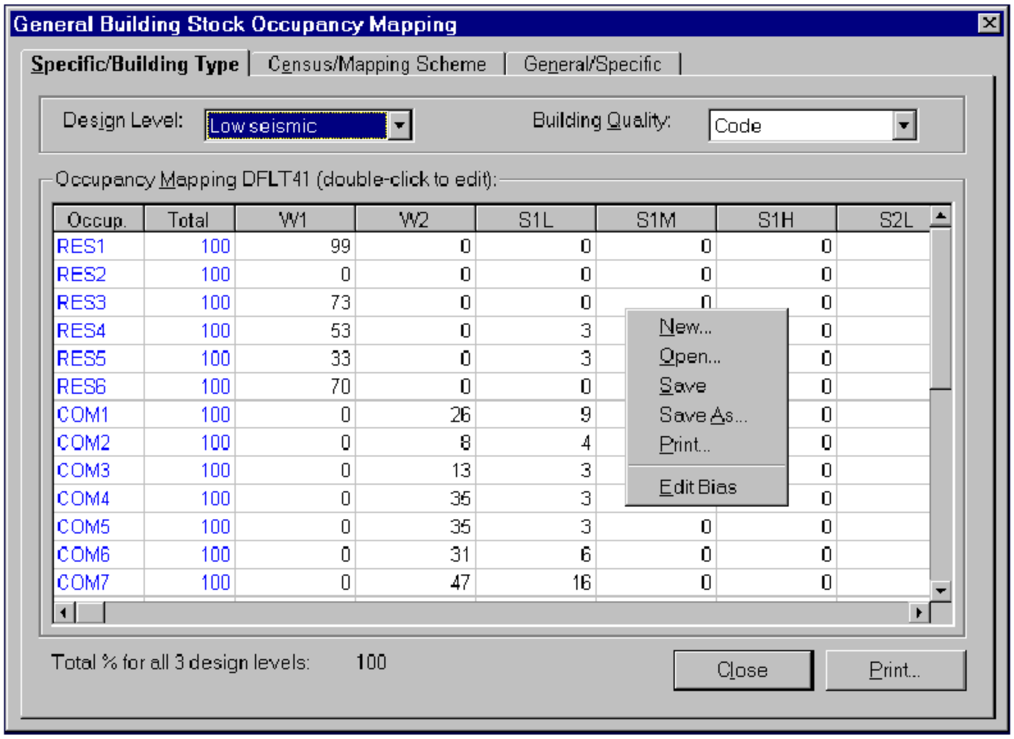


Figure 7.1 Window displaying a specific occupancy to model building type mapping scheme.

The data management menu shown in Figure 7.1 allows you to open other mapping schemes if they exist. Using the right mouse button, click anywhere on the spreadsheet to access the data management menu. Click on **Open…** and the dialog box shown in Figure 7.2 will appear. This dialog box shows you all of the occupancy to model building type mapping schemes that have been defined for your region. In this example, two default schemes are available: DFLT41 and DFLT41L. The description of the mapping scheme (in this case, Oregon State (Default)) can be seen in the lower portion of the window.

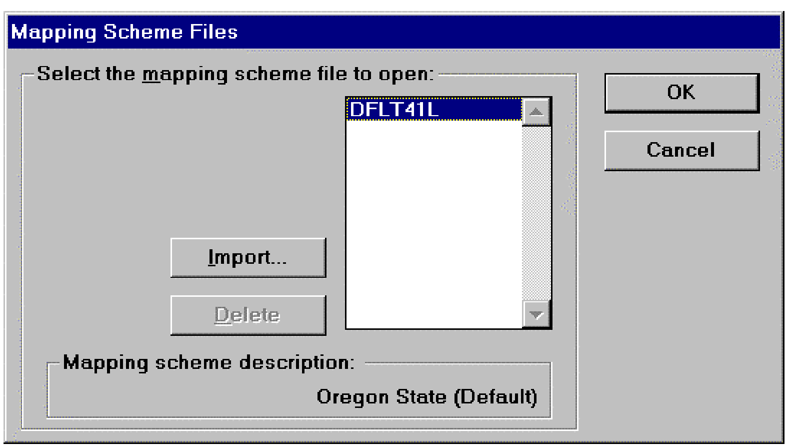


Figure 7.2 Selecting a model building type to occupancy mapping scheme

To view a scheme, highlight the file name of that mapping scheme and click on **OK**.

7.3.1 Modifying the Mix of Age and Building Heights

The default occupancy to building type mapping is based upon a default mix of ages and heights. The default mapping scheme varies by state and is displayed when the user opens the window displayed in Figure 7.1. It is possible that different census tracts within the study region will have different age and height mixes. A downtown area might have a large percentage of high-rise structures, whereas a residential area may not. To override the default the user can use the New Mapping Scheme Parameters window shown in Figure 7.4.

As an example of the use of the New Mapping Scheme Parameters menu, suppose you determined that 50% of the buildings in a census tract were low-rise and 50% were mid-rise, and that 50% of the buildings were built before 1950, 30% between 1950 and 1970 and 20% after 1970. Before you modify your mapping scheme, you should save it under a new name by clicking on the right button of your mouse and selection the **Save As** option shown in Figure 7.1. Clicking the right mouse button with the pointer positioned over the spreadsheet accesses the data management menu. After typing a new name (for this example - NEWMIX) and a description of the mapping (see Figure 7.3) click on the **OK** button.

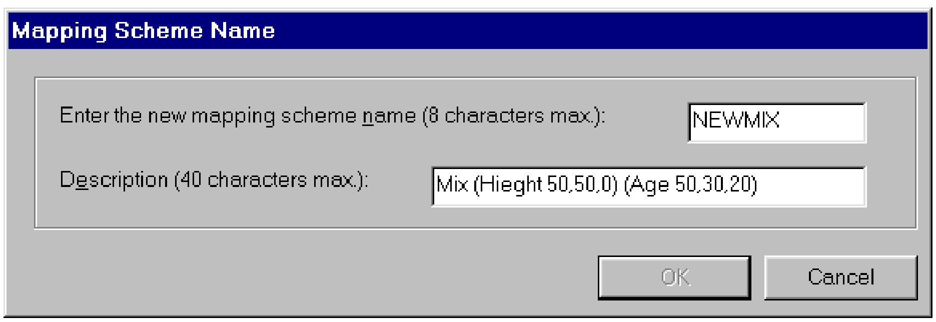


Figure 7.3 Saving a mapping scheme under a new name.

Clicking on the right mouse button anywhere in the table and choosing the option **New** as shown in Figure 7.1 can create the New Mapping Scheme Parameters window. Once the age and height percentages have been set as shown in Figure 7.4 and you have clicked the **OK** button, a new occupancy mapping automatically will be calculated. You will be asked to confirm that you want to overwrite the mapping scheme (see Figure 7.5). Click **OK** and you will be presented with the modified mapping shown in Figure 7.6. A detailed discussion of how age and height are used to modify the mapping scheme is found in Section 4.5. It is important to keep in mind that changing the age distribution only changes the percentages of building types. It does not change the design level. The design level is changed by using the **Edit Bias** option (Section 7.3.2).

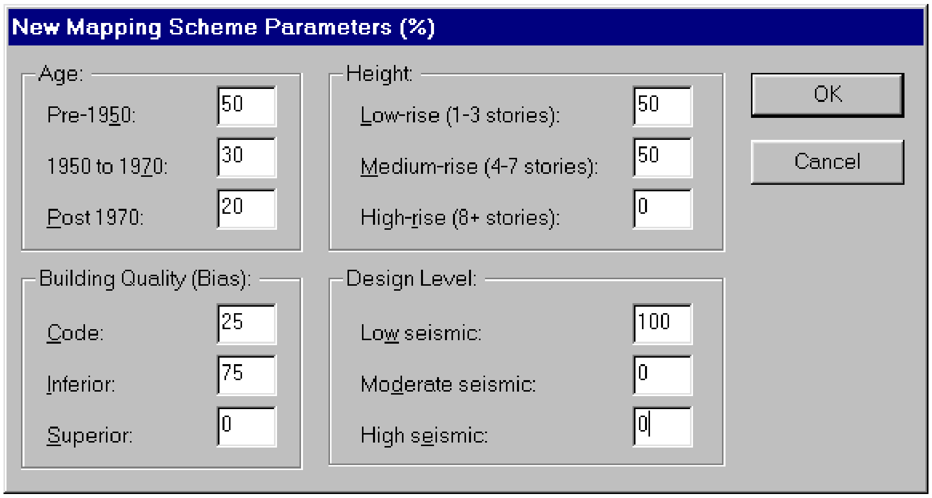


Figure 7.4 New Mapping Scheme Parameters window.

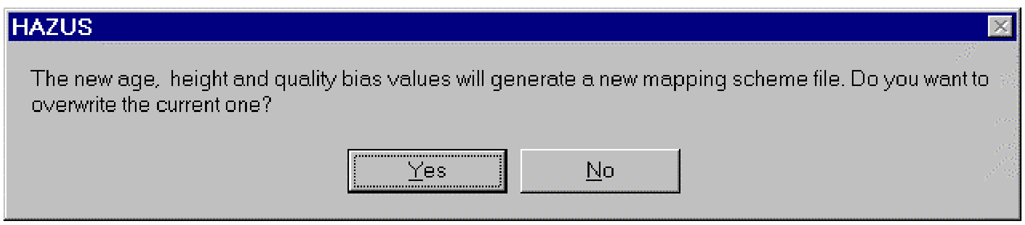
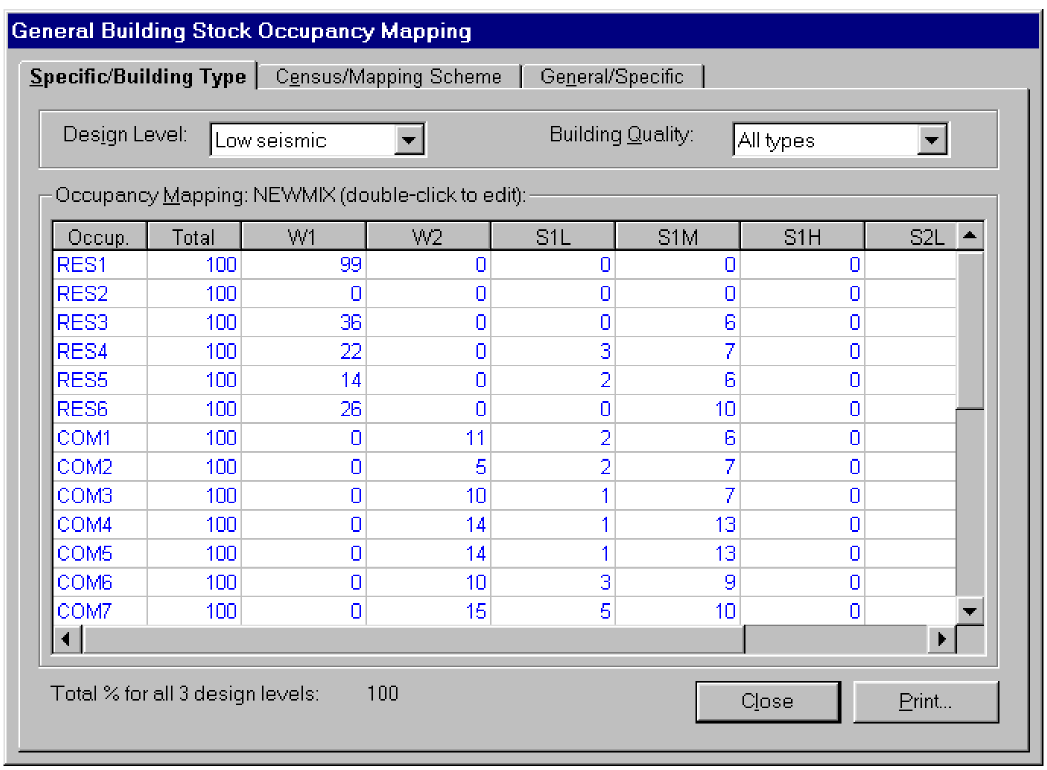


Figure 7.5 Confirmation window for overwriting a mapping scheme.



Occup.	Total	W1	W2	S1L	S1M	S1H	S2L
RES1	100	99	0	0	0	0	
RES2	100	0	0	0	0	0	
RES3	100	36	0	0	6	0	
RES4	100	22	0	3	7	0	
RES5	100	14	0	2	6	0	
RES6	100	26	0	0	10	0	
COM1	100	0	11	2	6	0	
COM2	100	0	5	2	7	0	
COM3	100	0	10	1	7	0	
COM4	100	0	14	1	13	0	
COM5	100	0	14	1	13	0	
COM6	100	0	10	3	9	0	
COM7	100	0	15	5	10	0	

Figure 7.6 Mapping scheme modified to reflect user defined age mix

7.3.2 Modifying the Mapping Scheme to Reflect Different Design Levels

The bias refers to whether the structures are built to code, are superior to the code or inferior. The default is that 25% of buildings are built to code and 75% are inferior. The bias is described in detail in Section 5.7 of the *Technical Manual*. The default bias should be used unless you have an in-depth understanding of building practices in your region.

HAZUS gives you the option to define a mix of design levels for each model building type. A mix of design levels can occur when structures are built at different times and are designed under different codes. The damage functions provided in the damage module are based on current NEHRP provisions (FEMA, 1991a) and are intended to represent current code provisions. Damage functions are developed for each of three seismic design regions, defined in terms of the 1994 NEHRP Provisions map areas: High Seismic Design (Map Area 7), Moderate Seismic Design (Map Areas 5 and 6), and Low Seismic Design (Map Areas 1 to 4).

In those regions that have not enforced seismic design codes or have a number of buildings that do not meet current standards, the damage functions may under-predict damage. In contrast, the damage functions may over-predict damage for buildings that are designed/constructed for performance beyond code requirements. The latter case is not expected to include a large population of buildings and is not expected to affect regional damage/loss estimation. The year when seismic provisions were included in building codes varies by region. The user should consult a local structural engineer or the local building department to determine what year seismic design provisions was enforced. Section 5.7 of the *Technical Manual* and FEMA publication 154 provide some general guidelines for different regions of the United States.

Users may tailor the damage functions to their study area of interest by determining the appropriate fraction of each building type that conforms essentially to current code provisions (for example, High in California, Moderate and Low in Florida) and the fraction that is substandard by a significant degree. Buildings that are considered significantly substandard would be assigned a lower seismic design group. For instance, certain types of older buildings in Map Area 7 should be evaluated using damage functions for Map Areas 5 & 6. Such buildings would include concrete moment frames (Building Type C1) on the west coast built prior to the mid-1970's. Buildings over 60 years old were likely designed only for wind and at least a portion of these older buildings may best be evaluated using the damage functions developed for Map Areas 1-4. To modify defaults, users must be knowledgeable about the type and history of construction in the study region of interest and apply engineering judgment in assigning the fraction of each building type to a seismic design group.

To clarify how to develop an occupancy mapping to reflect different design levels, assume that a census tract within the study region has a mixture of construction so that the RES1 occupancy mapping is as shown in Table 7.1. In this example, 73% of all single-family dwellings (RES1) are low-rise wood frame (W1), 5% are steel light frame (S3) and so on. Although this census tract is in a high seismic region, some of the structures were built before seismic design criteria were adopted. Thus 50% of all RES1 are seismically designed W1, 15% are moderate seismic W1 and 8% are low seismic W1.

An example of a low seismic construction would be a house with an unbraced cripple wall. All building types that are not shown in Table 7.1 are not present in the hypothetical census tract. For any occupancy class, the model building type percentages across all design levels must add to 100%. This is checked and indicated in the lower right-hand corner of the table.

Table 7.1 Sample occupancy mapping for occupancy RES1 (single family dwelling)

Design Level	Model Building Type						
	W1	S3	S4L	RM1L	URML	MH	
High Seismic	50%	5%	3%	3%	0%	2%	sum = 63%
Moderate Seismic	15%	0%	0%	3%	0%	0%	sum = 18%
Low Seismic	8%	0%	0%	3%	5%	3%	sum = 19%
Total Percent	73%	5%	3%	9%	5%	5%	sum = 100%

You would enter this mapping scheme in row one of the window shown in Figure 7.2 by toggling between design levels with the **Design Level** menu and entering the appropriate values for each design level. The result is shown in Figure 7.7. Note in Figure 7.7 that the total RES1 in the high seismic design level is 63%. However the sum of all three RES1 design level totals is 100%. If the total for all design levels is not 100%, you will be given an error message when you try to save the mapping.

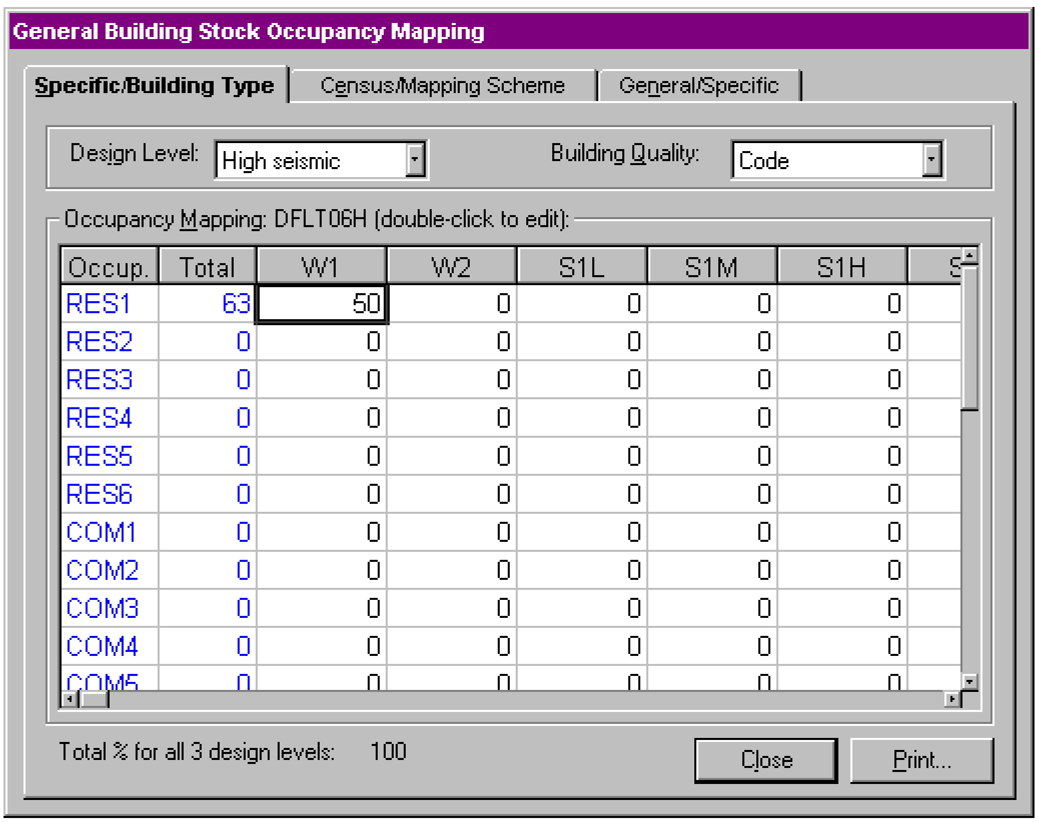


Figure 7.7 Mapping scheme modified to reflect different design levels.

7.4 Defining Different Mapping Schemes for Different Census Tracts

The user can create a series of occupancy mappings by modifying the default values and saving the different mapping schemes under different filenames (filename is in upper left portion of the spreadsheet in Figure 7.7). Different mapping schemes can then be assigned to different census tracts. The reason the user may wish to create different mapping schemes is that building practices may vary throughout the study region. For example, in an older area 30% of the retail buildings (COM1) may be low rise unreinforced masonry (URML), while in more recently developed areas, only 5% of COM1 may be of model building type URML.

Once a series of occupancy mapping schemes have been defined and saved using the right button mouse click **SAVE AS** option, you can then assign schemes to each census tract. This is done using the window shown in Figure 7.8. In this example, two mapping schemes have been defined (the default mapping and the new mapping that includes age and height mix). Initially, upon entering this window, all census tracts will be assigned the default mapping scheme for their particular state. You can override the default by clicking on the row number for a census tract and then double clicking on the desired mapping scheme. When you close this window, you will be asked to confirm your changes.

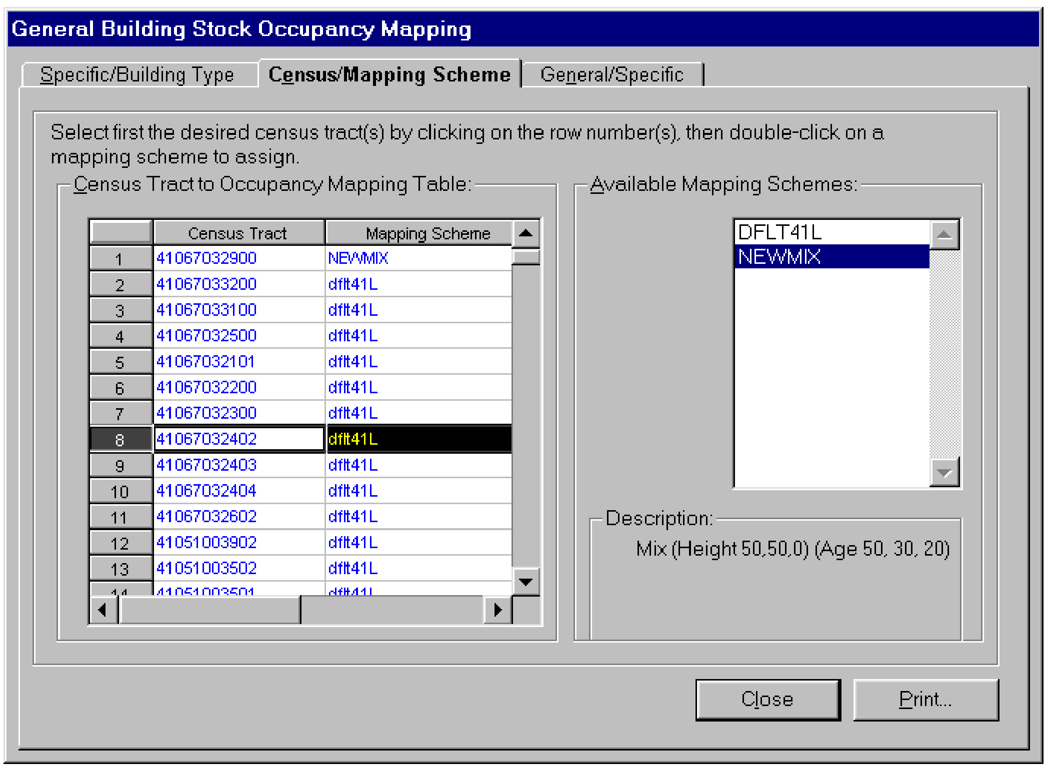


Figure 7.8 Occupancy mapping scheme assignment window

7.5 General to Specific Occupancy Mapping

You have the option to modify the distribution of specific occupancies within each general occupancy class. Within the general occupancy class Residential, there are six specific occupancy classes as summarized in Table A.3 in appendix A. An example of the distribution of residential occupancies is shown in Figure 7.9. In this window, it is shown that for census tract 41005020600 89% of residential construction is RES1, 0% is RES2, 11% is RES3, and 0% is RES4, RES5, and RES6. Within each general occupancy class (residential, commercial, industrial, agriculture, religion/non profit, government and education) the specific occupancies must sum to 100%. Default distributions are provided in **HAZUS**. These defaults are based on the 1990 Census and 1996 Dun and Bradstreet Data. Modifications to these defaults cannot be made in the window shown in Figure 7.9 and are made by altering the dollar exposure values in Figure 7.10. This window is accessed from the **Inventory|General Building Stock| Square Footage** menu.

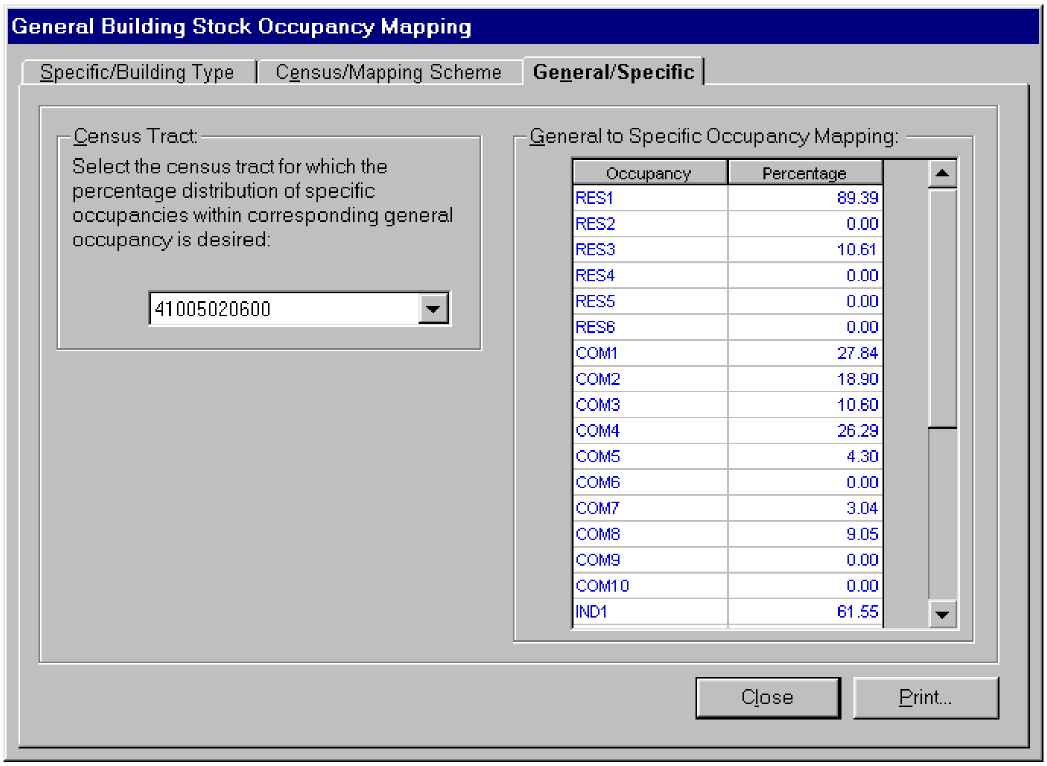
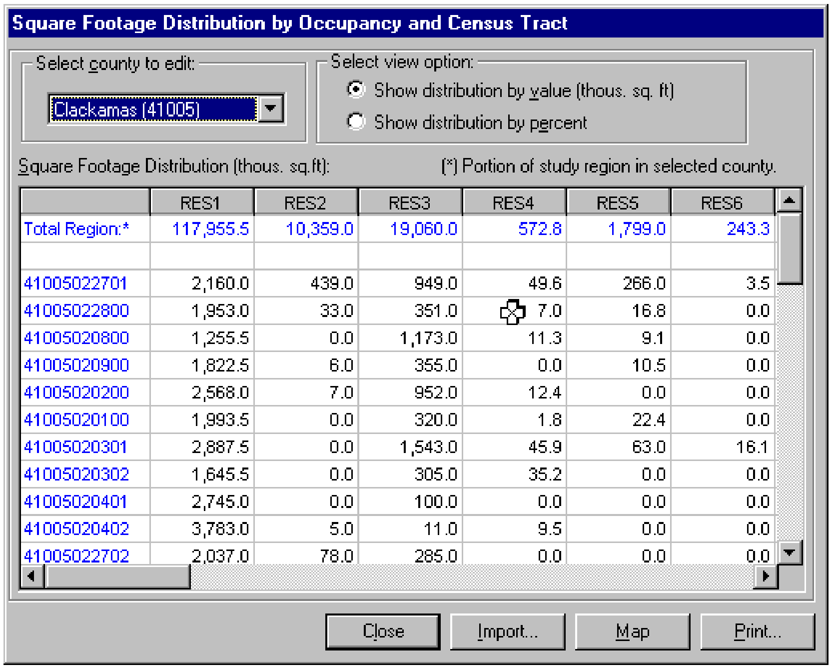


Figure 7.9 General to specific occupancy mapping scheme.



	RES1	RES2	RES3	RES4	RES5	RES6
Total Region:*	117,955.5	10,359.0	19,060.0	572.8	1,799.0	243.3
41005022701	2,160.0	439.0	949.0	49.6	266.0	3.5
41005022800	1,953.0	33.0	351.0	7.0	16.8	0.0
41005020800	1,255.5	0.0	1,173.0	11.3	9.1	0.0
41005020900	1,822.5	6.0	355.0	0.0	10.5	0.0
41005020200	2,568.0	7.0	952.0	12.4	0.0	0.0
41005020100	1,993.5	0.0	320.0	1.8	22.4	0.0
41005020301	2,887.5	0.0	1,543.0	45.9	63.0	16.1
41005020302	1,645.5	0.0	305.0	35.2	0.0	0.0
41005020401	2,745.0	0.0	100.0	0.0	0.0	0.0
41005020402	3,783.0	5.0	11.0	9.5	0.0	0.0
41005022702	2,037.0	78.0	285.0	0.0	0.0	0.0

Figure 7.10 Square footage per census tract and occupancy.

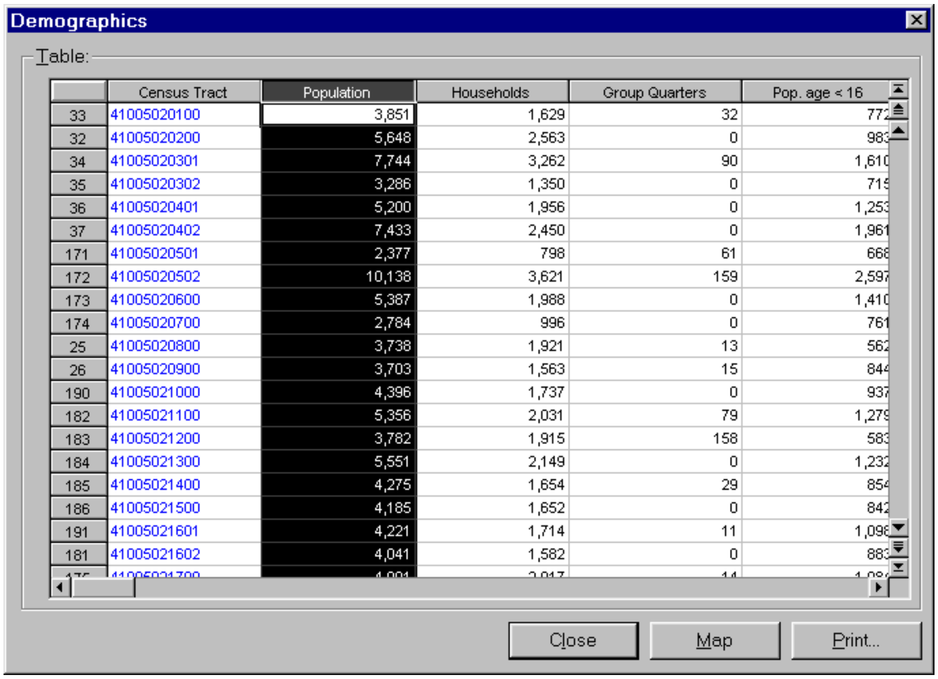
7.5.1 Mapping a Database

All databases can be mapped using the **Map** button at the bottom of the window. MapInfo tools can be used to modify legends and to bring different layers to the front. Entries in site-specific databases, such as emergency facilities and lifeline components, will appear as symbols on the map. Other types of databases, such as census data, soil types, and general building stock inventory, are displayed as thematic maps. In thematic maps, shading or colors are used to display attributes of a particular region. For example, hatching represents areas with dense population, and dotting represents areas with less dense population as shown Figure 7.12.

7.5.1.1 Modifying the Ranges and Colors of a Thematic Map

When you click on the **Map** button at the bottom of a database window, a thematic map will be displayed using a default setting for the ranges and colors of data. It is very simple to customize the look of a map to meet your own needs. The following is an example of the procedure to customize a population data map.

1. Select the **Inventory|Demographics** menu option and the table shown in Figure 7.11 will appear. The database contains many attributes that can only be mapped one at a time. In order to map the population information, click on the word *Population* to highlight that column of the database. Click on the **Map** button and the map in Figure 7.12 will be generated.



Demographics

Table:

	Census Tract	Population	Households	Group Quarters	Pop. age < 16
33	41005020100	3,851	1,629	32	772
32	41005020200	5,648	2,563	0	983
34	41005020301	7,744	3,262	90	1,610
35	41005020302	3,286	1,350	0	715
36	41005020401	5,200	1,956	0	1,253
37	41005020402	7,433	2,450	0	1,961
171	41005020501	2,377	798	61	668
172	41005020502	10,138	3,621	159	2,597
173	41005020600	5,387	1,988	0	1,410
174	41005020700	2,784	996	0	761
25	41005020800	3,738	1,921	13	562
26	41005020900	3,703	1,563	15	844
190	41005021000	4,396	1,737	0	937
182	41005021100	5,356	2,031	79	1,279
183	41005021200	3,782	1,915	158	583
184	41005021300	5,551	2,149	0	1,232
185	41005021400	4,275	1,654	29	854
186	41005021500	4,185	1,652	0	842
191	41005021601	4,221	1,714	11	1,098
181	41005021602	4,041	1,582	0	883

Close | Map | Print...

Figure 7.11 Highlighting the population column of the population inventory.

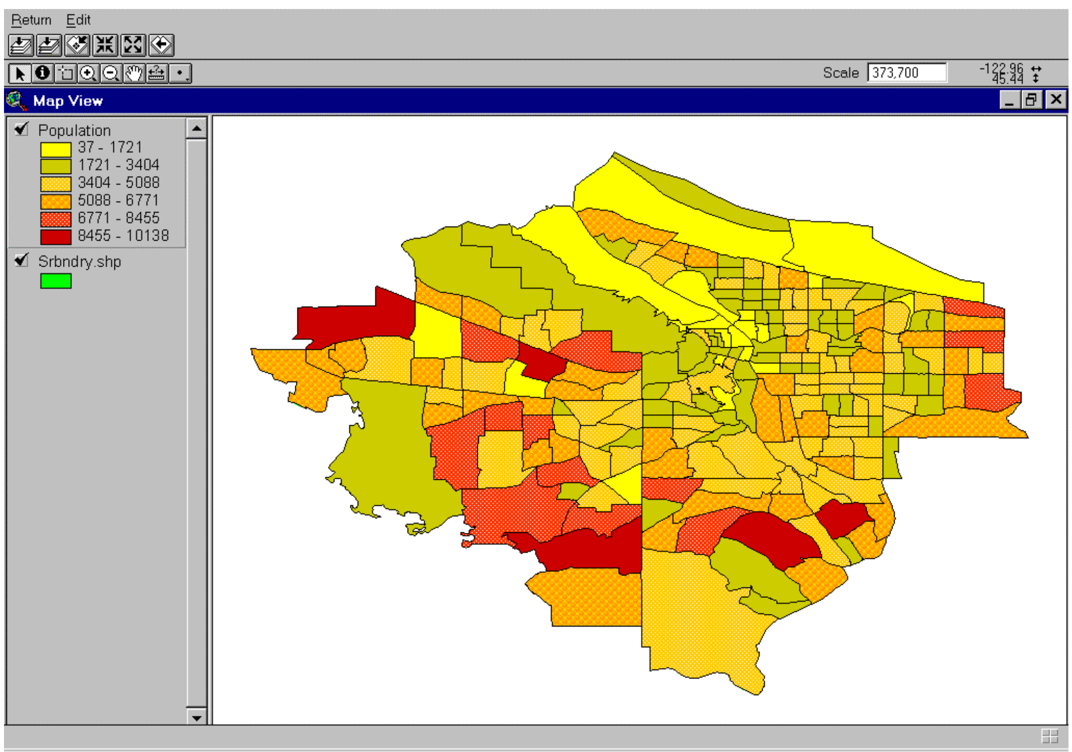


Figure 7.12 Default thematic map of population as displayed by HAZUS

2. To modify the thematic map, make the Population map the active layer by clicking on the word "Population" that appears in the Table of Contents (left side of the widow) of Figure 7.12. Double click on the active layer (the Population Layer) and the window shown in Figure 7.13 will appear.

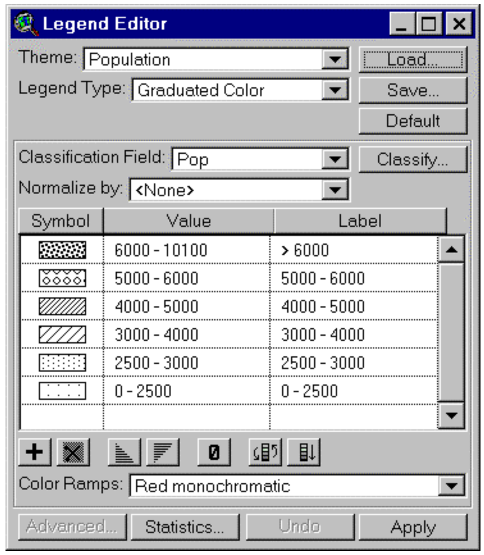


Figure 7.13 Window used to modify the thematic map characteristics

3. The **Legend Editor** window, shown in Figure 7.13, allows you to modify your data in a variety of ways. You can divide the data into as many or as few ranges as you wish by clicking on the **Classify..** button in Figure 7.13. From the **Classification** dialog box shown in Figure 7.14, you can modify the classification type, number of classes and the data round off value. For this example, we selected the Equal Interval classification type, 6 classes, and round by 1000. Click the **OK** button. The new values will be displayed in the **Legend Editor** dialog window. If you are satisfied with the new range definition, click the **Apply** button shown in Figure 7.13. If not, click on the **Classify..** button again and re-modify your classifications.

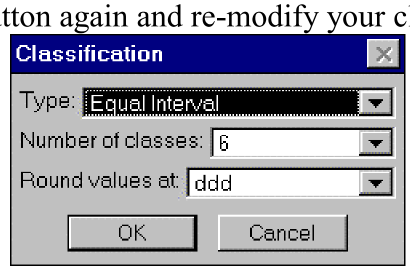
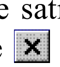


Figure 7.14 Ranges classification property window

You can also customize your own ranges and labels. From the **Legend Editor** window, you can individually highlight existing ranges under the Value column and overwrite them. You can further label that range with any value or text by highlighting the existing values listed under the Label column and overwriting them. Click on the Apply button and preview the map. If you are satisfied with the new ranges, close the **Legend Editor** window by clicking on the  button in the upper right corner. If not, go back and re-modify the classifications or the ranges or both.

4. The **Legend Editor** window, shown in Figure 7.13, will also allow you to modify the symbols featured for each range. From the Legend Editor window, double click on the "symbol" that appears under the Symbol column for each range. To modify pattern, line style, symbol, font, or color, you need to access the Fill Palette, Pen Palette, Marker Palette, Font Palette and Color Palette (shown in Figure 7.15) by

clicking on the following button respectively . Once all the modifications have been implemented, a map will appear reflecting all the customized changes (Figure 7.16).

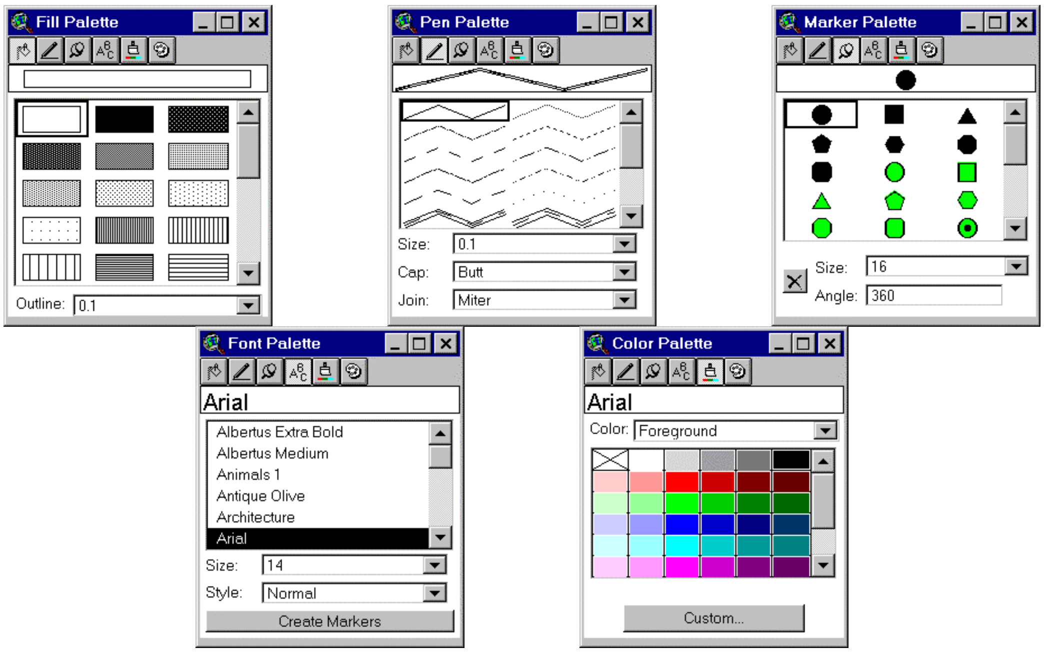


Figure 7.15 Different palettes for style modifications to the thematic map

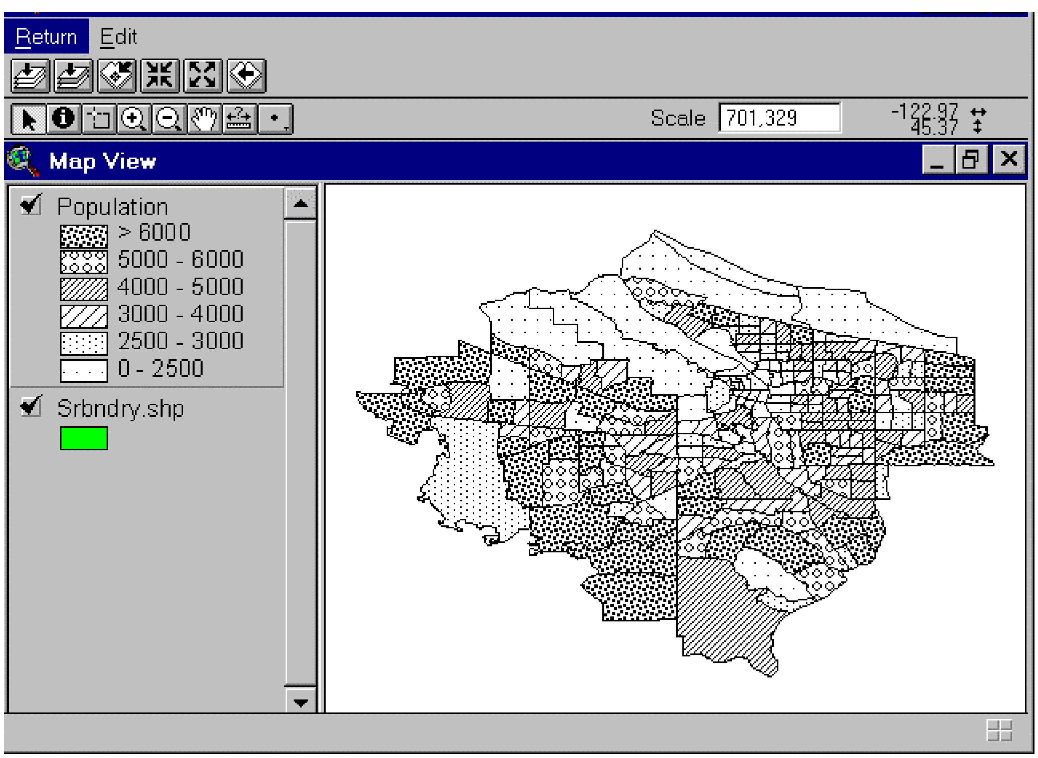


Figure 7.16 Thematic map with modifications to the range definitions

7.5.1.2 Saving a Reloading a Thematic Map Features

You have the option of saving the characteristics of a thematic map and reapplying them to the same map or a different map. To do so, click on the **Save** button in the **Legend Editor** window (Figure 7.13) and a **Save Legend** window will appear (Figure 7.17). Name the legend file and click the **OK** button.

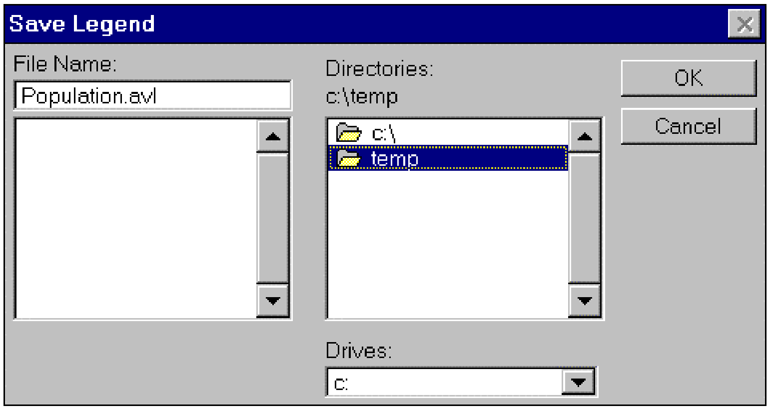


Figure 7.17 The Save Legend widow allows the saving of thematic map characteristics.

To reload a previously saved legend file, click on the **Load** button in Figure 7.13. A **Load Legend** window, such as the one shown in Figure 7.18, will appear. Navigate your drives and directory and locate the desired legend file and click the **OK** button.

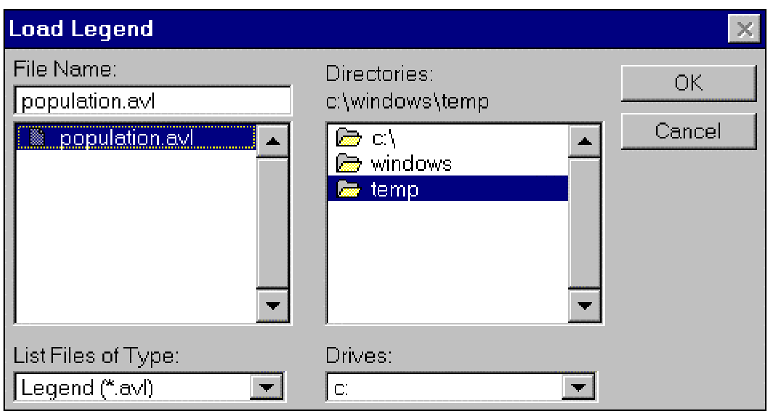
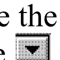


Figure 7.18 Window used to load a previously saved legend file.

Clicking the OK button will to a take you to another **Load Legend** window such as the one shown in Figure 7.19. You may choose to reload all the saved thematic map features by checking the *All* box or you may choose to only reload the previously saved classes and/or symbols by checking the *Classes* or *Symbols* boxes, or both.

If you want to apply the thematic map features to a different field, you can scroll among the fields in the **Load Legend** dialog box (Figure 7.19) by clicking the  button next to the **Field:** bar and selecting the new desired field. You can also change the field from the **Legend Editor** dialog box shown in Figure 7.13 by again clicking the  button next to the **Classification Field:** and selecting the new desired field.

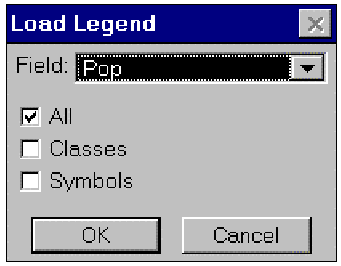


Figure 7.19 Selecting the thematic map options to be loaded.

7.5.1.3 Creating a Layout Window and Printing Maps

Layout windows are used to format maps for printing.

1. Select the **Window|New Layout Window** menu option.
2. **HAZUS** automatically generates the Layout window shown in Figure 7.20. When **HAZUS** first opens the layout, it sets the page size and orientation according to the current settings for your printer. For example, in Figure 7.20 the page was set to 8.5 X11 inches and landscape orientation. To change these settings, go to **Layout|Page Setup…** and the menu shown in Figure 7.24 will appear. You can resize the layout window using your mouse by clicking once on the map and dragging the corner boxes that will appear at each corner of the layout window border. If the map seems too small or too big, use the "zoom in" and "zoom out" tools from the tool bar to resize it.

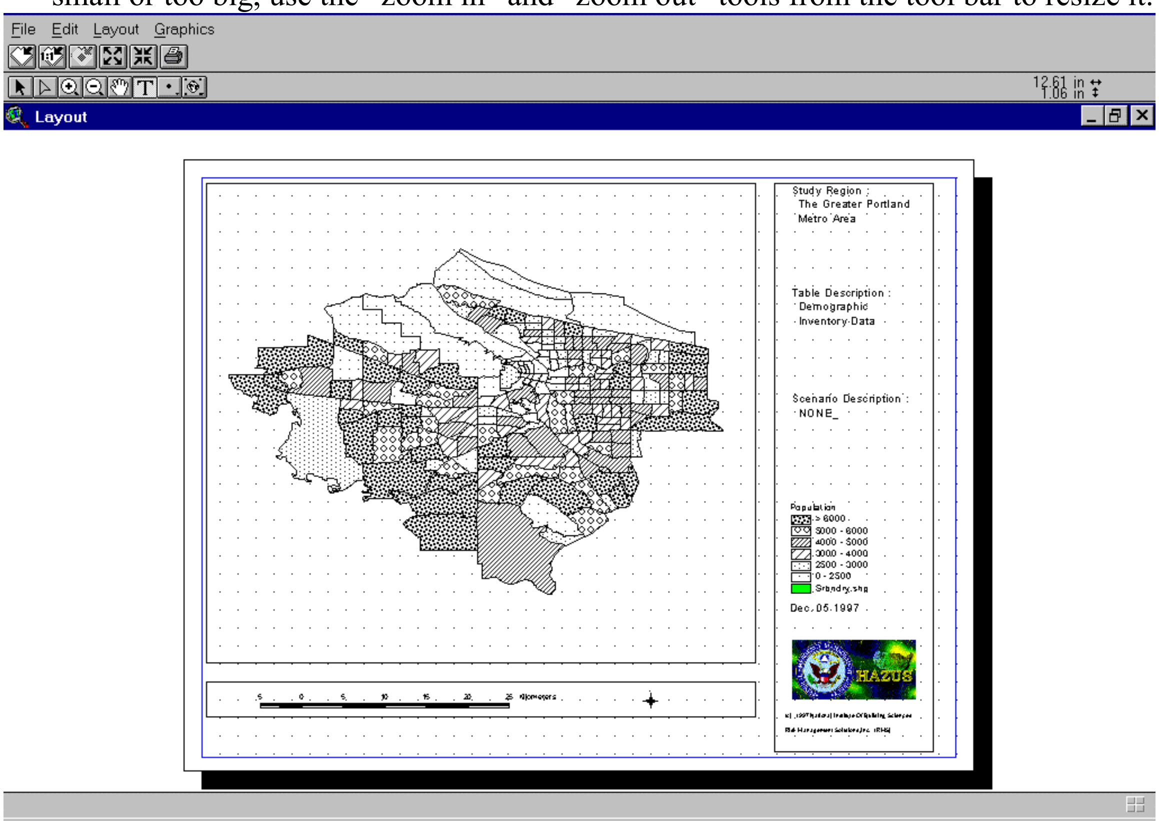


Figure 7.20 Layout window, used to modify a map for printing.

3. To add a title or other labels to the map, click the [T] button from the tool bar. Click on the desired map location and the **Text Properties** dialog window will appear

(Figure 7.22). Type in the appropriate label and select the desired *Horizontal Alignment*, *Vertical Spacing Line* and *Rotation Angel* and click the OK button. The location and properties of the label may be changed after the text is entered. To do so, click the button from the tool bar and double click on the label. The **Text Properties** window will appear again and you can modify your previous entries.

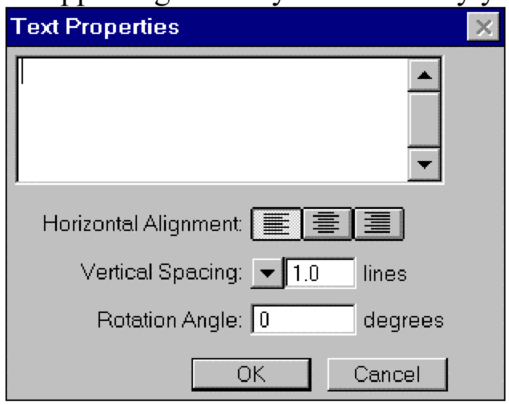


Figure 7.21 Text properties window used to add and modify map labels

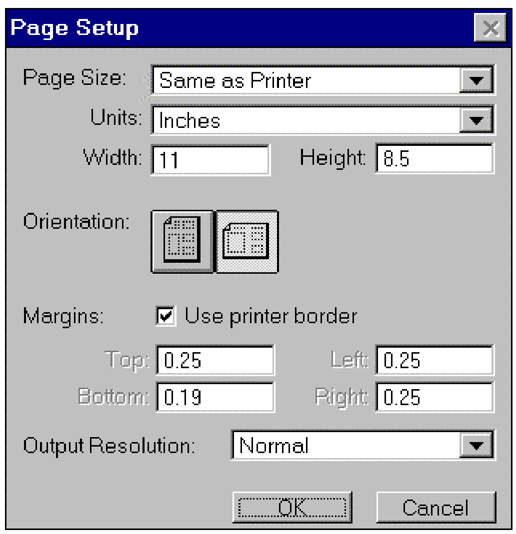


Figure 7.22 Page setup window for printing layouts

4. You can adjust the location of any object in the layout window by clicking on the button from the tool bar. Click once on the object that you wish to move and the arrow cursor will change its shape to ✣. With your left mouse button held down, drag the object and drop it in the new desired location.
5. You can also adjust the size and location of an object within its own frame. To do so, click once on the desired object in the layout window and select **Graphics|Size and Position**. Figure 7.23 or 7.24 will appear depending on the type of object that you have selected for modifications. The '*from top*' and '*from bottom*' values determine the margin around the object. The *height* and *width* values determine the size of the object.

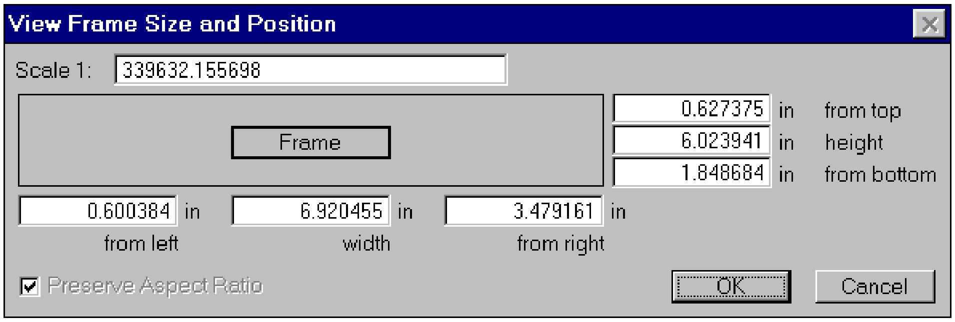


Figure 7.23 View Frame Size and Position window used to modify the location and size of a Frame

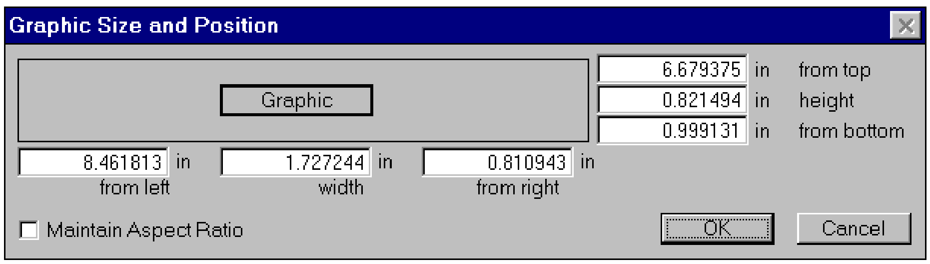


Figure 7.24 Graphic Size and Position window used to modify the location and size of a graphic object.

6. To set up the printer, select the **File|Print Setup** menu option. The dialog box shown in Figure 7.25 will appear. Adjust the settings as needed and click **OK**. To print, select the **File|Print** option and the dialog box shown in Figure 7.26 will appear. Click **OK** if you want to send the layout to the printer that you have selected under *Printer Name* in the **Print Setup** dialog box. Alternatively, you can save the layout to a file by checking the box next to *Print To a File* and typing the name in the *To file:* bar.

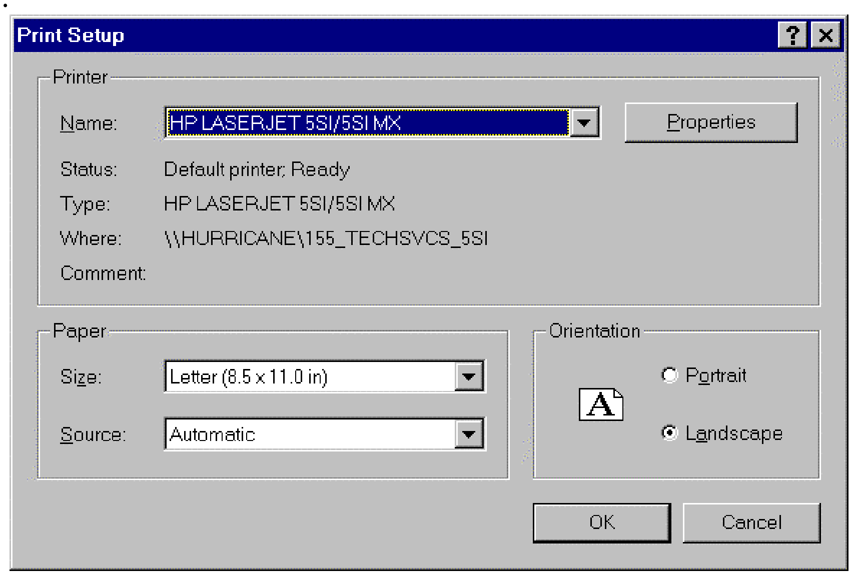


Figure 7.25 Print Setup window for printing layouts.

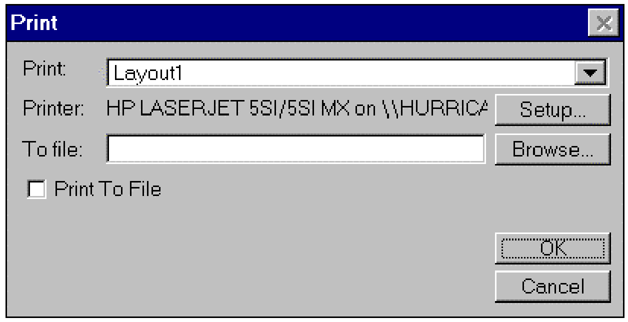


Figure 7.26 Print window for printing layouts

Chapter 8. Building-Data Import Tool (BIT)

The building-data import tool (**BIT**) is a utility that is designed to help you import large databases of property information and to process that data so as to be able to create occupancy to model building type relationships. It can read a variety of different types of database formats and configurations and will translate these into a standard format for use by **HAZUS**. The **BIT** includes a utility that allows you to run queries on databases so that you can identify certain types of properties (e.g. unreinforced masonry) or gather information about buildings with certain characteristics.

8.1 Getting Your Data in the Right Format

Before you run **BIT** you need to ensure that your data is in a form that the program can process. For example, if you have purchased tax assessor's files on magnetic tape, you will have to have those tapes read and transferred to floppy disk or CD-ROM. You will need to convert your database to a *.dbf format if it is in some other database format such as *.db, *.xls, etc. Many database management programs have the option of saving data in a *.dbf format, so this may be relatively simple. Another problem that can occur is that square foot building area is not reported as a single number but instead a sub-area is given for each floor or each portion of the building. In this case you will have to sum the individual sub-areas for each building and put the total building area in a single field. In the case of commercially available property data, you will need to extract the records from the database using software supplied by the vendor. Other problems you may encounter are appearance of properties more than once if they have multiple owners, or the reporting of multi-building complexes, and the use of two or three different occupancy definitions for a single property. All of these will require judgment on your part, and some of these problems will be very challenging.

BIT can only work with the following three types of files:

- ASCII delimited (*.asc)
- Dbase file (*.dbf)
- Fixed length file (*.txt)

If your database is not in one of these three formats, you will need to use an external database management program to convert your data into one of these formats.

The **BIT** can only import data from one county at a time. If your data file contains properties from multiple counties, you will need to use a database management program to sort the data by county and organize the data into separate files for each county.

8.2 Starting BIT

BIT can be launched in two ways: either from within **HAZUS** or stand-alone.

To launch **BIT** from within HAZUS, select the command **Inventory|General Building Stock|Building Import Tool (BIT).**

To launch **BIT** independent of **HAZUS**, select **Start|FEMA Risk Assessment System|BIT.** This location assumes that **BIT** was installed in the default group (**FEMA Risk Assessment System)**.

8.3 Specifying the Input File

After starting the **BIT**, you will be presented with the window shown in Figure 8.1. This window guides you through the five steps needed to develop the occupancy to model building type relationships for your region. The first step in the process is to specify the property data file you will be using. To start this step click on the **Specify Input File...** button.

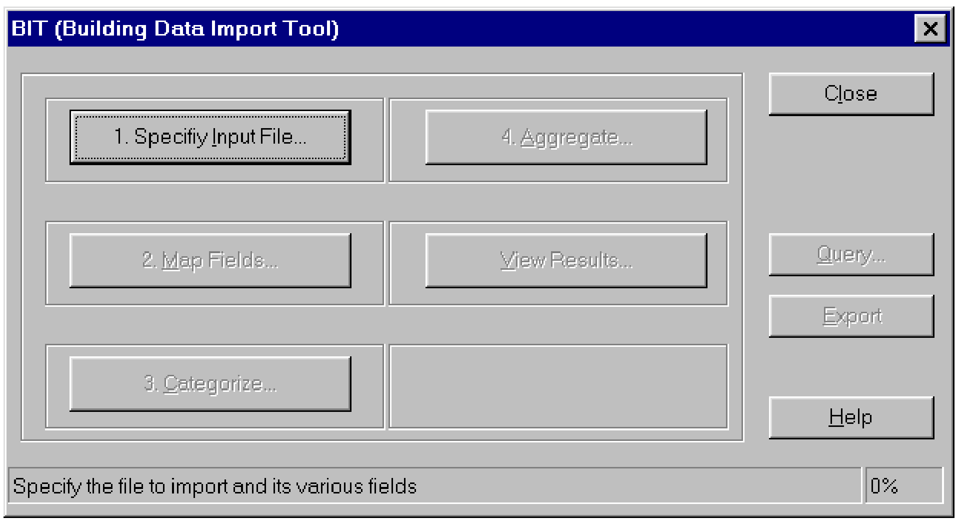


Figure 8.1 Building data import tool main menu

You will be asked to select an input file. You can choose from one of the four following options: ASCII delimited (*.asc), Dbase file (*.dbf), fixed length file (*.txt), and configuration file (*.bcf). A configuration file is generated by the **BIT**, and is available only if you have started the import process previously, but did not complete all five steps. The *.bcf file allows you to continue an incomplete import activity without starting over from the beginning.

8.3.1 Importing an ASCII Delimited Database

After you click on the **Specify Input File...** button in Figure 8.1, you will be presented with the window shown in Figure 8.3. Suppose that the particular property data file that you want to import is an ASCII delimited file. A delimited file is one that uses a specific character to separate the fields of information. Delimited files come with a variety of different characters to separate the fields. The most common are the comma and the tab. However, the delimiter can be any character. An example of two records from an ASCII delimited file is shown here:

```
"521-525 Main St","Anytown","94102-1102","121.00","Store
Building",4195,"1",2,"883263",16,"79","","880720","C","Concrete","Stucc
o","Concrete","Steel","Flat", "Built-up","","Average","$357",",","0284-
000"
```

```
"332 North St","Anytown","94102-
2607","125.00","Apartment",16030,"6",24,
"341314",23,"72","72","830404","C","Concrete","Concrete","Concrete","Co
ncrete",
"Flat","Tar & Gravel","","Fair","$17",",","0333-001"
```

Figure 8.2 Two records from an ASCII delimited file

Each record shown in Figure 8.2 spans three lines and each field is separate by a comma. Quotes are used to indicate alphanumeric (text) data and entries without quotes are numbers. The **BIT** is capable of distinguishing these two types of inputs and it shouldn't cause you any problems when both types appear in the same record. It is important to understand that the **BIT** can recognize this file as ASCII delimited only if you specify the filename extension as .asc.

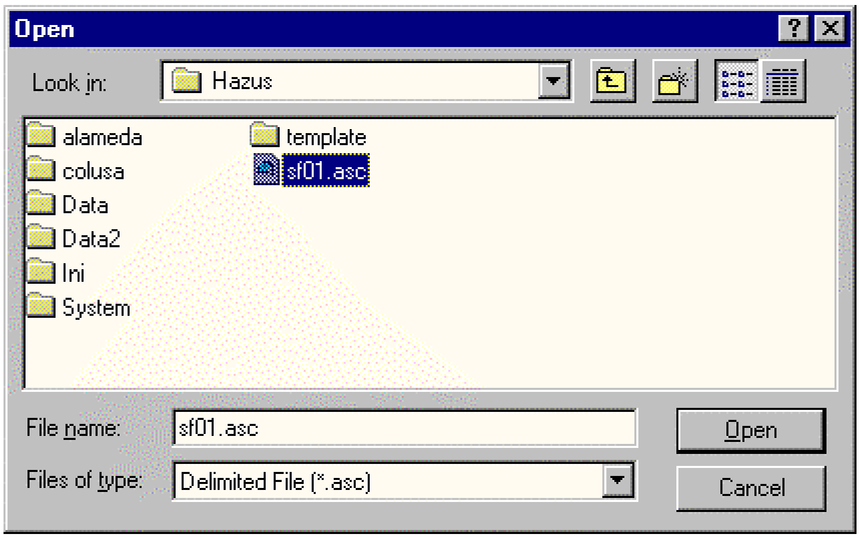


Figure 8.3 Specifying a *.asc input file in the building-data import (BIT) tool

After you have specified the file name in Figure 8.3, you will be asked to specify the type of delimiter that is being used as shown in Figure 8.4. If the delimiter is not a comma or a tab, click on **Other** and then type the delimiter in the box to the right. The delimiter can be a single character such as a ' or a ? or a !. At the bottom of the Delimited ASCII Import window is a box entitled **Change default field names**. If you mark this box, you will be presented with the Field Names window shown in Figure 8.5. If you do not mark this box (so that it is blank), you will skip to the state and county information window shown in Figure 8.6.

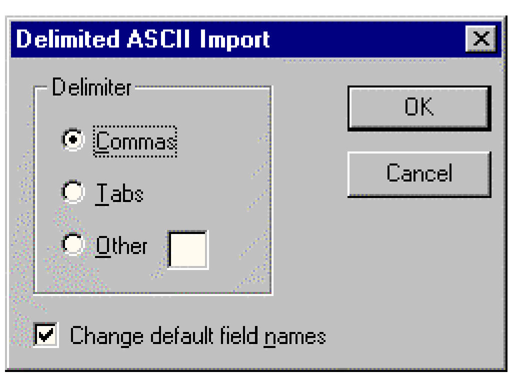


Figure 8.4 Specifying the delimiters for an ASCII delimited file

Generally, an ASCII delimited file does not contain embedded field names. Thus when the ASCII delimited file is read by **BIT** the fields will be called Field001, Field002 and so on. The supplier of the data file should have provided you with documentation that indicates what is contained in each field. The Field Names window in Figure 8.5 allows you to rename the fields in your database so that they are easier to keep track of. In this example, the user has already changed the names of the first three fields. To make a change, double click on the field name so that it is highlighted, then type in the new name. When you have changed the desired fields (you do not have to name all fields), click the **OK** button to save the changes.

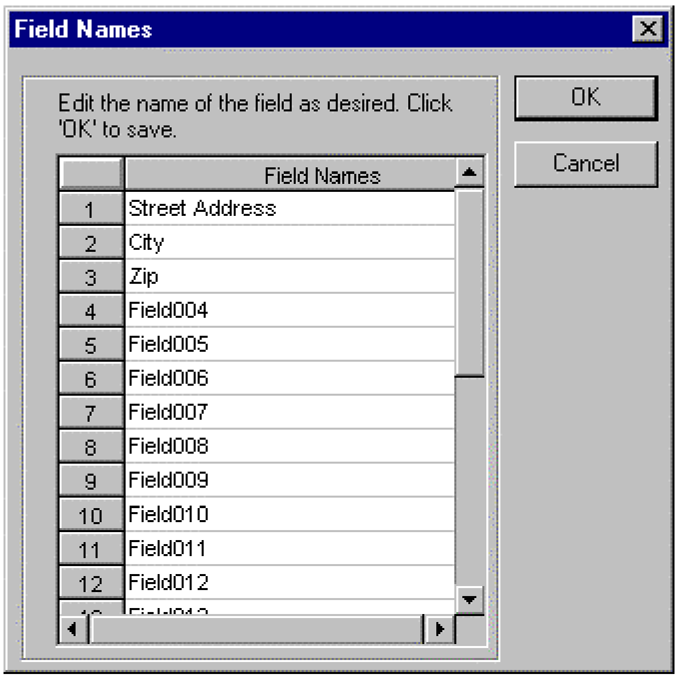


Figure 8.5 Changing the field names in an ASCII delimited file

The next task is to indicate which state and county pertains to your data file (see Figure 8.6). As discussed earlier, the **BIT** can operate on only one county at a time. Therefore your data file must contain data from only one county. The information from this step is used to convert census tract data into a format that can be used by **HAZUS**. The census tract for the first record in Figure 8.2 is “121.00”. The **BIT** will add the state and county codes to this and convert the census tract number to 0607512100, indicating that this census tract is in San Francisco County. When you click the **OK** button you will be ready for the next step of mapping fields (see Section 8.3).

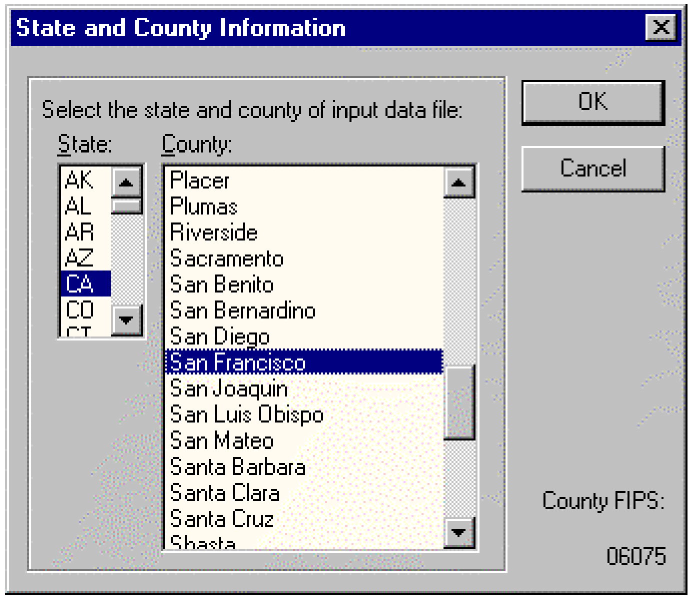


Figure 8.6 Indicating the state and county of the property data file

8.3.2 Importing a *.dbf Database

A file that is in a *.dbf format does not require some of the steps that are required for an ASCII delimited file. Simply specify the file name as shown in Figure 8.7. You will then be presented with the state and county information window shown in Figure 8.6. Complete this information, click **OK**, and you will be ready for mapping fields (see Section 8.3).

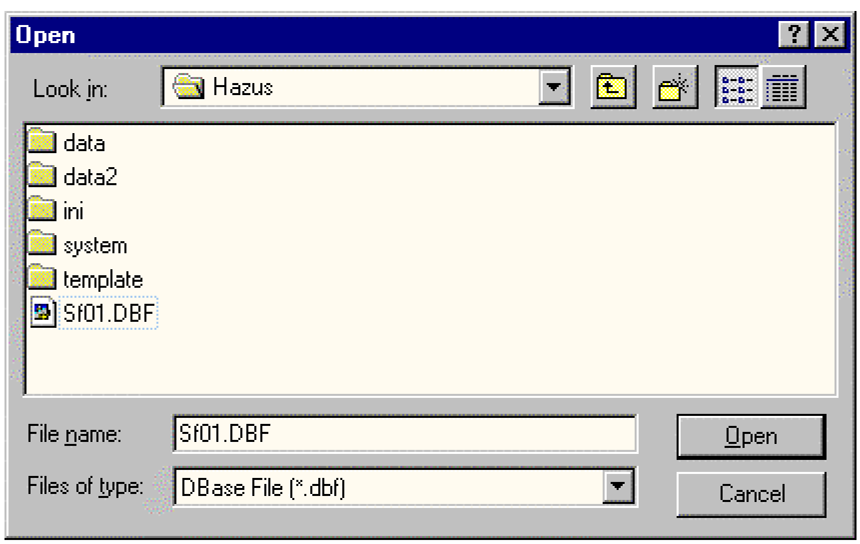


Figure 8.7 Specifying a *.dbf input file in the building-data import tool

8.3.3 Importing a Fixed Length Field Database

A fixed length field file is one that uses a specified number of characters to represent the data in each field. Some fields may be one character long, while other fields may contain 25 characters. Two records from a fixed length field file are shown in Figure 8.8. This is the same data as the comma-delimited records shown in Figure 8.3.

```
521-525 Main St      Anytown    941021102 121.00Store Building         4195
1 2 883263 16 79    880720CConcrete   Stucco    Concrete   Steel       Flat
Built-up       Average    $357    0284-000

332 North St         Anytown    941022607 125.00Apartment             16030
6 24341314 23 7272  830404CConcrete   Concrete Concrete   Concrete    Flat
Tar & Gravel   Fair       $17     0333-001
```

Figure 8.8 Two records from a fixed length field file

Each record shown in Figure 8.8 spans three lines and the blank spaces indicate missing information or fields that are not completely full. For example, the address field is the first field in the database and the city name is the second. The address field is 20 characters long, but the address in the first record is only 15 characters, thus there are five blank spaces before the city name. Sometimes blank spaces are indicated by something other than a space. For example, all blanks could be filled with the number 8. This is information you need to get from the supplier when you acquire the data. It is important to understand that the **BIT** can recognize a file as a fixed length field file only if you specify the extension of the filename as .txt. To open the file, use the **Open** window shown in Figure 8.9 and specify the file type as **Fixed-length File (*.txt)**.

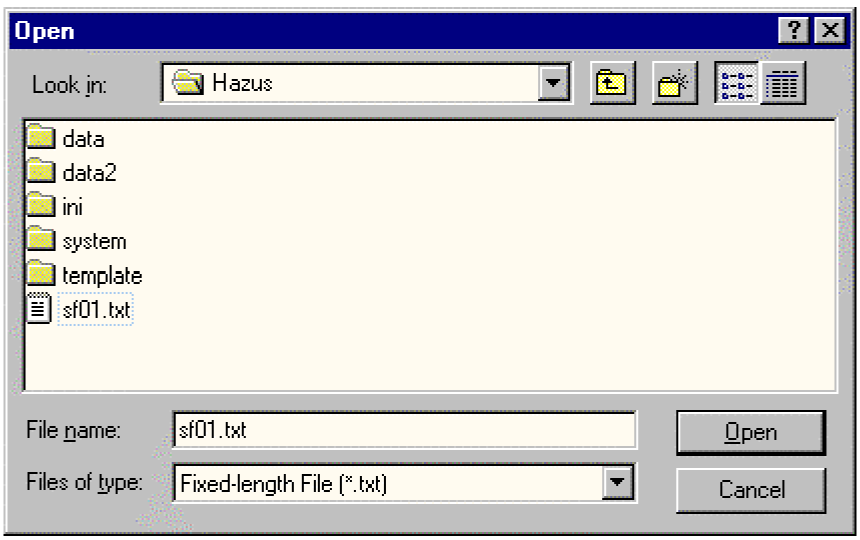


Figure 8.9 Specifying a *.txt input file in the building-data import tool

A fixed-length field file does not contain embedded field names. Thus, when the **BIT** reads the file, the fields will be called Field001, Field002 and so on. The supplier of the data file should have provided you with documentation that indicates what is contained in each field and how long each field is. The Fixed Length File Import Options window in Figure 8.10 is used to name and define the lengths of the fields in your database. In this example, the user has already defined the names and lengths of the first three fields and is in the process of defining the fourth.

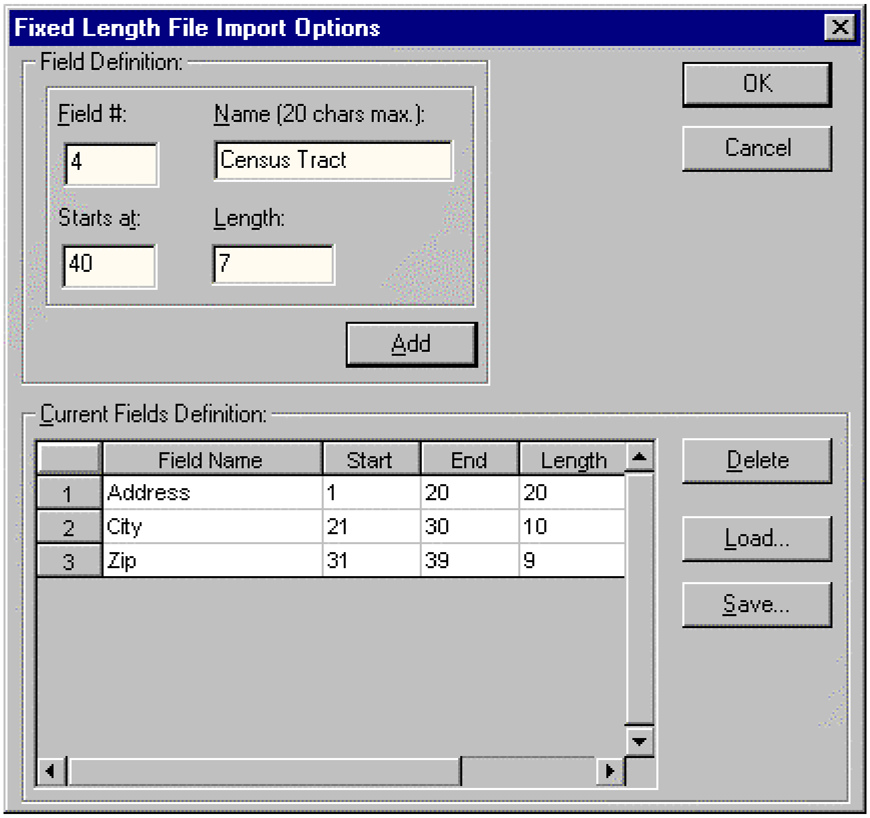


Figure 8.10 Defining and naming fields for a fixed length field file

To define a field, type in the field name and then indicate the length of the field. Click on the **Add** button and the field will be added to the **Current Fields Definition** box. If you realize you have made a mistake after the definition has been added to the **Current Fields Definition** box, highlight the field and click on the **Delete** button. Redefine the field and add it back. When you have defined all of the fields, click the **OK** button to move to the next step. It is important to note that you must define fields for all of the characters in a record in order for the **BIT** to correctly process the database.

Defining all of the fields for long records requires quite a lot of typing. You may want to save the field definitions using the **Save** button. Then if you import any other data files with the same format, you can load the previously established field definitions using the **Load** button.

After you have finished defining the fields and you have clicked **OK**, you will need to indicate the state and county of the database using the window shown in Figure 8.11. The explanation for this step is found in Section 8.2.1.

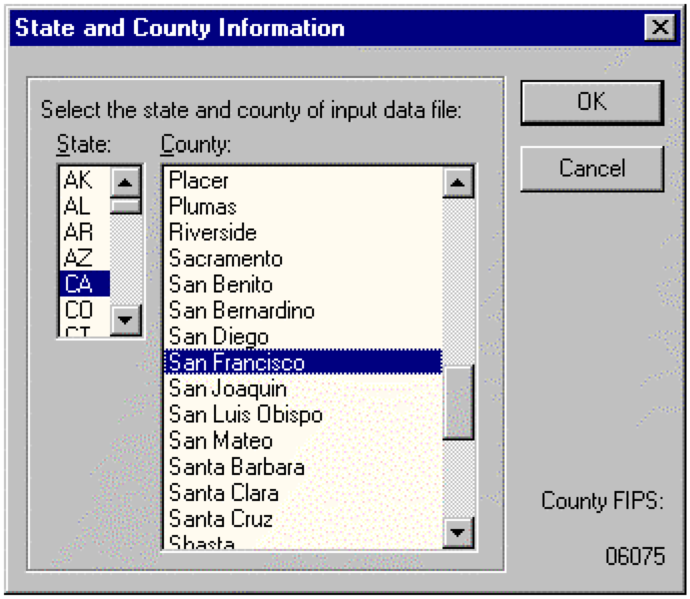


Figure 8.11 Indicating the state and county of the property data file

8.4 Mapping Fields

After having specified the input file, you will need to map the fields in your database (the source) to the fields used in the **HAZUS** database (the target database). The steps for importing data and creating occupancy to model building type relationships must be completed in the numbered sequence. The labels for steps that are not yet available to you will appear in light gray. To start this step, click on the **Map Fields** button in the main **BIT** menu (see Figure 8.12).

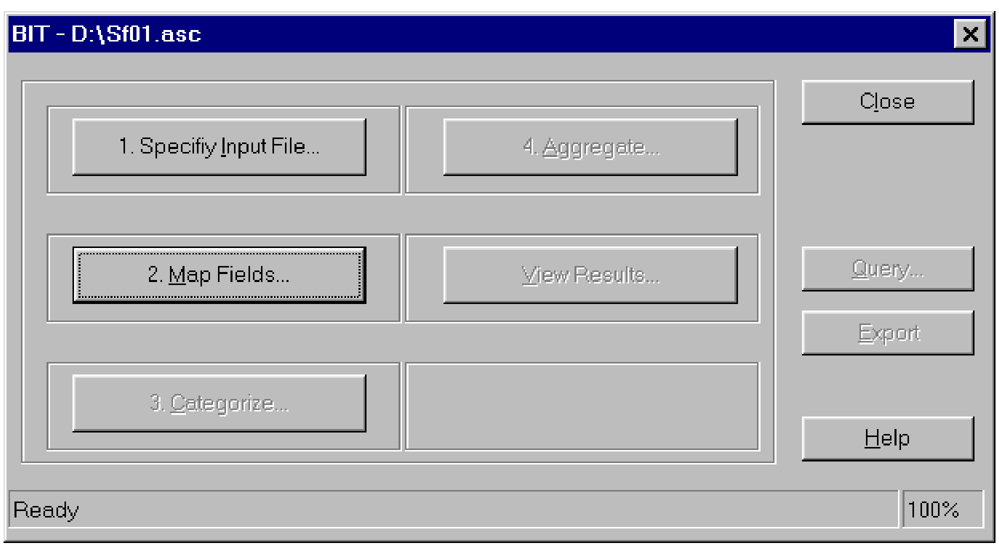


Figure 8.12 Starting the field mapping step from the BIT main menu

Since the **BIT** is used to develop occupancy to model building type relationships for your region, the most important information to capture is the occupancy, structural type, square footage and height of your buildings. However, the database you create can have as many fields as you want, allowing you to maintain many types of data. Using the mapping tool outlined in this section, you can be certain that all of the databases you maintain will be in a standard format.

The mapping window shown in Figure 8.13 is used to map the fields in your database (the source) to the fields used in **HAZUS** (the target database). The source-database fields do not have to be in the same order nor do they have to have the same names as the target-database fields. For example, in Figure 8.13 the occupancy types are in a field called "OCCUPANCY" in the source database whereas the field that contains this information in the target database is called "OCC_TYPE". When you click on the target field name, a short definition of the field appears right below the list of target fields.

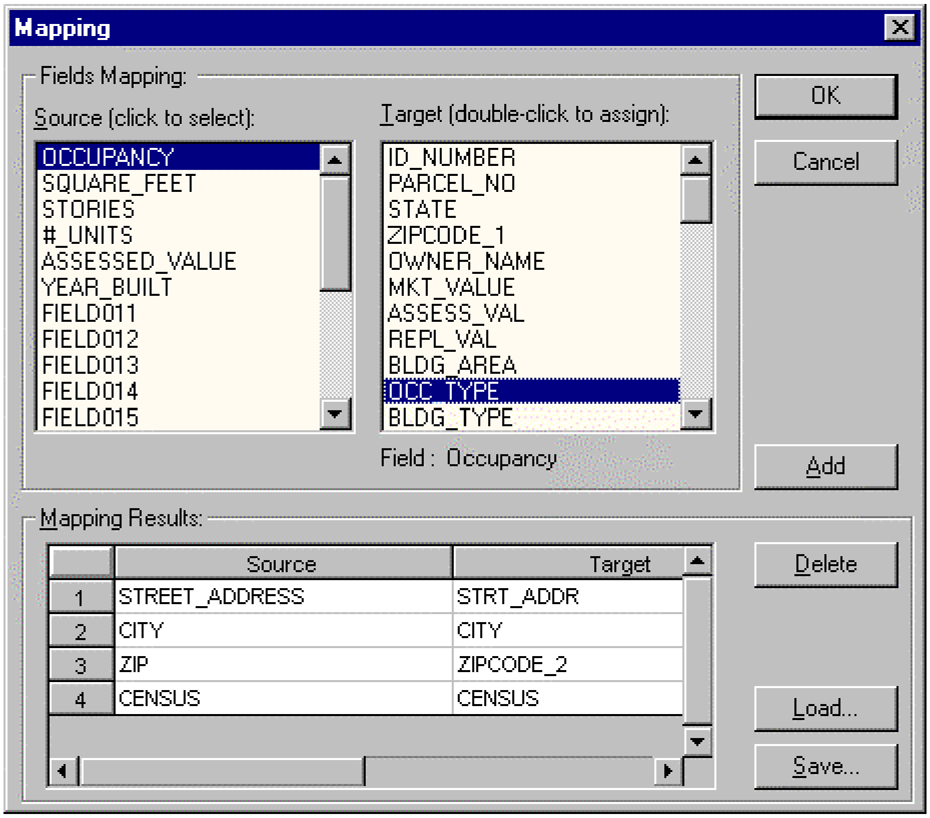


Figure 8.13 Defining a mapping scheme from the source database to the target database in the BIT

To define the desired mapping, simply click on a field name in the source database (e.g. OCCUPANCY) and the corresponding field name in the target database (e.g. OCC_TYPE) and then click on the **Add** button. After each time you perform this operation the mapping you have defined will appear in the **Mapping Results** box at the bottom of the window. At the same time, these fields will disappear from the **Fields Mapping** box at the top of the window. If you make a mistake, click the **Delete** button and the last mapping pair you have defined will be undone. In this example the user has already defined four relationships and is in the process of defining a fifth. When you have completed mapping all of the fields, click on the **OK** button, wait a moment, and your database will be reconfigured into the standardized format. At the end of this step a file with the same name as your original file and the extension .TG1 will be created. Your original file will remain unchanged. NOTE: You do not have to map all of the fields from the source database; however, any fields you do not map will not be imported into the target database. There are key fields that must be mapped without which you won't be able to proceed with the mapping. The **BIT** tool will prompt you with the key field (s) that you missed mapping once you try to click the OK button to move on to the next step. An example of this window is shown in Figure 8.14. The window also includes the list of the "must mapped" fields for the **BIT** tool.

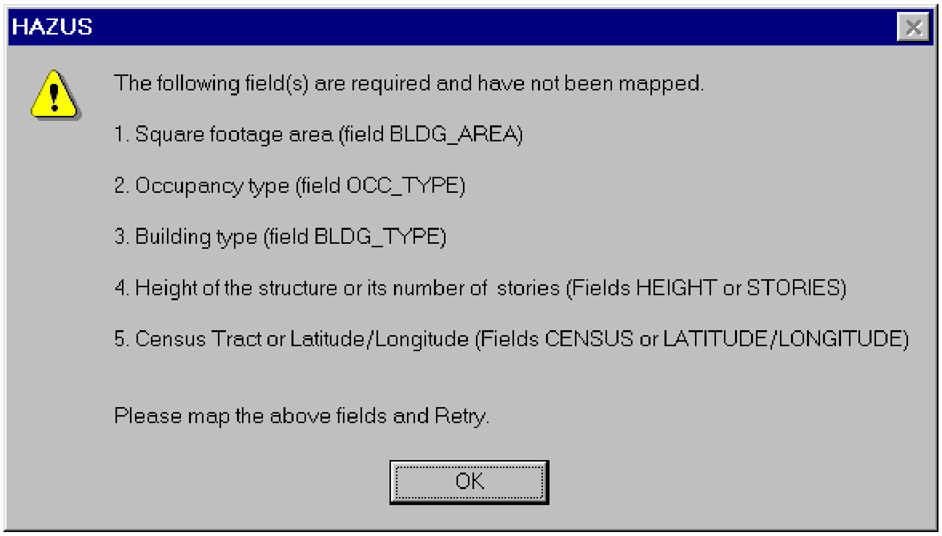


Figure 8.14 An example of a warning message in case you miss mapping key field(s)

It is possible you have several databases with the same format and you would like to save the mapping that you have just defined. Before you click the **OK** button, click the **Save** button in Figure 8.13. A save window will appear and you will need to enter a name for the saved mapping scheme. Retrieve the saved mapping scheme by clicking on the **Load** button in Figure 8.13.

8.5 Categorizing Data

The next step in creating standardized data formats is to convert the data to the classification systems defined in Appendix A. For example, your database may use the term "wood" for low-rise wood frame construction whereas this would be classified as a W1 model building type in **HAZUS**. Thus, records with structural type "wood" in the source database need to be converted to "W1" in the target database. To do this step, click on the **Categorize...** button shown in Figure 8.15. At the end of this step a new file will be created. It will have the same name as your original file and a new extension: .TG2. This database is the same as the *.TG1 database except that all of the replacements you have requested have been made.

Note that at this point the query tool has been enabled. A discussion of the query tool is found in Section 8.8

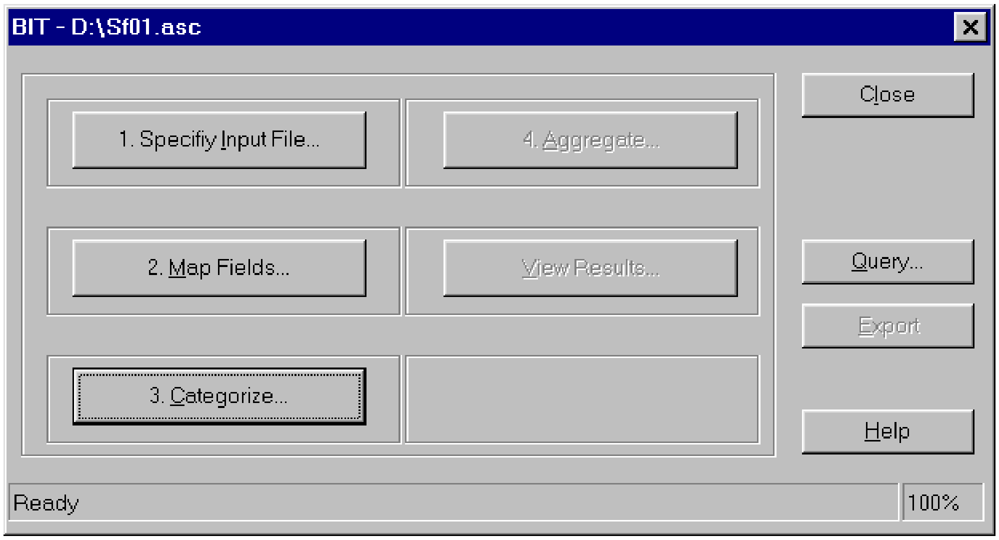


Figure 8.15 Starting the categorize function of the BIT

You have the option to select which fields of data you want to categorize (see Figure 8.16). It is likely that none of your data will be in the standardized format and you will want to select all four options (Stories, Year Built, Occupancy Types and Building Types). To select the items, simply click on them. When you are finished, click the **OK** button.

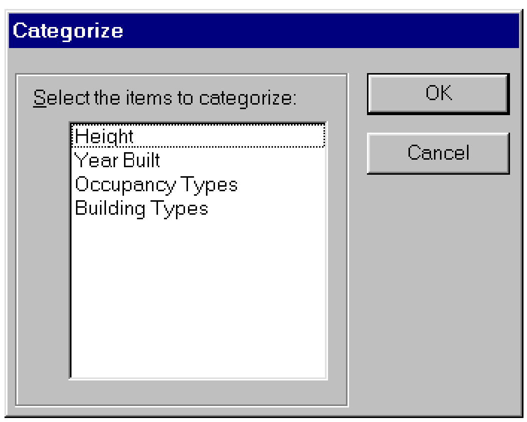


Figure 8.16 Selecting which fields you want to categorize

8.5.1 Categorizing Number of Stories Data

HAZUS lumps groups of buildings into low, medium and high-rise structures. Thus ultimately, any building with one to three stories height will be classified as low rise. If your database uses numbers to specify the height of the building in feet, the **BIT** will automatically convert the height to low, medium or high-rise. Blank fields will be classified as unknown. If the building height that you have is in non-feet units, you can use the conversion factor to convert the data to feet. If on the other hand the database that is being used has characters or words for number of stories, then you will need to define a mapping scheme to convert your data to the standardized format. The window in Figure 8.17 is used to indicate which of these situations apply to your data.

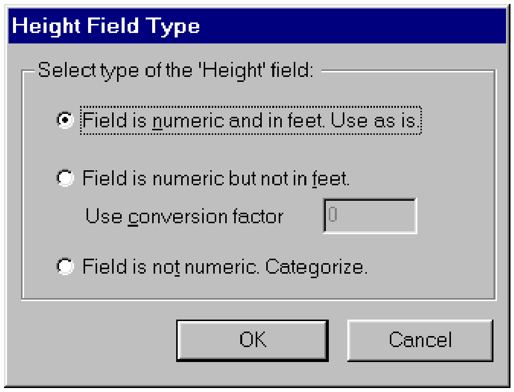


Figure 8.17 Indicating what type of building story data you have

If you click on **Field is non-numeric. Categorize**, then press **OK**, the window in Figure 8.18 is displayed allowing you to define a mapping from your database to the standardized format. As indicated by the text labeled **# occurrences** and **Out of,** there are ten records in this example, and all of the records have a blank in the field containing the number of stories data. The user has mapped the blank to "Unknown". As with other mapping windows, after you have defined each mapping, click on the **Add** button and the mapping will appear in the **Results** portion of the window. If you make a mistake, use the **Delete** button.

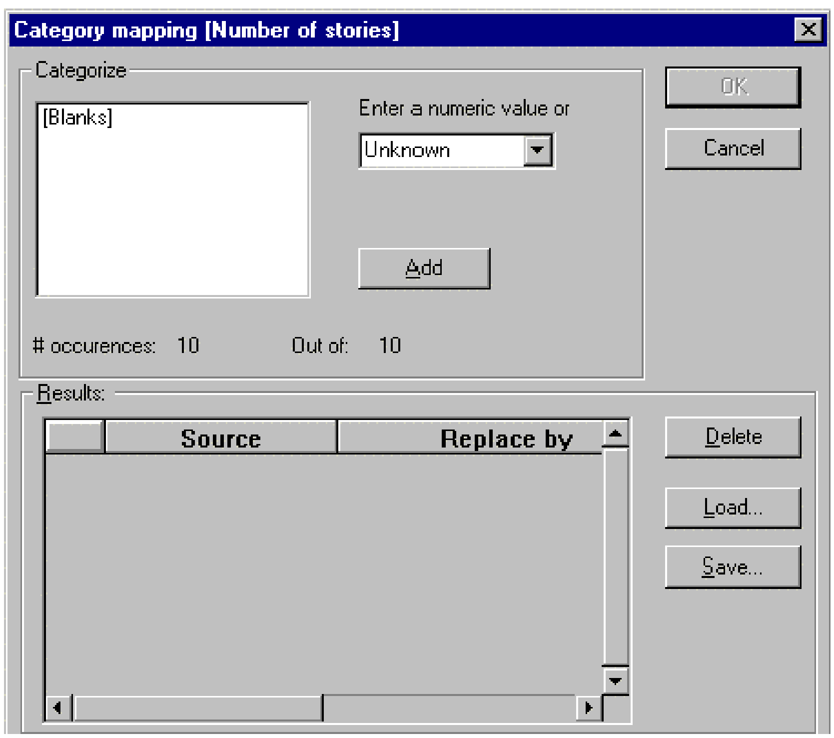


Figure 8.18 Categorizing number of stories data

To save your data mapping scheme, click on the **Save...** button. Use the window shown in Figure 8.19 to name the mapping scheme. A scheme for mapping number of stories will have an .ssl extension, whereas a scheme for mapping building height will have an .hsl extension.

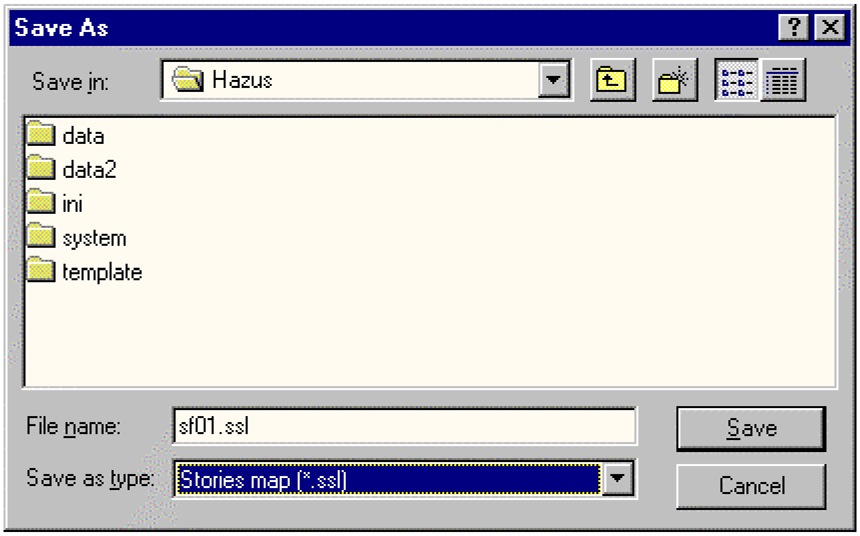


Figure 8.19 Saving number of stories categories

8.5.2 Categorizing Year Built Data

HAZUS lumps buildings into three age groups: pre-1950, 1950-1970 and post-1970. Occupancy to model building type relationships is developed for each of these three groupings. Year-built data is found in a variety of formats in assessor's files and other commercially available property files. It is most common to find the year built expressed in a two-digit format, such as 95, or in a four-digit format, such as 1995. However, it is possible that other formats could be used such as old, moderate and new. The **BIT** has the flexibility to read any of these formats by selecting the appropriate buttons in Figure 8.20. Perhaps most problematic is how to deal with a zero. A zero can mean that a structure was built in 1900, 2000 or it can mean that the data is unknown. You may have to ask the supplier of the data how to interpret the occurrence of a zero in the data.

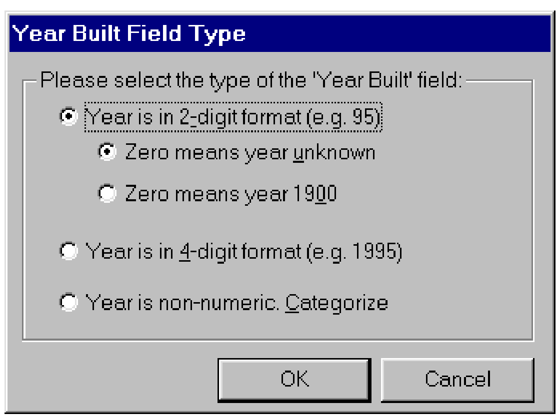


Figure 8.20 Categorizing year built data

8.5.3 Categorizing Occupancy Class Data

In this step you will be required to map the occupancies found in the source database to the standardized occupancies defined in **HAZUS** (See Appendix A, Table A.3). All of the 28 specific occupancy classes found in Table A.3 are listed in the **Target** list box found in Figure 8.21. In addition to the specific occupancy classes, you will find five general occupancy classes (Residential, Commercial, Industrial, Government, Education) and the class "Unknown". General occupancy classes are in all upper-case letters. Some property databases contain very limited information about occupancy; for example, labels such as residential, commercial, and industrial. In this case you will need to use the general occupancy classes for categorizing occupancy.

To define a mapping, click on an occupancy in the **Source** list box and then double click on the corresponding standardized occupancy in the **Target** list box. You can map multiple occupancies at the same time by highlighting (clicking on) all of the occupancies in the Source list box that correspond to a single standardized occupancy. For example, in Figure 8.21 the user has already highlighted "apartment", "condominium", "hotel", and "duplex" in the **Source** list box and then double clicked on "Multi Family Dwelling" in the **Target** list box. This resulted in the four separate mappings found in the **Mapping Results** box. If you find you have made a mistake any time during this process, simply click on the incorrect mapping in the **Mapping Results** box and click on the **Delete** button. Redefine the correct mapping for that occupancy and continue. When you have completed the mapping for all categories in the source database, click the **OK** button.

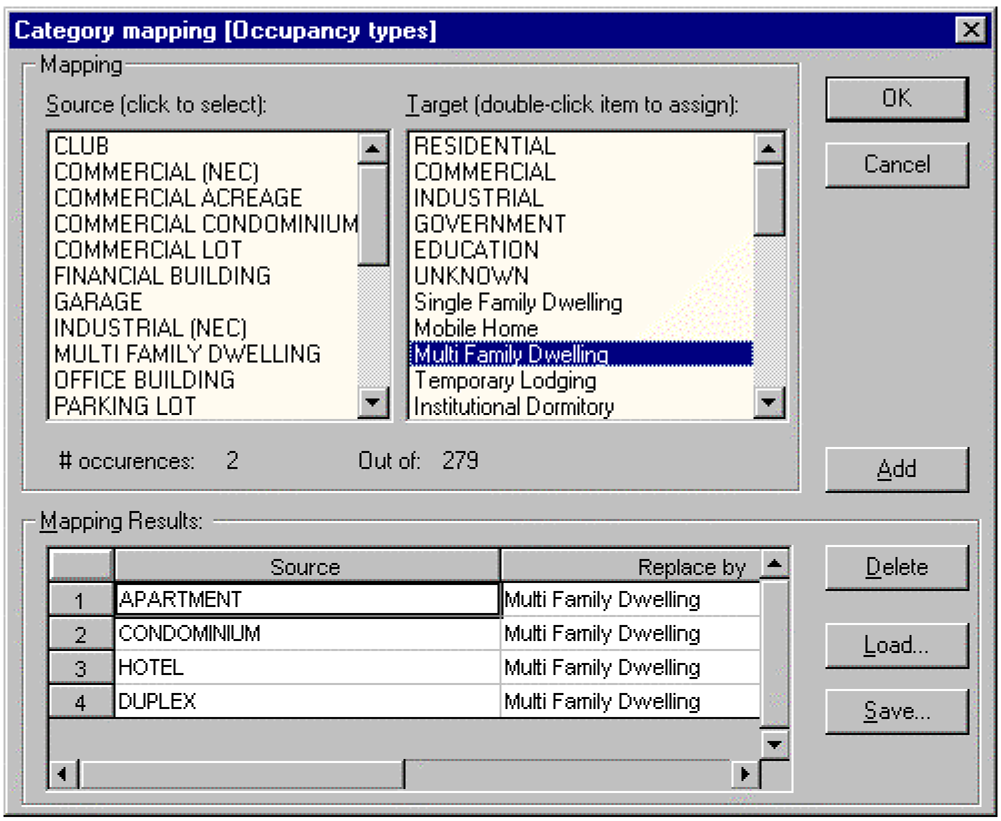


Figure 8.21 Categorizing occupancy class data

Categorizing occupancy class data can be somewhat tricky and can require judgment on your part. Some of the occupancy classes in the property file may not fit perfectly into **HAZUS** classifications. For example, you may find a class such as "Office & Residential" in your database that could be classified as either RES3 "Multi-Family Dwelling" or COM4 "Financial/Professional/Technical Services". You will have to use your judgment in deciding which standardized class best typifies this mixed occupancy.

Another problem you may find is that source-database occupancy classes do not always provide a correct description of the property. For example, parking lot, residential lot or vacant lot would imply that these properties have no structures on them. However, in many cases in the sample database used here, there were buildings on these types of properties. You should not be surprised to find that certain occupancies such as universities, institutional housing and government services, to name a few may, be completely absent from your database. As noted in Section 5.1.2, property databases rarely provide detailed information on tax-exempt properties.

As with other mappings defined in the **BIT**, you have the option to save the occupancy class mapping for use on other files. To save the mapping, click on the **Save...** button before clicking **OK**. The occupancy mapping file will be saved with an .osl extension as shown in Figure 8.22. To use the mapping in the future, click on the **Load...** button in Figure 8.21.

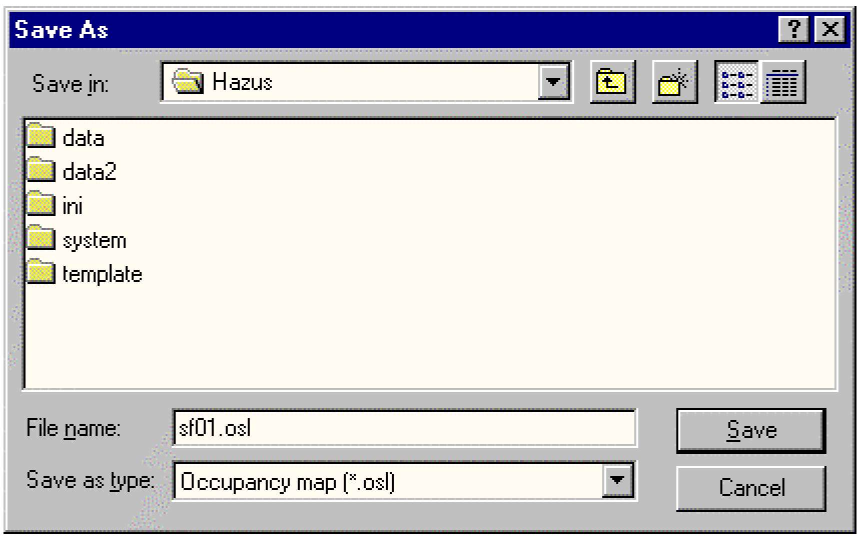


Figure 8.22 Saving an occupancy mapping scheme

8.5.4 Categorizing Building Type Data

In this step you will be required to map the structural types found in the source database to the model building types defined in **HAZUS** (See Appendix A, Table A.2). The 16 general building types found in Table A.2 are listed in the **Target** list box shown in Figure 8.23. In addition to the general model building types, you will find four basic building material types (Wood, Steel, Concrete, Masonry) and the class "Unknown". Basic building material types are in all upper-case letters. Many property databases contain very limited information about the structural system used, and the categories used are often based on fire safety information. For example, in this sample database shown in Figure 8.2 and 8.8, category C contains brick, tilt-up and formed concrete construction. The user has chosen to map category C to masonry. Clearly, this will introduce uncertainty into the occupancy to model building type relationships that are produced by the **BIT**. It is rare to find a property database that provides sufficient information to define reliable mappings to all general building types.

To define a mapping, click on a building type in the **Source** list box and then double-click on the corresponding standardized building type in the **Target** list box. You can map multiple building types at the same time by highlighting (clicking on) all of the building types in the **Source** list box that correspond to a single standardized building type. For example, in Figure 8.23 the user highlighted "A" and "S" in the **Source** list box and then double clicked on "STEEL" in the **Target** list box. This resulted in the two separate mappings found in the **Mapping Results** box. If you find you have made a mistake any time during this process, simply click on the incorrect mapping in the **Mapping Results** box and click on the **Delete** button. Redefine the correct mapping for that building type and continue.

When you have completed the mapping for all categories in the source database, click the **OK** button. At this point the **BIT** will substitute the standardized categories for the original categories in the source database. Depending on the size of the database this will take a few minutes to more than an hour.

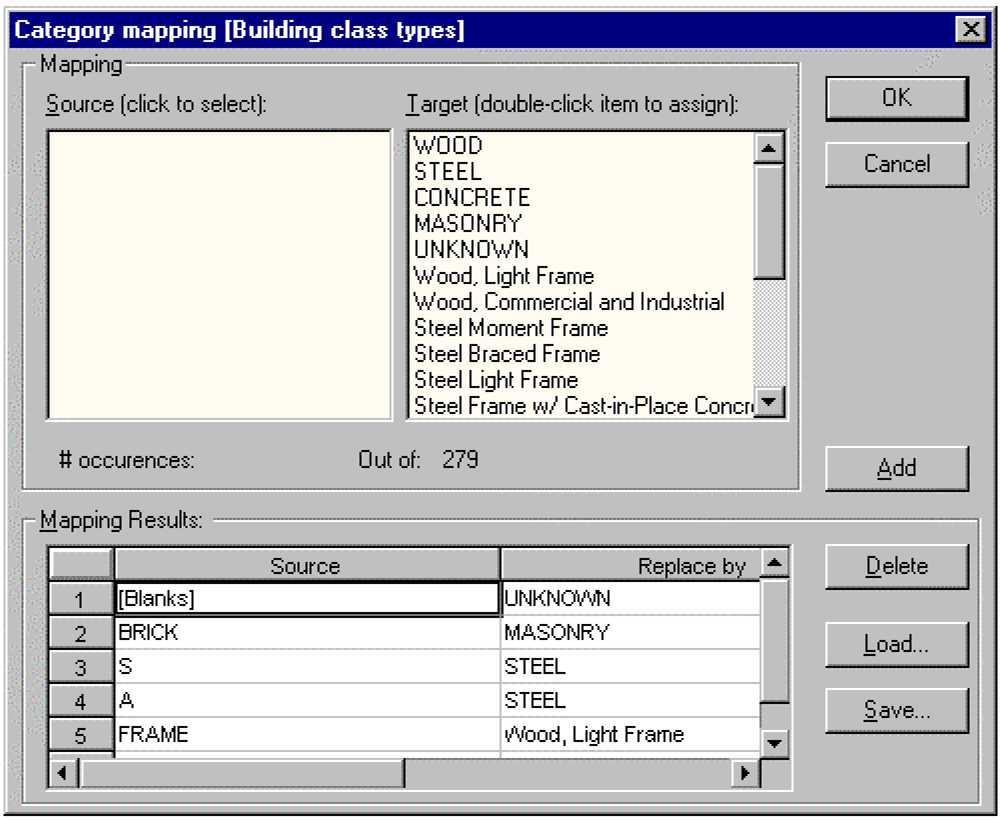


Figure 8.23 Categorizing building type data

As with other mappings defined in the **BIT**, you have the option to save the building type mapping for use on other files. To save the mapping, click on the **Save...** button before clicking **OK**. The building type mapping file will be saved with a .bsl extension as shown in Figure 8.24. To use the mapping in the future, click on the **Load...** button in Figure 8.23.

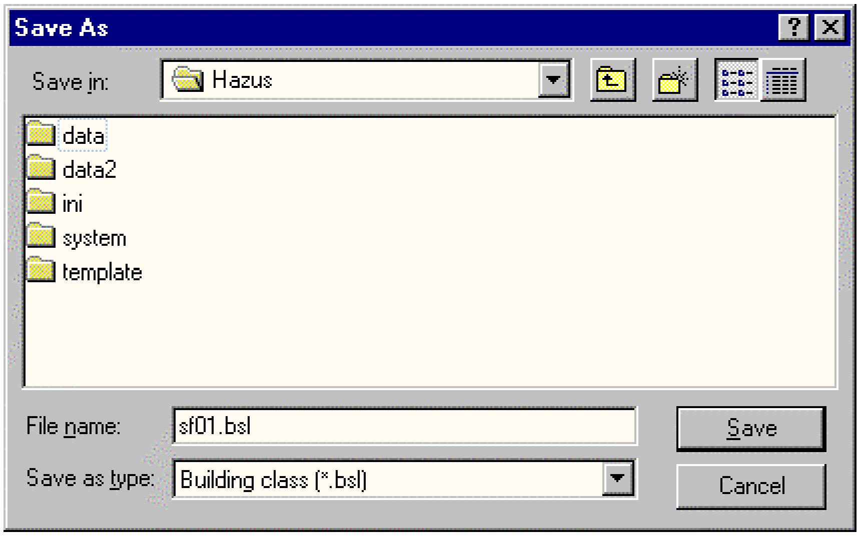


Figure 8.24 Saving a building type mapping scheme

8.6 Aggregating the Database Statistics

At this point the **BIT** is ready to create the occupancy to model building type relationships for each census tract. Click on the **Aggregate** button (shown in Figure 8.25) and wait. When the aggregation is done you will be able to view the results using the **View Results** button.

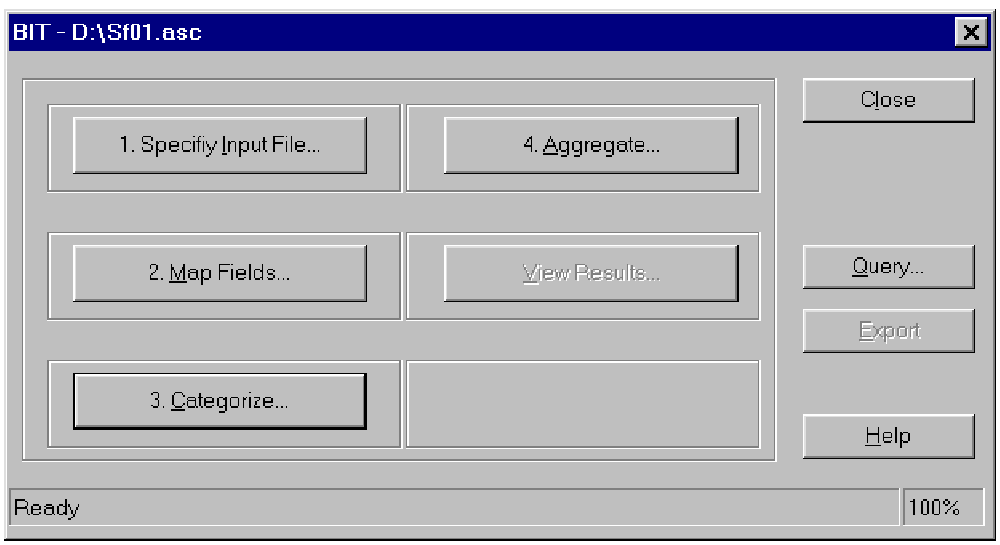


Figure 8.25 Starting the aggregation utility

If for some reason you have changed your database in some way and need to run the aggregate utility again, you will be asked if you want to overwrite the files you created previously. An example of this window is found in Figure 8.26.

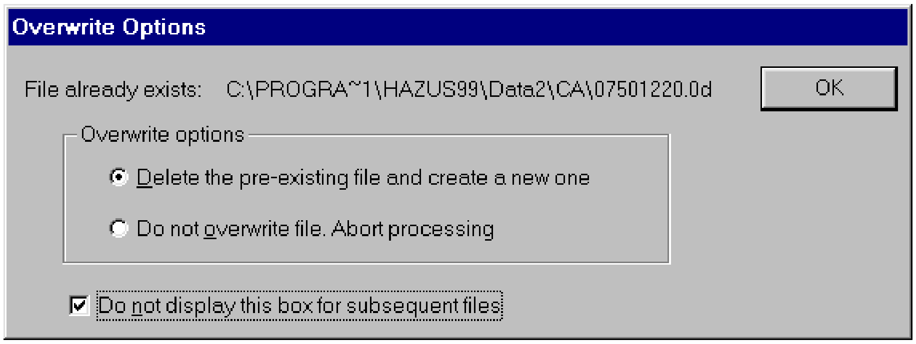


Figure 8.26 Overwriting previously developed occupancy to model building type relationships

8.7 Viewing the Results

To view the updated databases and the occupancy-to model-building-type mapping schemes, click on the **View Results...** button shown in Figure 8.27.

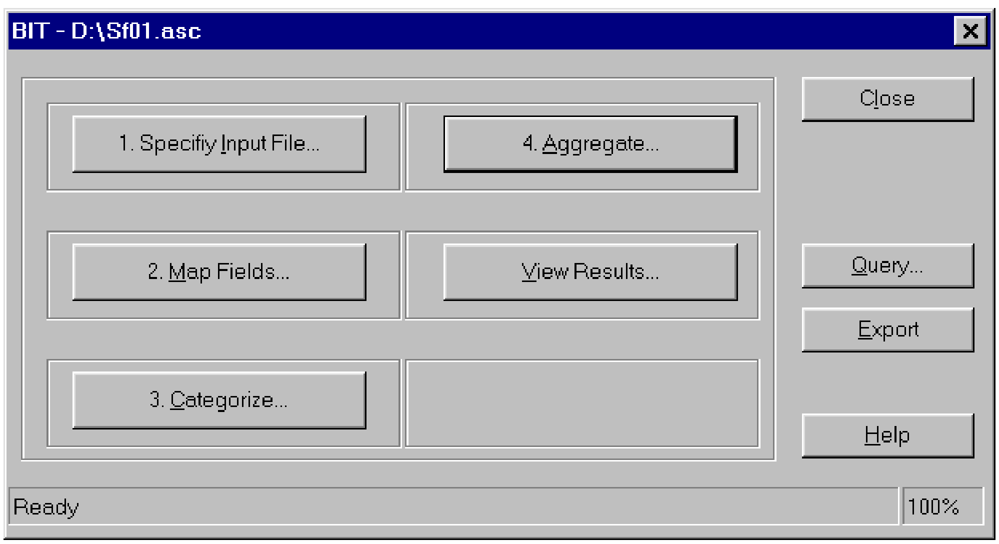
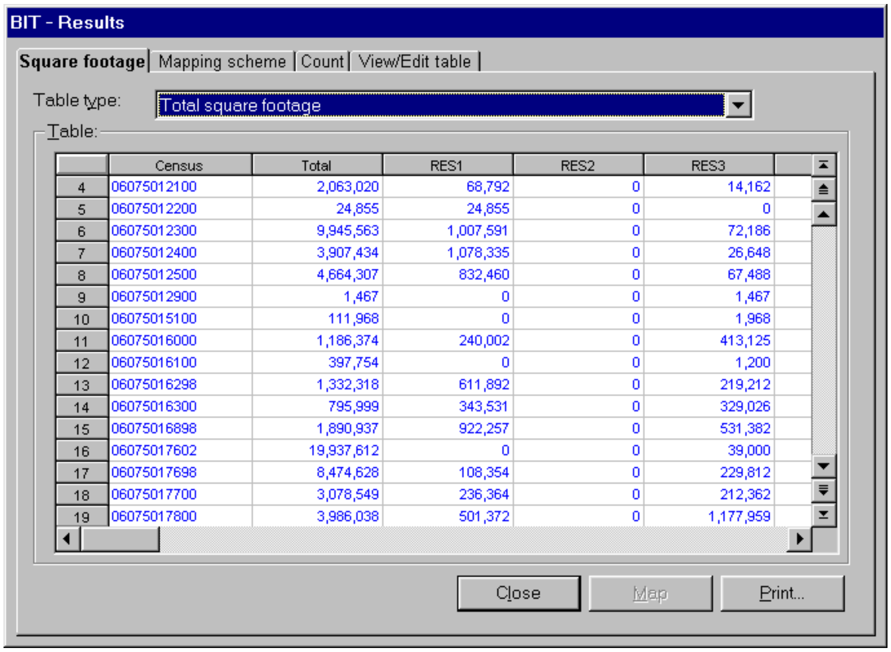


Figure 8.27 Starting the View Results utility

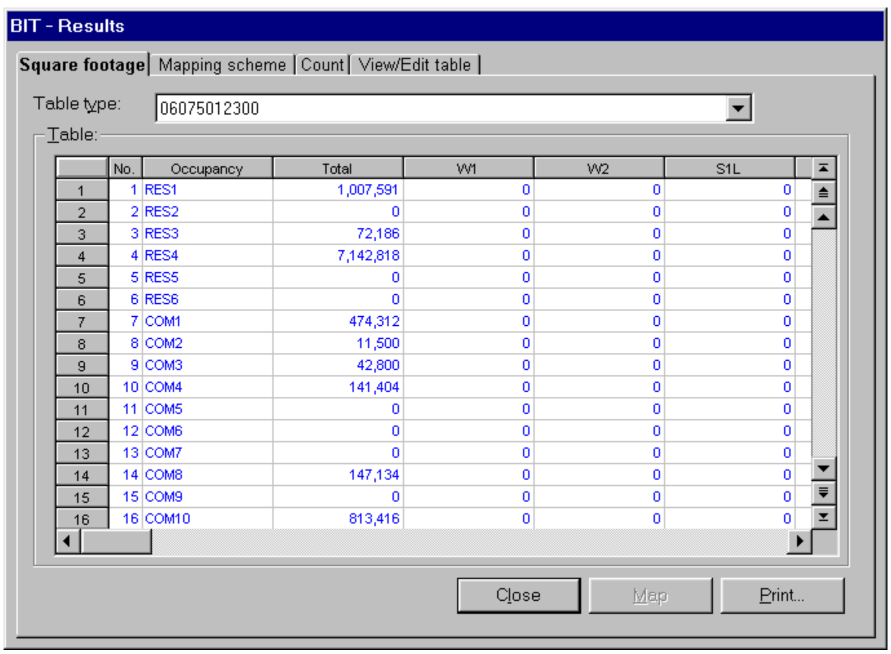
8.7.1 Viewing Square Footage

The **BIT** gives you the option to view the total square footage for each occupancy type and census tract as shown in Figure 8.28. Alternatively, for any individual census tract you can view the square footage for each occupancy and building type as shown in Figure 8.29. To access a particular census tract, use the **Table type:** list box near the top of the **BIT** - **Results** window in Figure 8.29 and click on the census tract of interest to you.



	Census	Total	RES1	RES2	RES3
4	06075012100	2,063,020	68,792	0	14,162
5	06075012200	24,855	24,855	0	0
6	06075012300	9,945,563	1,007,591	0	72,186
7	06075012400	3,907,434	1,078,335	0	26,648
8	06075012500	4,664,307	832,460	0	67,488
9	06075012900	1,467	0	0	1,467
10	06075015100	111,968	0	0	1,968
11	06075016000	1,186,374	240,002	0	413,125
12	06075016100	397,754	0	0	1,200
13	06075016298	1,332,318	611,892	0	219,212
14	06075016300	795,999	343,531	0	329,026
15	06075016898	1,890,937	922,257	0	531,382
16	06075017602	19,937,612	0	0	39,000
17	06075017698	8,474,628	108,354	0	229,812
18	06075017700	3,078,549	236,364	0	212,362
19	06075017800	3,986,038	501,372	0	1,177,959

Figure 8.28 Viewing total square footage for each occupancy type



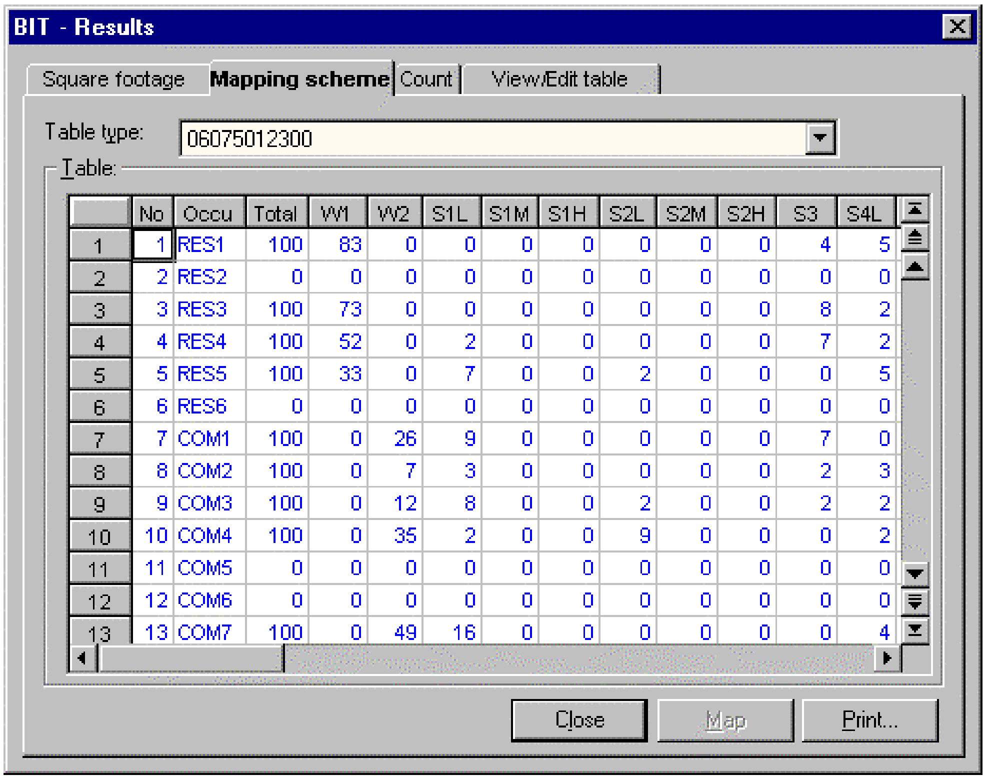
	No.	Occupancy	Total	W1	W2	S1L
1	1	RES1	1,007,591	0	0	0
2	2	RES2	0	0	0	0
3	3	RES3	72,186	0	0	0
4	4	RES4	7,142,818	0	0	0
5	5	RES5	0	0	0	0
6	6	RES6	0	0	0	0
7	7	COM1	474,312	0	0	0
8	8	COM2	11,500	0	0	0
9	9	COM3	42,800	0	0	0
10	10	COM4	141,404	0	0	0
11	11	COM5	0	0	0	0
12	12	COM6	0	0	0	0
13	13	COM7	0	0	0	0
14	14	COM8	147,134	0	0	0
15	15	COM9	0	0	0	0
16	16	COM10	813,416	0	0	0

Figure 8.29 Viewing occupancy and model building type square footage for a particular census tract

8.7.2 Viewing and Using Mapping Schemes

Mapping schemes can be accessed by clicking on the **Mapping Scheme** tab at the top of the **BIT - Results** window. A mapping scheme has been created for each census tract. To access a mapping scheme for a particular census tract, use the **Table type:** list box near the top of the **BIT - Results** window and click on the census tract of interest to you.

The mapping scheme is presented in terms of percentages. For example, for census tract 06075012300 in Figure 8.30, 52% of RES4 are building type W1, 2% are S1L, 7% are S3, 2% are S4L and so on. It should be noted that in developing this mapping scheme, the **BIT** made use of default mappings in cases where no data was available from the property file.



	No	Occu	Total	W1	W2	S1L	S1M	S1H	S2L	S2M	S2H	S3	S4L
1	1	RES1	100	83	0	0	0	0	0	0	0	4	5
2	2	RES2	0	0	0	0	0	0	0	0	0	0	0
3	3	RES3	100	73	0	0	0	0	0	0	0	8	2
4	4	RES4	100	52	0	2	0	0	0	0	0	7	2
5	5	RES5	100	33	0	7	0	0	2	0	0	0	5
6	6	RES6	0	0	0	0	0	0	0	0	0	0	0
7	7	COM1	100	0	26	9	0	0	0	0	0	7	0
8	8	COM2	100	0	7	3	0	0	0	0	0	2	3
9	9	COM3	100	0	12	8	0	0	2	0	0	2	2
10	10	COM4	100	0	35	2	0	0	9	0	0	0	2
11	11	COM5	0	0	0	0	0	0	0	0	0	0	0
12	12	COM6	0	0	0	0	0	0	0	0	0	0	0
13	13	COM7	100	0	49	16	0	0	0	0	0	0	4

Figure 8.30 Viewing a mapping scheme for census tract 06075012300 created by the BIT

To use this mapping scheme, exit the **BIT** and start the **HAZUS** program. Open the study region that includes this census tract. From the **Inventory|General Building Stock| Occupancy Mapping...** menu click on the **Open...** button. You will be presented with the Mapping Scheme files window shown in Figure 8.31. In this example, the user has already imported mapping schemes developed by the **BIT**: 1AV107Y4, 1AV109C4, 1AV109HO…etc. The names of these mappings, constrained by a limitation of eight characters, are difficult to interpret; however, the census tract designation is displayed at the bottom of Figure 8.33 to clarify.

Click on the **Import...** button. Select one or more mapping schemes to import from the window in Figure 8.32. If you want to import a group of census tracts, click on the first census tract number in the group and then hold down the Shift key and click on the last census tract number in the group. To import several census tracts that are not listed consecutively, hold down the Ctrl key and click on the census tracts you want. When you have selected the census tracts, click **OK**. Once you have imported the mapping schemes, follow the instructions in Section 7.3 of this manual.

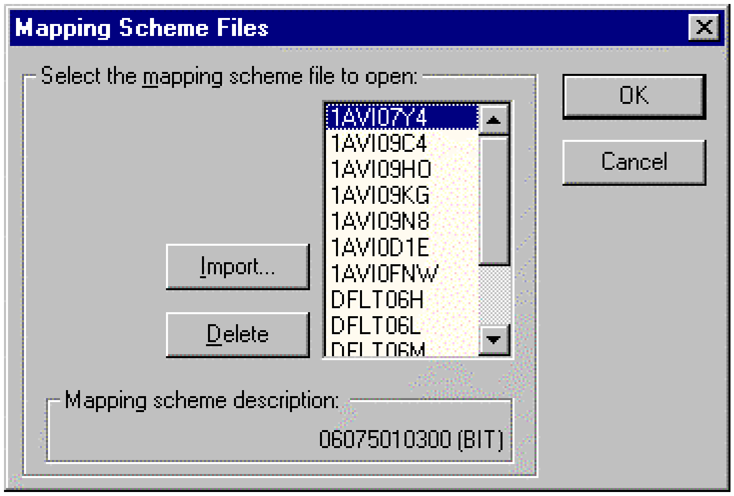


Figure 8.31 Selecting the mapping scheme developed for census tract 06075010300

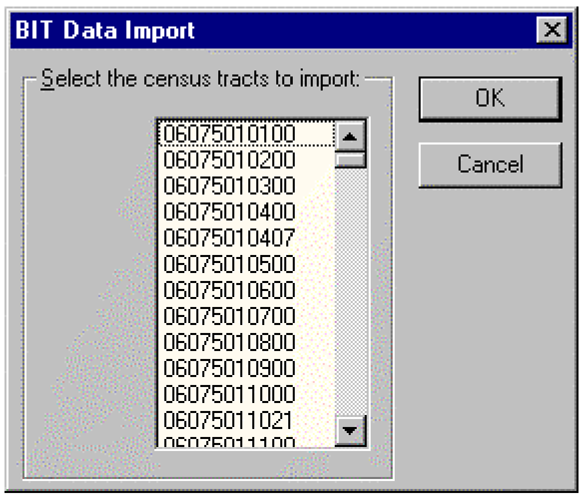
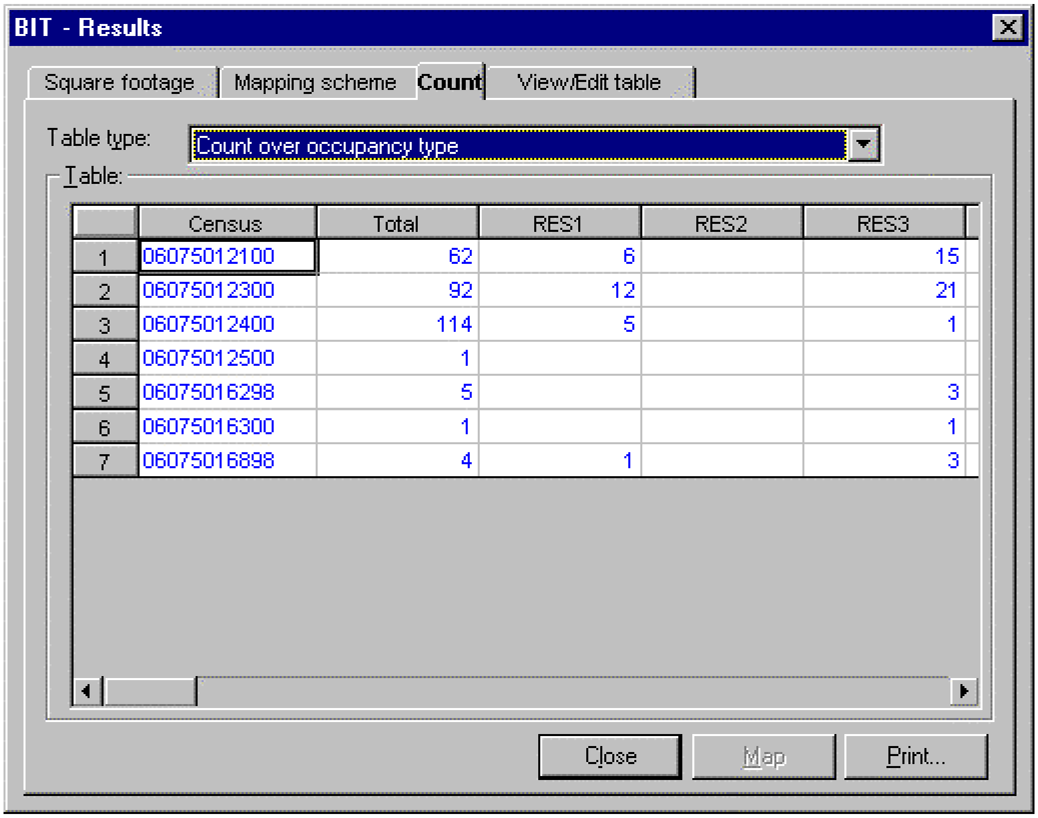


Figure 8.32 Importing mapping schemes developed by the BIT

8.7.3 Viewing Building Counts

By clicking on the **Count** tab at the top of Figure 8.33, for each census tract you can view the number of buildings that were found in the property file for each specific and general occupancy class. This may be helpful in determining the reliability of the mapping scheme. For example, in census tract 06075016300, only one building was identified, thus the resulting mapping scheme will be essentially the default mapping scheme defined in **HAZUS**.

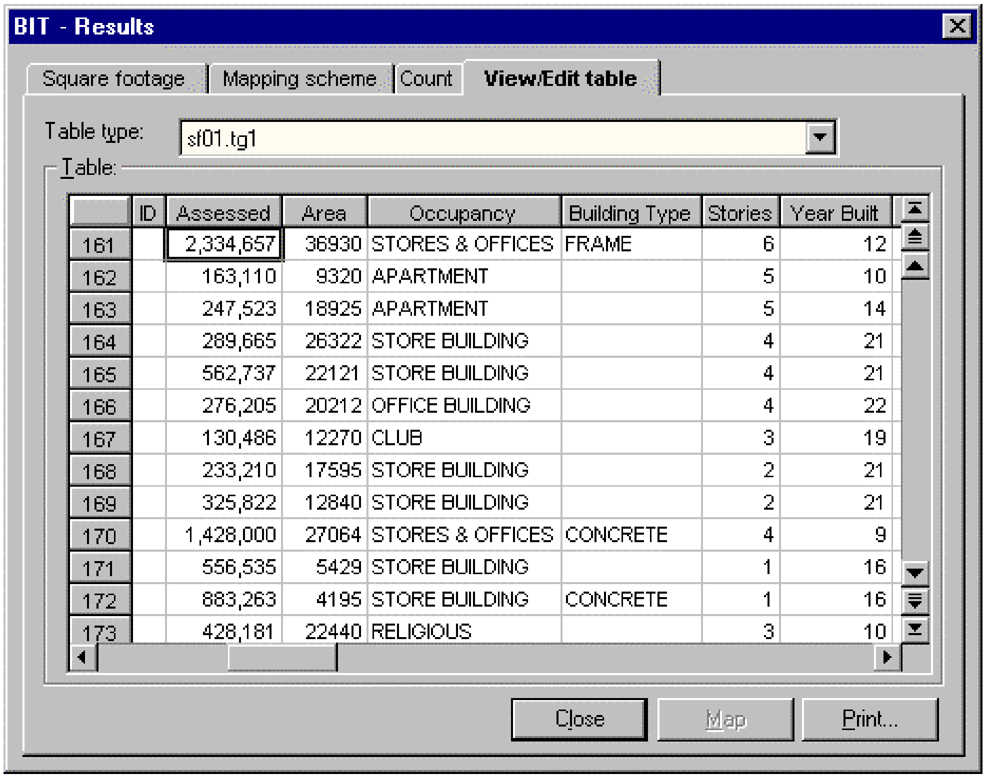


	Census	Total	RES1	RES2	RES3
1	06075012100	62	6		15
2	06075012300	92	12		21
3	06075012400	114	5		1
4	06075012500	1			
5	06075016298	5			3
6	06075016300	1			1
7	06075016898	4	1		3

Figure 8.33 Viewing the number of buildings for each occupancy

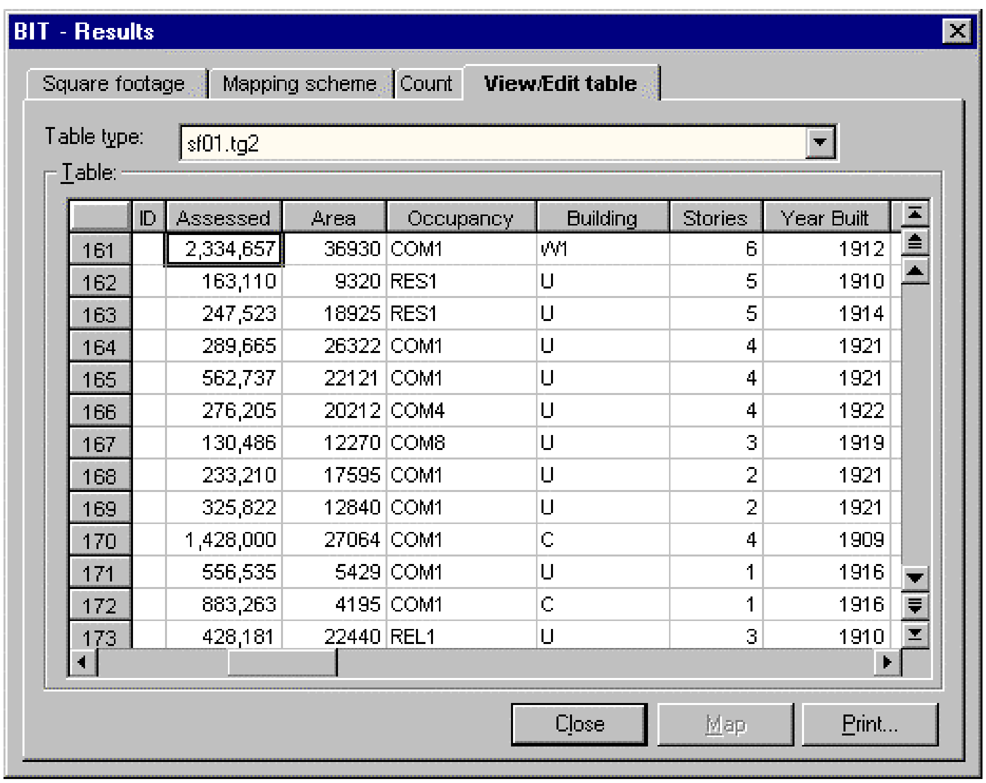
8.7.4 Viewing and Editing Property Files

Clicking on the View/Edit table tab at the top of Figure 8.34 allows you to view the property database that you have imported with the **BIT**. Two files have been created during the process discussed in this chapter: *.tg1 and *.tg2. The *.tg1 file (Figure 8.34) maintains the data exactly as it was in the original property file. The *.tg2 file (Figure 8.35) contains the standardized occupancies, years, types and heights resulting from the substitutions made. Accessing either of these files is achieved by using the **Table type:** list box at the top of Figure 8.34.



	ID	Assessed	Area	Occupancy	Building Type	Stories	Year Built
161		2,334,657	36930	STORES & OFFICES	FRAME	6	12
162		163,110	9320	APARTMENT		5	10
163		247,523	18925	APARTMENT		5	14
164		289,665	26322	STORE BUILDING		4	21
165		562,737	22121	STORE BUILDING		4	21
166		276,205	20212	OFFICE BUILDING		4	22
167		130,486	12270	CLUB		3	19
168		233,210	17595	STORE BUILDING		2	21
169		325,822	12840	STORE BUILDING		2	21
170		1,428,000	27064	STORES & OFFICES	CONCRETE	4	9
171		556,535	5429	STORE BUILDING		1	16
172		883,263	4195	STORE BUILDING	CONCRETE	1	16
173		428,181	22440	RELIGIOUS		3	10

Figure 8.34 Viewing the property database before substitutions have been made



	ID	Assessed	Area	Occupancy	Building	Stories	Year Built
161		2,334,657	36930	COM1	W1	6	1912
162		163,110	9320	RES1	U	5	1910
163		247,523	18925	RES1	U	5	1914
164		289,665	26322	COM1	U	4	1921
165		562,737	22121	COM1	U	4	1921
166		276,205	20212	COM4	U	4	1922
167		130,486	12270	COM8	U	3	1919
168		233,210	17595	COM1	U	2	1921
169		325,822	12840	COM1	U	2	1921
170		1,428,000	27064	COM1	C	4	1909
171		556,535	5429	COM1	U	1	1916
172		883,263	4195	COM1	C	1	1916
173		428,181	22440	REL1	U	3	1910

Figure 8.35 Viewing the property database after substitutions have been made

8.8 Querying Your Database

As noted in Section 8.4, after completing the Map Fields step the query tool is enabled. This tool allows you to search your database to look for particular building types or view summary statistics. The query tool can be used at the Map Fields step to look at the *.tg1 file. In this case you will be looking at the property file before any substitutions of standardized occupancies etc. have been made. Alternatively, it can be run after the Categorize step (on the *.tg2 file) to perform queries using the standardized occupancies and building types.

After you click on the **Query** button (see Figure 8.27), the **Query Statement** window shown in Figure 8.36 will appear. In the window you can choose whether to query the *.tg1 file or the *.tg2 file using the **Table to query:** list box. You can set up any sort of query statement using up to three conditions. The query statements can have equalities and inequalities. In this particular example, the user has a database that uses the letter C to define a building that is either cast-in-place concrete or masonry. She has decided to look for all properties that might be masonry by finding properties where the BLDG_TYPE column contains the letter C.

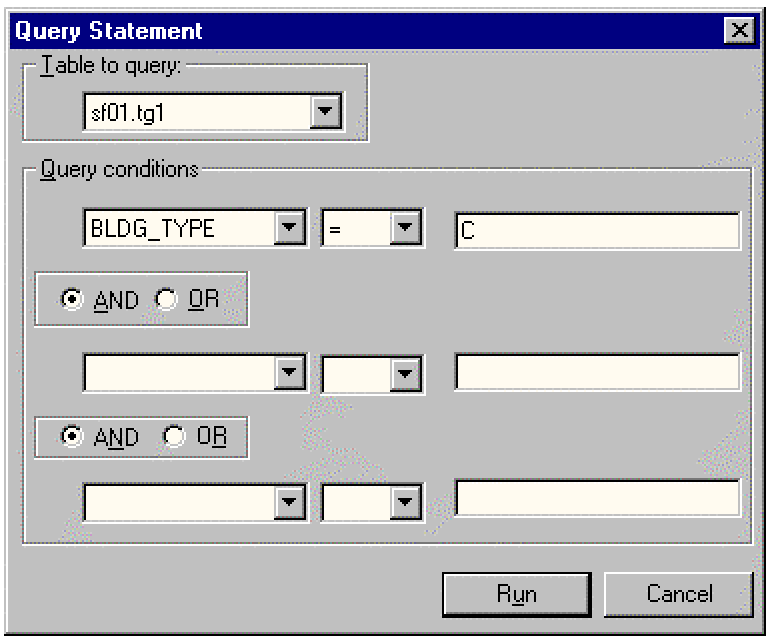
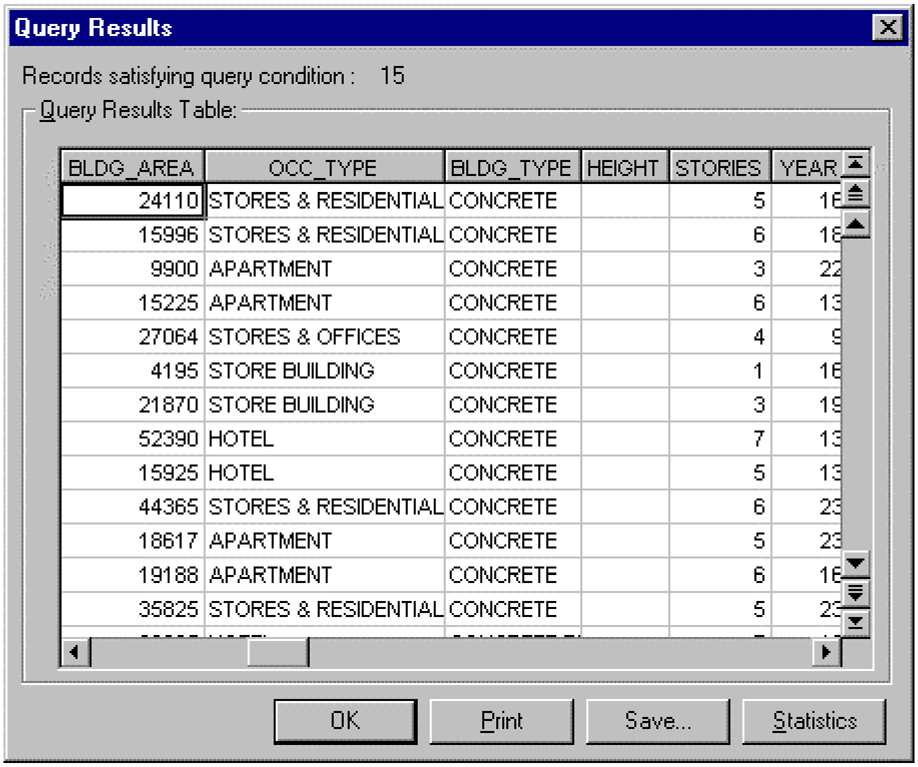


Figure 8.36 Setting up a query statement

The results of the query are found in Figure 8.37. As can be seen at the top of the window, 15 properties were found. Only a few of the columns of the database are shown in the figure, and you can scroll to the left or the right to view other columns. If you were to scroll to the left you would find all of the addresses of the properties. The important thing to note is that the occupancy, the number of stories and the year built are in the format of the original property file.



BLDG_AREA	OCC_TYPE	BLDG_TYPE	HEIGHT	STORIES	YEAR
24110	STORES & RESIDENTIAL	CONCRETE		5	16
15996	STORES & RESIDENTIAL	CONCRETE		6	18
9900	APARTMENT	CONCRETE		3	22
15225	APARTMENT	CONCRETE		6	13
27064	STORES & OFFICES	CONCRETE		4	9
4195	STORE BUILDING	CONCRETE		1	16
21870	STORE BUILDING	CONCRETE		3	19
52390	HOTEL	CONCRETE		7	13
15925	HOTEL	CONCRETE		5	13
44365	STORES & RESIDENTIAL	CONCRETE		6	23
18617	APARTMENT	CONCRETE		5	23
19188	APARTMENT	CONCRETE		6	16
35825	STORES & RESIDENTIAL	CONCRETE		5	23

Figure 8.37 Results of query to identify all buildings of type "C"

You can perform statistical analyses on the results of this query by clicking on the **Statistics** button at the bottom of Figure 8.37. You can find out how many square feet of building type "C" are in the property file by highlighting the BLDG_AREA column (clicking on the label) and then clicking on the **Statistics** button. The statistics results are found in Figure 8.38.

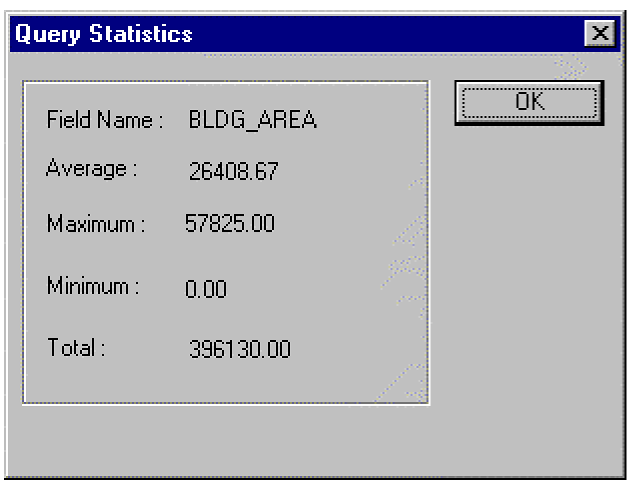


Figure 8.38 Statistics on BLDG_AREA column of query results

The results of a query in a *.dbf file can be saved for use at a later time. To do this click on the **SAVE...** button in Figure 8.38 and name the file in the window shown in Figure 8.39. You can now open this file at any time using Excel, or any database manager that reads a dBase file. It could also be imported into **HAZUS**.

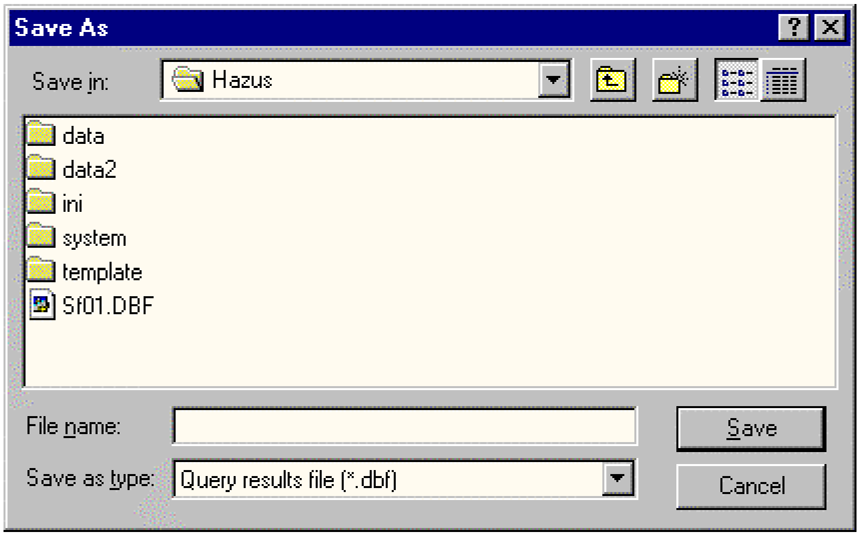


Figure 8.39 Saving a query.

You can also constrain the query to ensure that you are identifying masonry buildings. In addition to buildings with a BLDG_TYPE = C condition, you can also constrain the BLDG_TYPE column to have the word BRICK or the word MASONRY in it. This query statement is shown in Figure 8.40. Since a previous query has already been performed, you will be asked if you want to overwrite the previous query (Figure 8.41). Since the previous query was saved, you will answer yes.

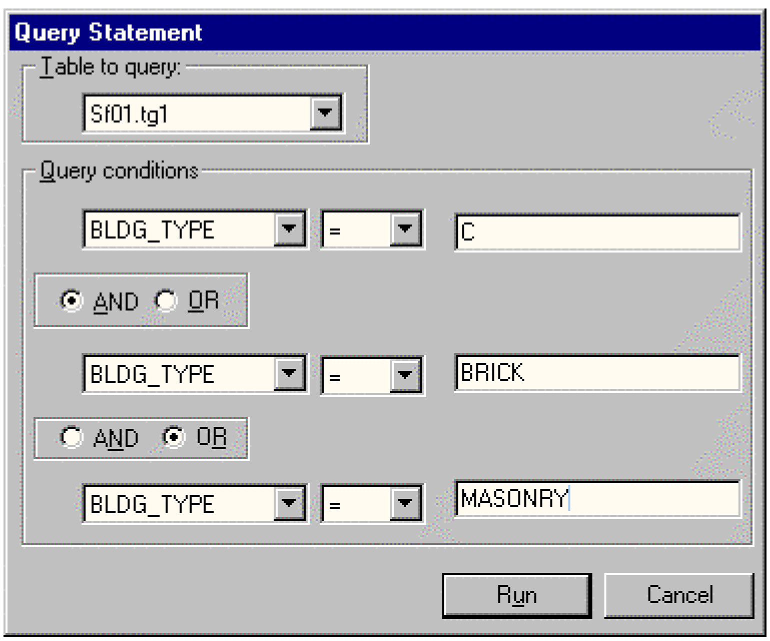


Figure 8.40 Query to identify masonry buildings

Figure 8.41 Confirmation to overwrite a previous query

The results of the query are found in Figure 8.42. This time only 5 properties were identified. You can see that the building area and occupancy type are two of the types of information that are available. The user can then do sidewalk surveys of these properties, import this database and map these properties or a number of other useful things.

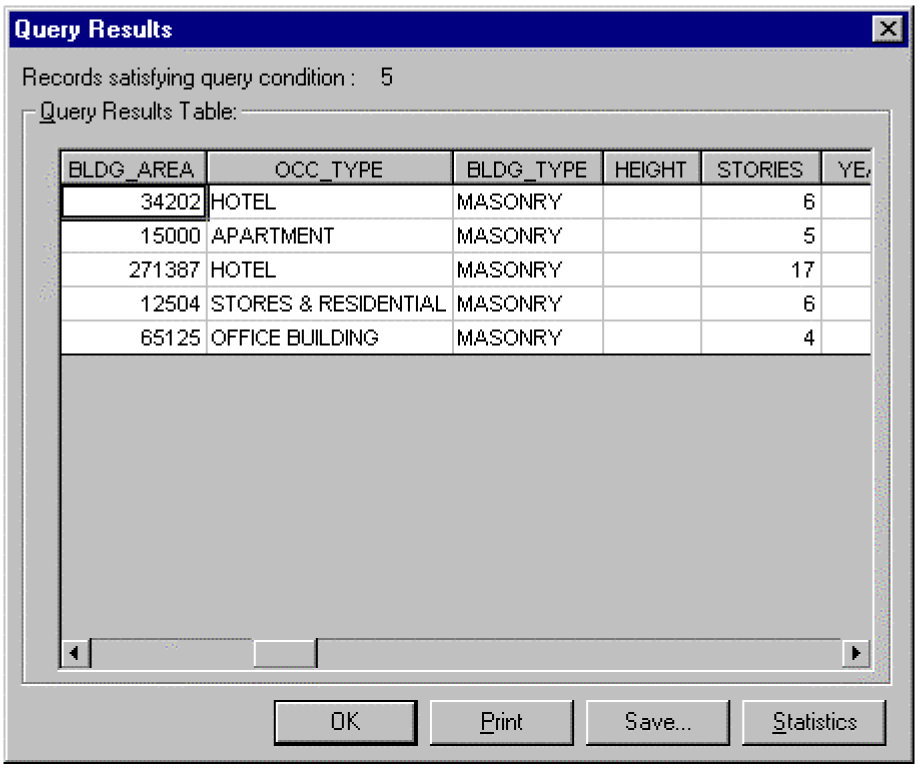


Figure 8.42 Results of query

8.8.1 Errors with the Query Tool

If you create a query statement that cannot be interpreted by the query tool you will get an error message such as the one in Figure 8.44. Here the query tool has tried to find properties where the ID_NUMBER column contains the letter C, as shown in Figure 8.43. Since the ID Number is not a letter the query tool has returned an error.

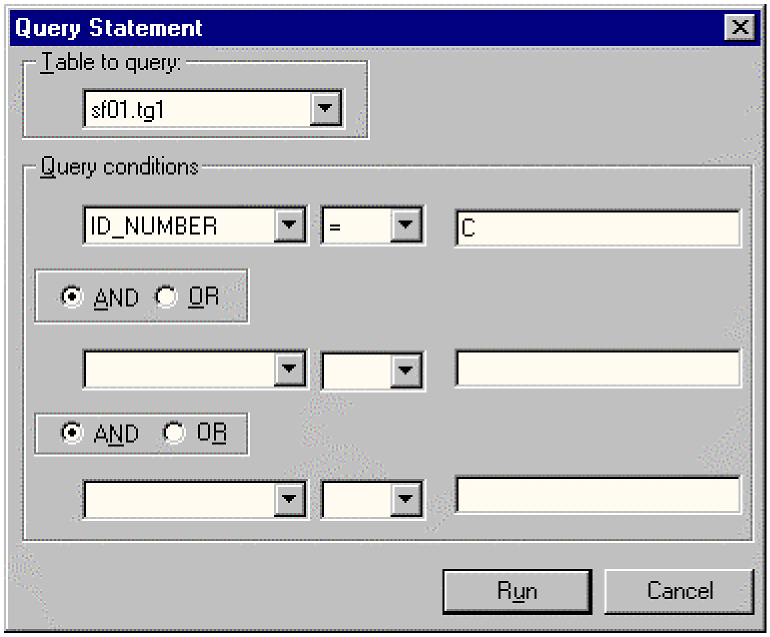


Figure 8.43 An incorrect query

Figure 8.44 Error message for an incorrect query

Similarly, the query has tried to obtain statistics for a non-numeric field and has generated the error message in Figure 8.45.

Figure 8.45 Error message for statistics tool

8.9 Exporting a Database

The databases that are created by the **BIT** tool can be quite large. It is unlikely that they will fit on a floppy disk unless they are compressed. The Export utility shown in Figure 8.46 compresses a database for transfer onto a floppy disk. Simply click on the Export button as shown in Figure 8.46 to use the Export utility.

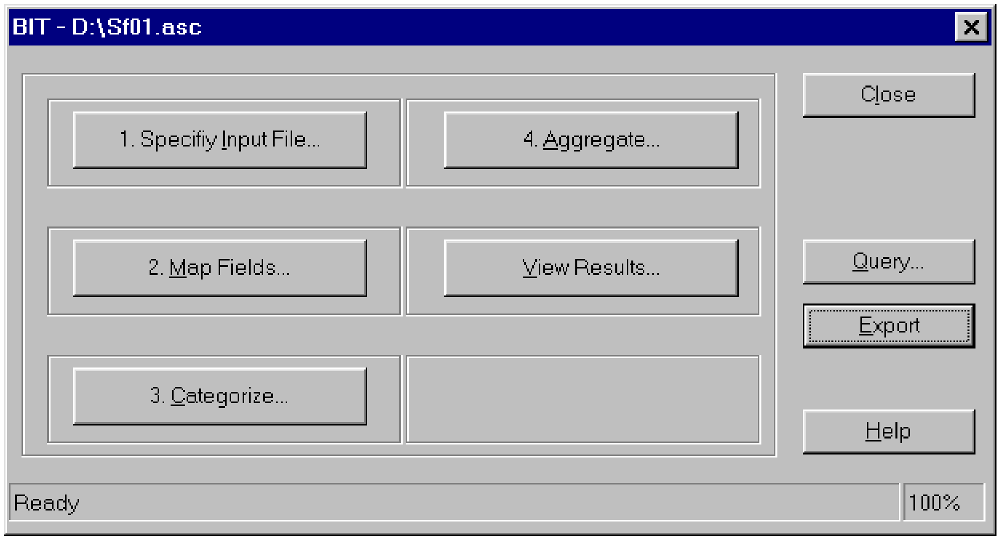


Figure 8.46 Export utility

After clicking on the Export button, the Save As dialog appears as shown in Figure 8.47. Click the Save button to complete compressing the database.

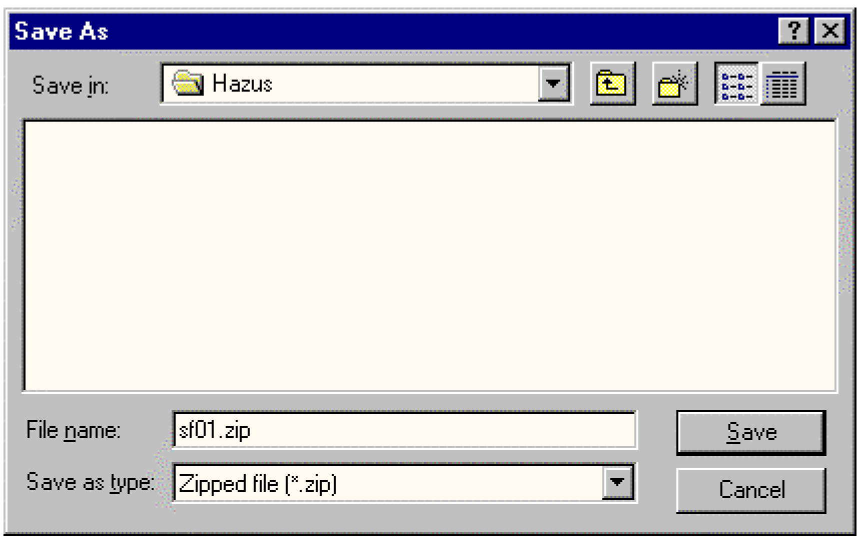


Figure 8.47 Compress and saving the database.

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 either 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. The epicenter is defined either by entry of latitude and longitude or graphically on a map. The user 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 eight return periods. An additional option in **HAZUS** 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.

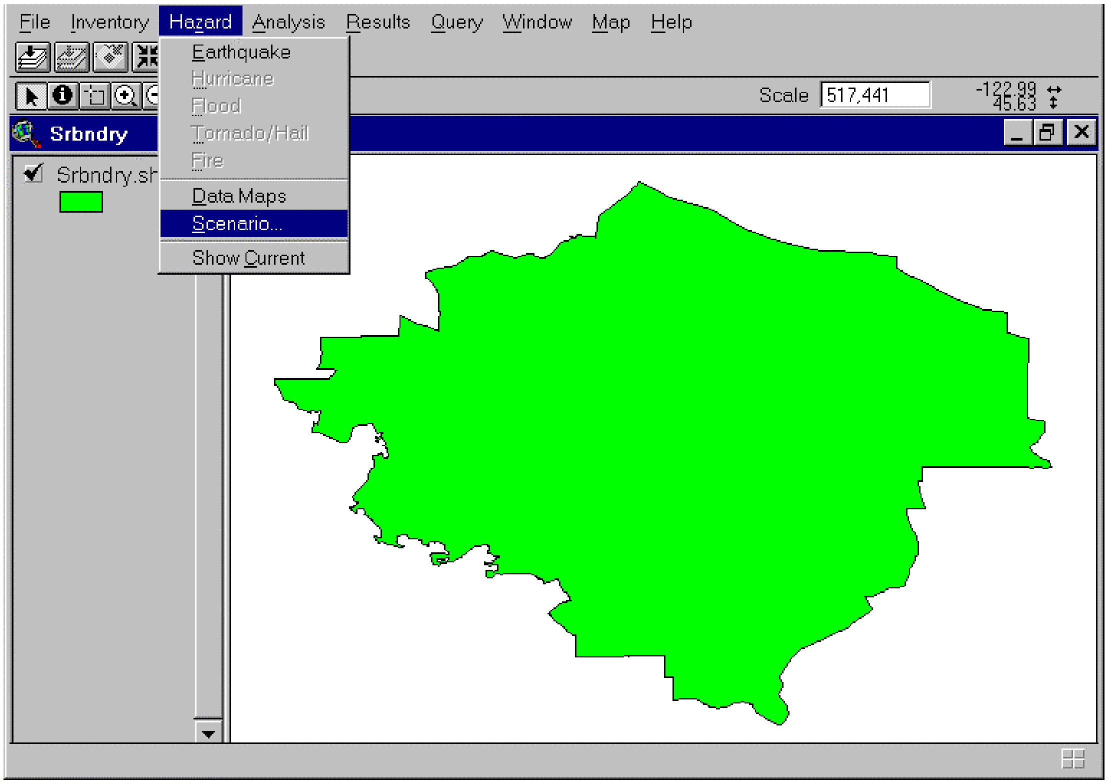


Figure 9.1 Hazard definition menu in HAZUS.

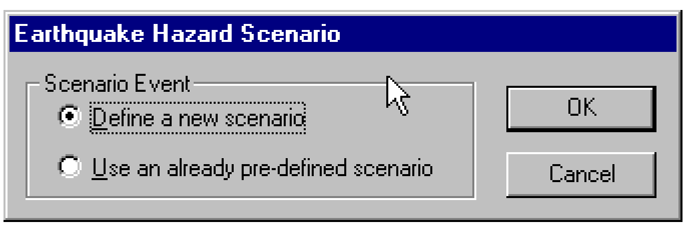


Figure 9.2 Earthquake Hazard Scenario window in HAZUS.

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.

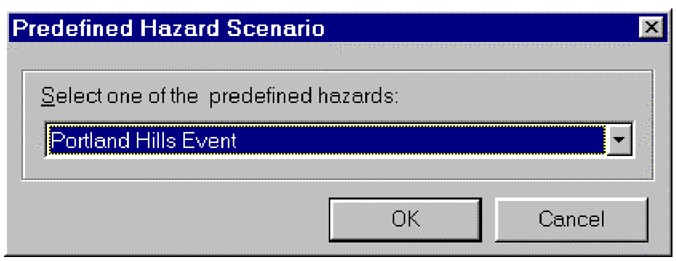


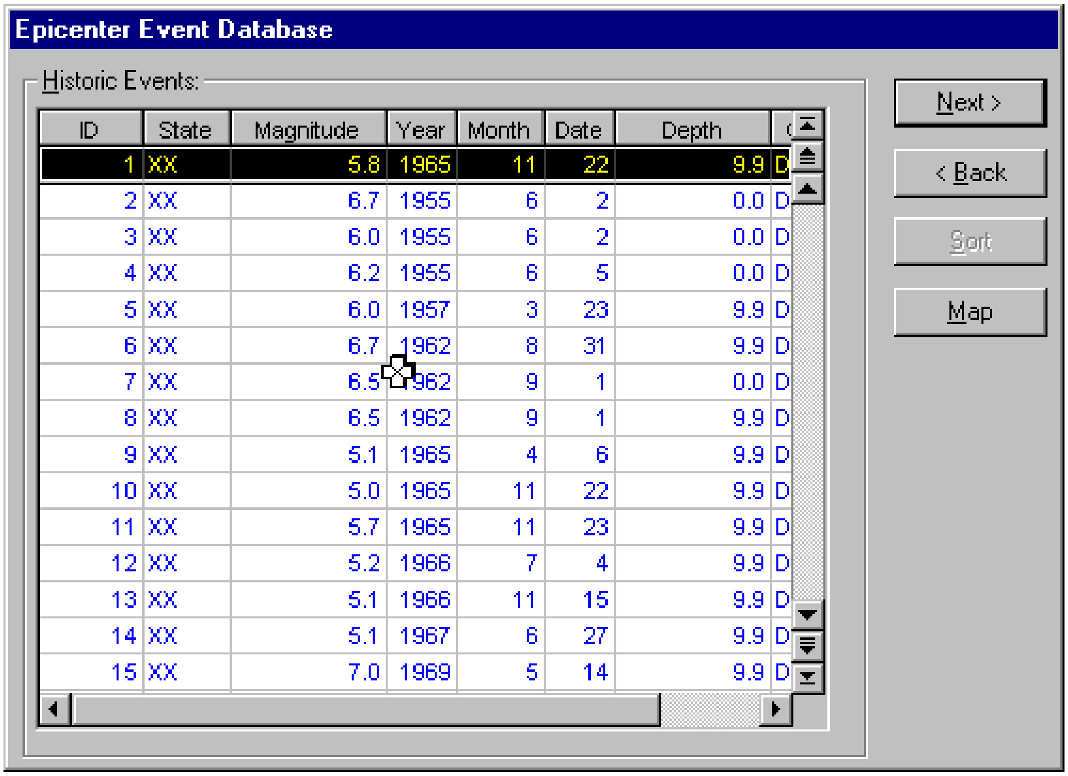
Figure 9.4 Predefined Hazard Scenario window in HAZUS.

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, click the **OK** button and a window (see Figure 9.5) displaying 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.

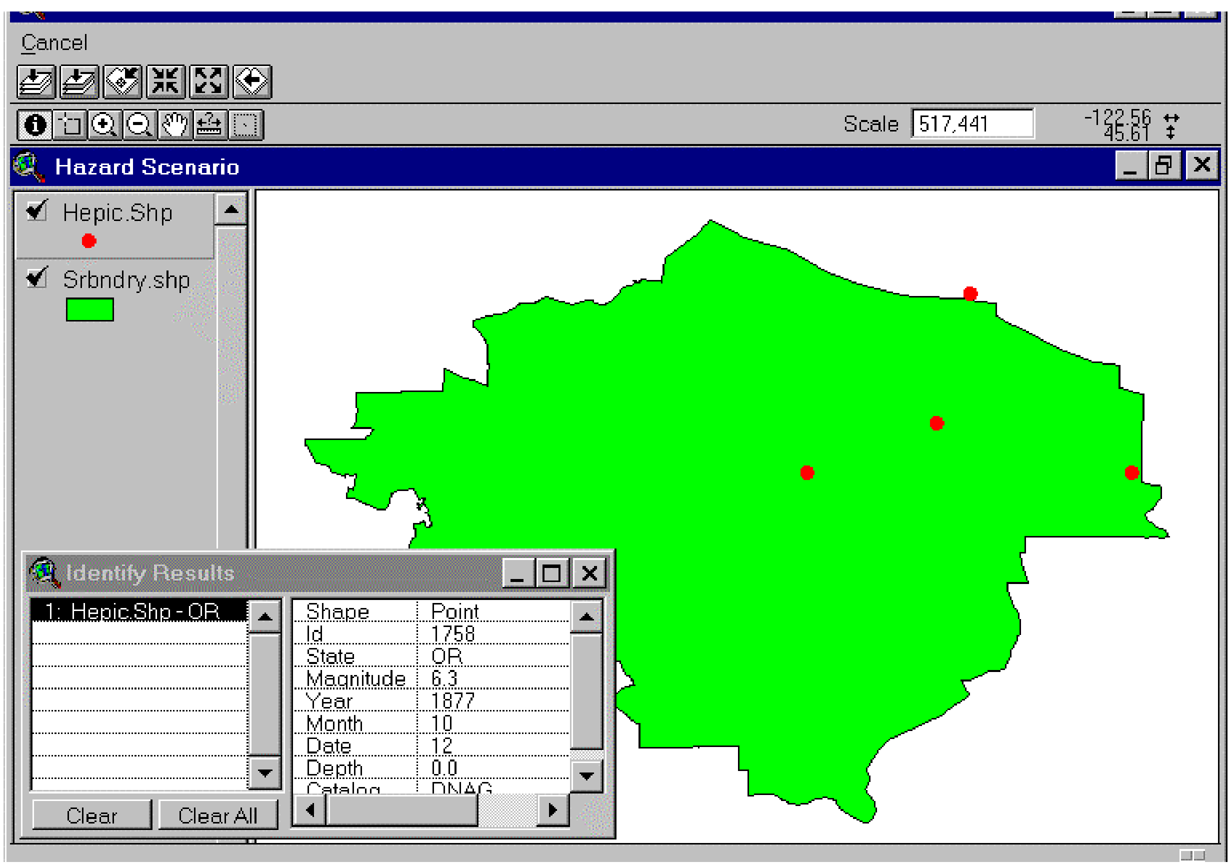


Figure 9.6 Map of historic earthquakes in or near the study region.

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.

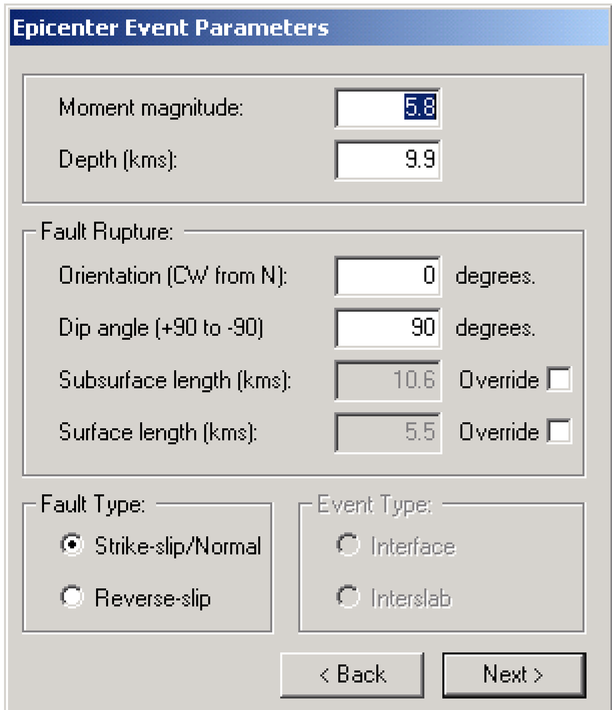


Figure 9.7 Window to modify parameters of a selected historical event.

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.

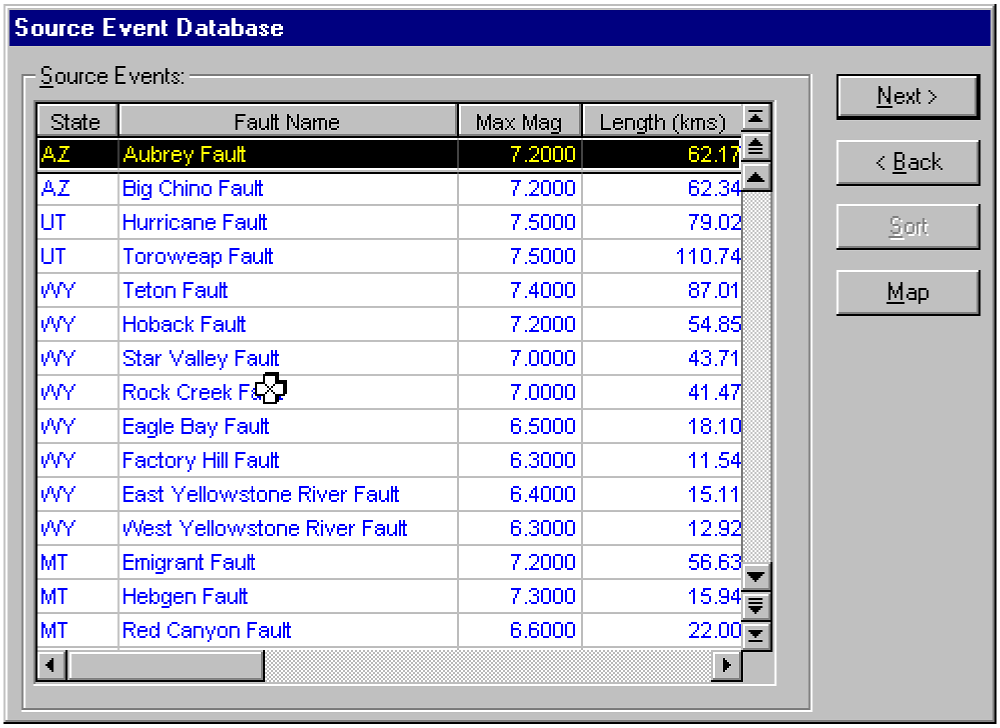


Figure 9.8 Selecting the fault from the HAZUS source database.

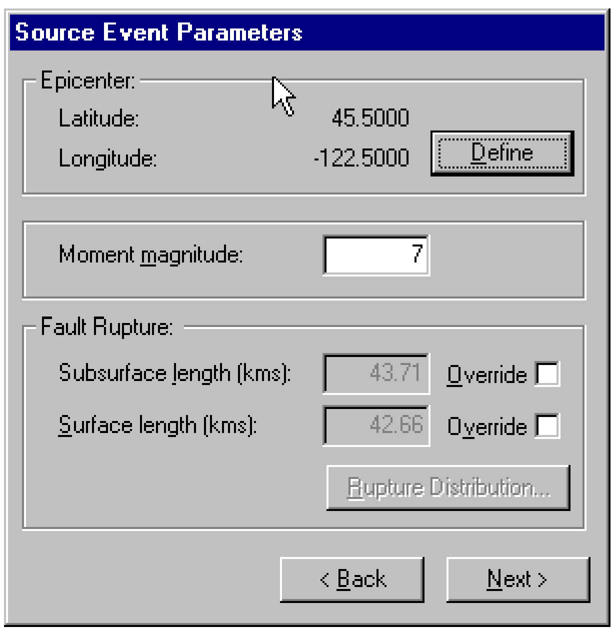


Figure 9.9 Window to modify parameters for the selected source.

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 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.

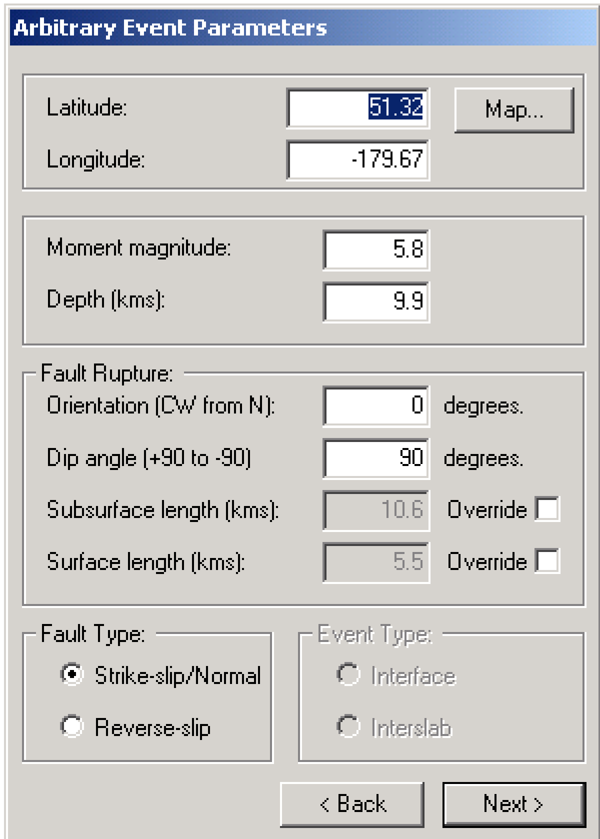


Figure 9.10 Window to define parameters for an arbitrary event.

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[5] 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.

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

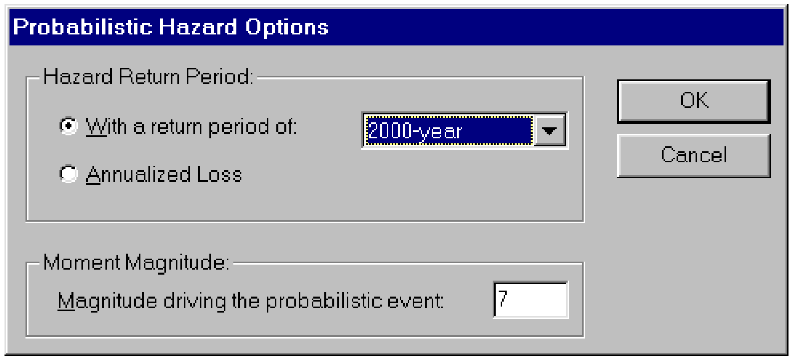


Figure 9.11 Probabilistic Hazard Options window.

9.2.4 User-defined Hazard

The user can supply the ground shaking maps used as the PESH input for estimating damage and loss. To utilize this option, the user must obtain ground shaking maps in a **HAZUS** compatible format (see Chapter 6). The data formats for the ground shaking maps are provided in Appendix E. The location of the maps is specified in the **User-defined Hazard Data** dialog shown in Figure 9.12 which is accessed from the **User-supplied hazard…** in Figure 9.3.

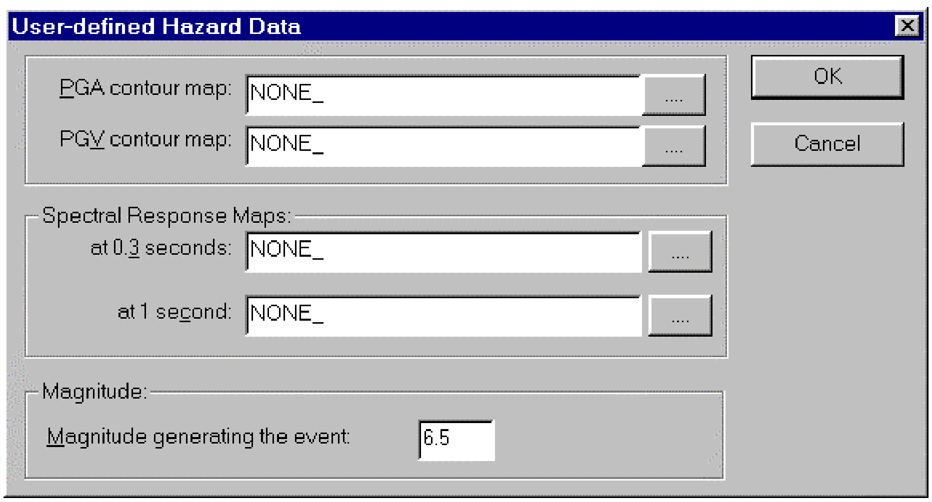


Figure 9.12 Dialog for specifying the location of user-supplied shaking maps.

9.2.5 Choosing an Attenuation Function

HAZUS contains default attenuation relationships that define how ground motion decreases as a function of distance from the source. For the Western United States, seven attenuation functions are available. For the Eastern United States, four attenuation relationships are available. The default **HAZUS** attenuation functions are selected to be consistent with the USGS Project97 studies. The user can modify the attenuation relationship used in the analysis through the **Ground Motion** dialog box shown in Figure 9.3. Detailed descriptions of the available attenuation relationships are provided in Chapter 4 of the *Technical Manual*.

9.2.6 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 rupture length, measured in kilometers, is automatically computed by **HAZUS** but can be overwritten by the user. **HAZUS** uses a relationship between rupture length and magnitude (Wells and Coppersmith, 1994) to estimate the default rupture length. A description of the technical approach is provided in Chapter 4 of 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.

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.

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.

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.

<u>Earthquake Scenario from Previous Study</u>: 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**.

9.2.7 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.

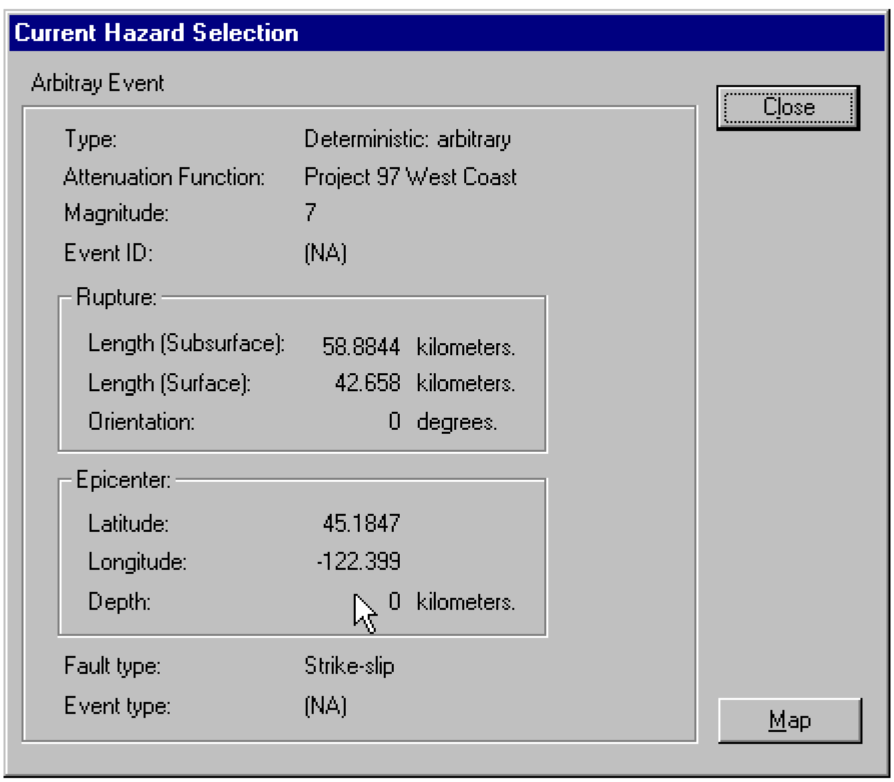


Figure 9.13 Viewing the parameters of the current hazard definition.

9.2.8 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.

9.2.9 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 may tend to tear them apart.

9.2.9.1 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	---	---	---

9.2.9.2 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. The methodology provides basic rules for defined the landslide susceptibility based on the geologic group, ground water level, slope angle and the critical acceleration (a_c). 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. Chapter 4 of 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

9.2.9.3 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.

Surface fault rupture can be included by selecting the **Surface fault** option under **PESH** when the analysis is run. **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.

9.2.10 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*.

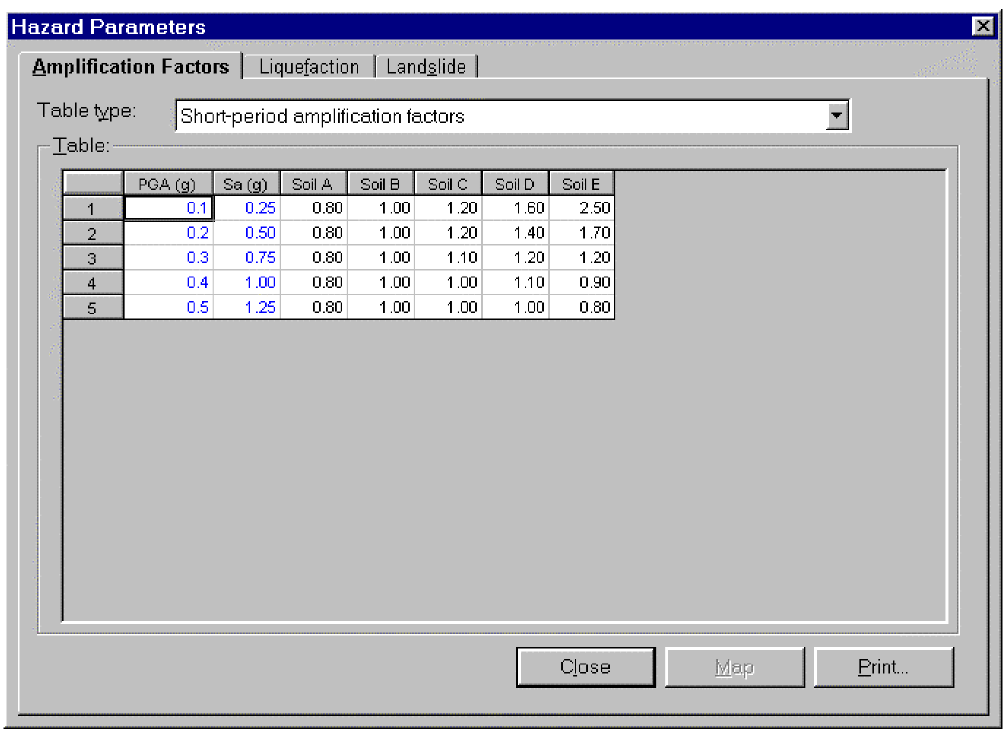


Figure 9.14 Window for modifying soil amplification factors.

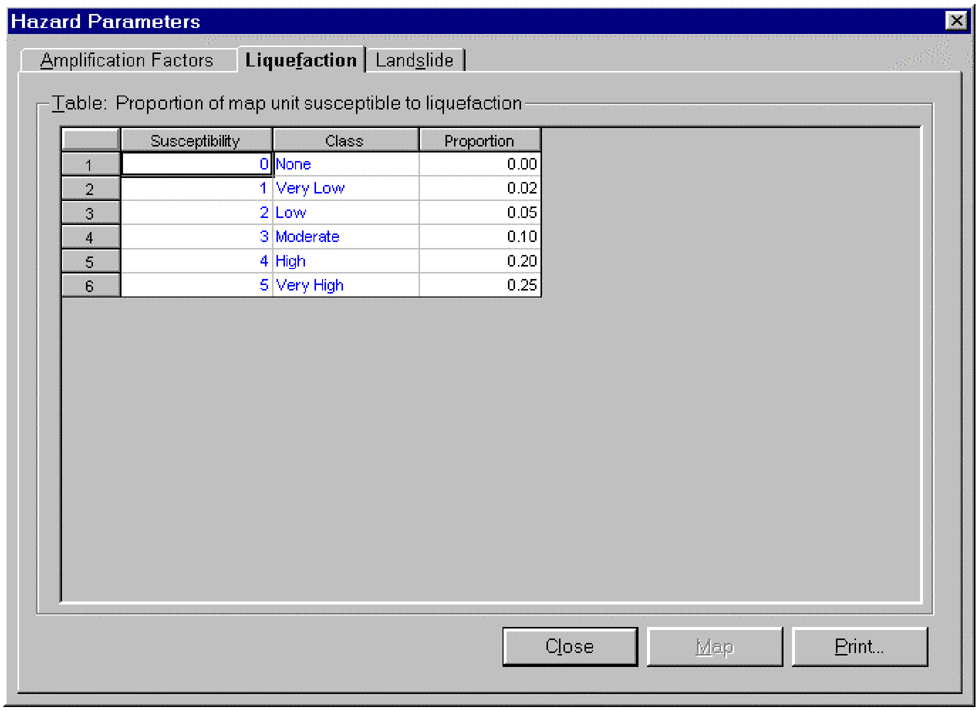


Figure 9.15 Window for modifying the proportion of map area that is susceptible to liquefaction.

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.

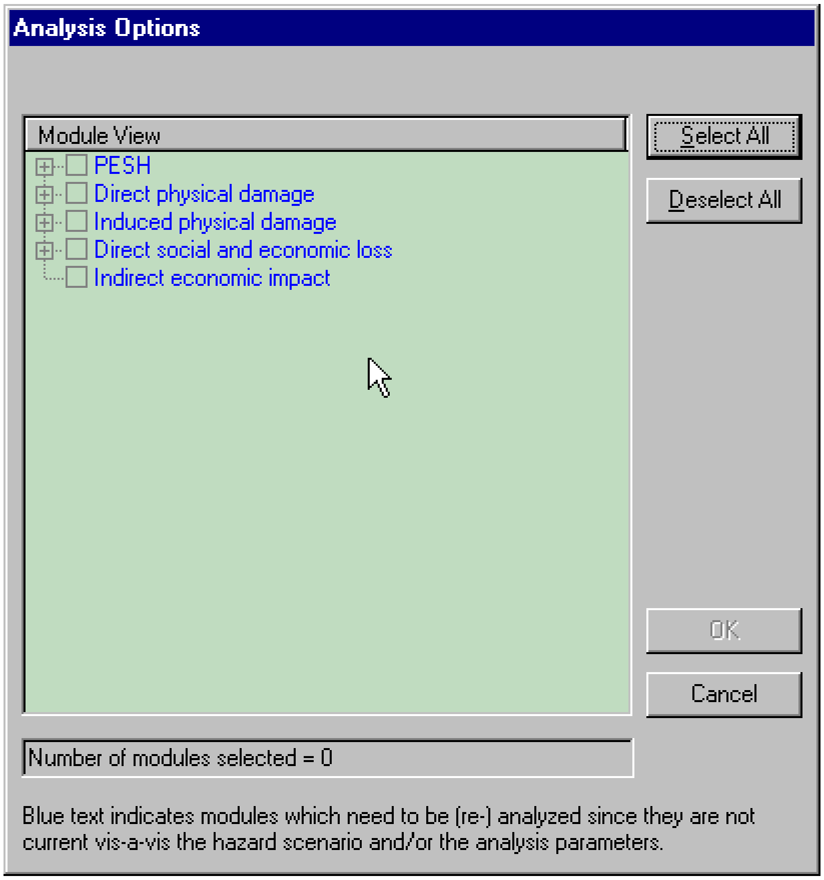


Figure 9.16 Analysis options in HAZUS.

Figure 9.16 shows the Analysis Options menu for **HAZUS**. Clicking on **PESH** followed by **OK**, brings up the PESH Analysis Options window shown in Figure 9.17. These menus are discussed in Section 3.3.

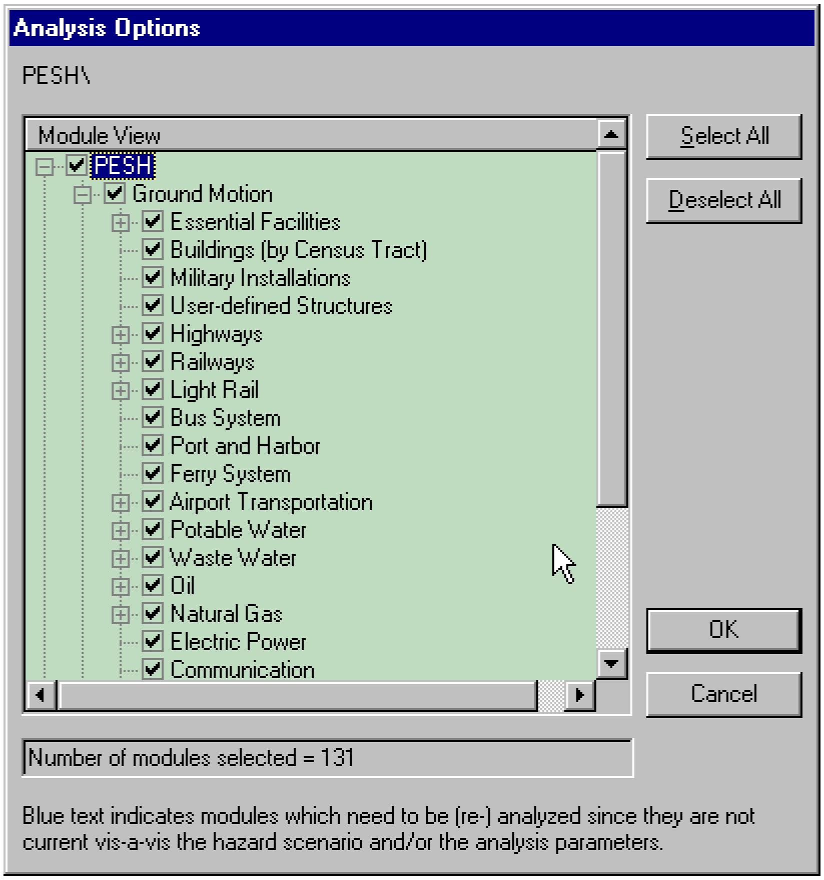


Figure 9.17 PESH analysis options in HAZUS.

9.4 Running the Direct Physical Damage Option

The **Direct physical damage** analysis option is used to estimate damage to buildings and lifelines. Selecting the **Direct physical damage** option in the window shown in Figure 9.16 will cause the following menu to appear.

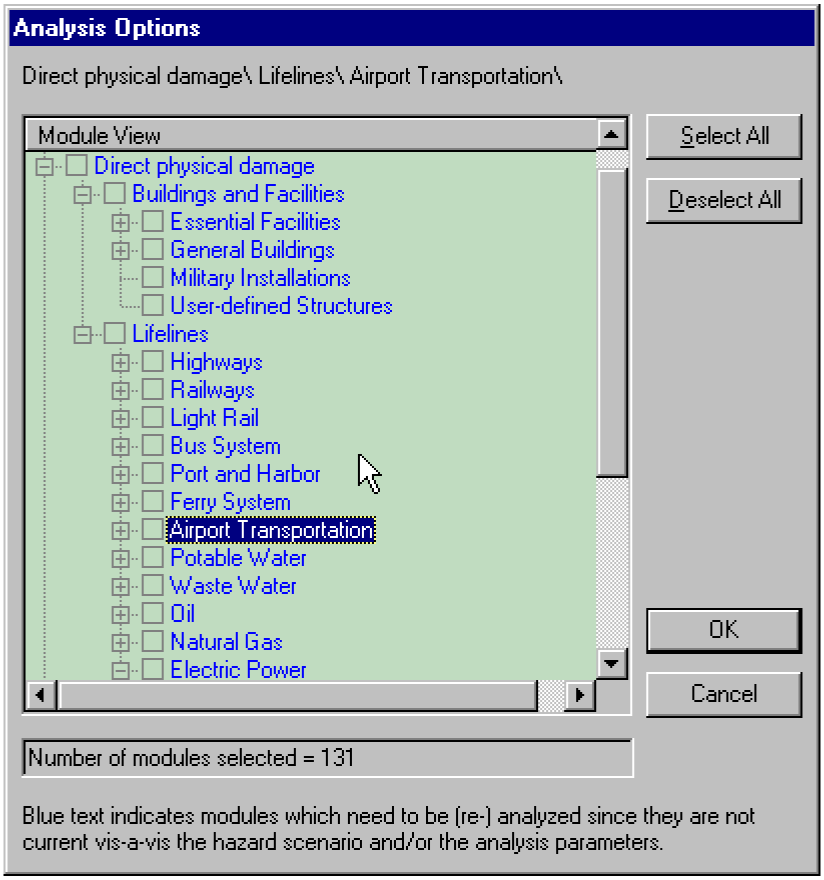


Figure 9.18 Options for selecting Direct Physical Damage analysis options.

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, click on the **Close** button and then click on the **OK** button shown in the window in Figure 9.16. 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.

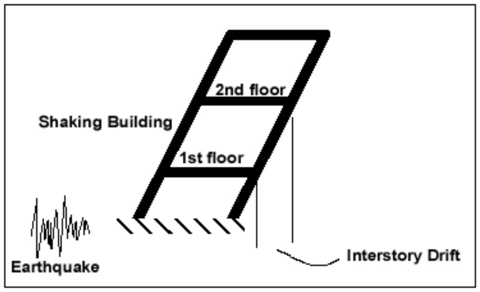


Figure 9.19 Inter-story drift in a shaking building.

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 inter-story 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.

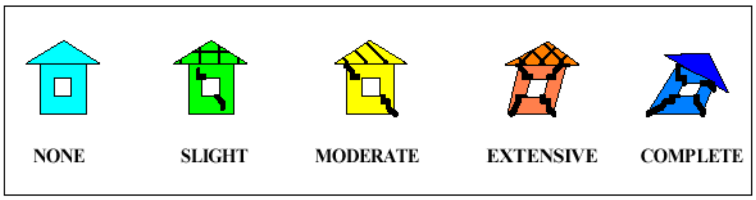


Figure 9.20 The five damage states.

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 inter-story 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.

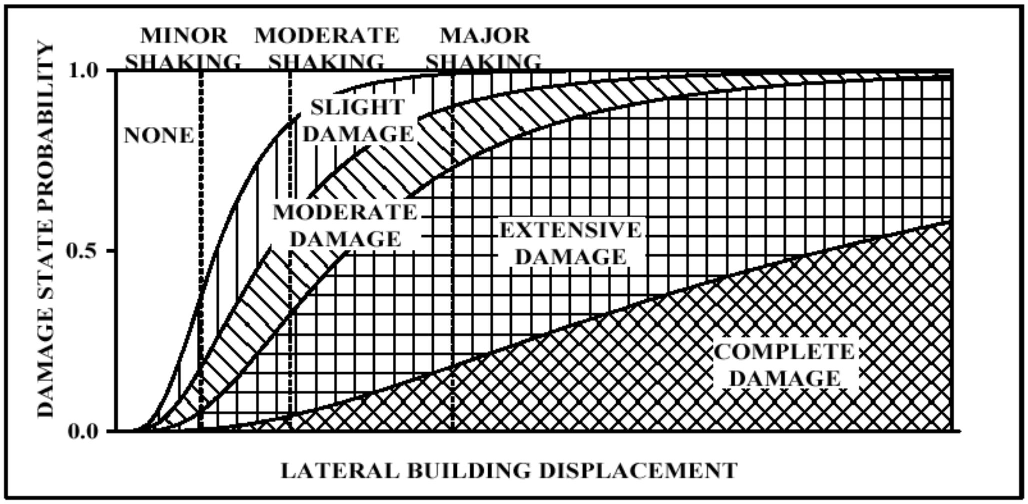


Figure 9.21 Sample building fragility curve.

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.

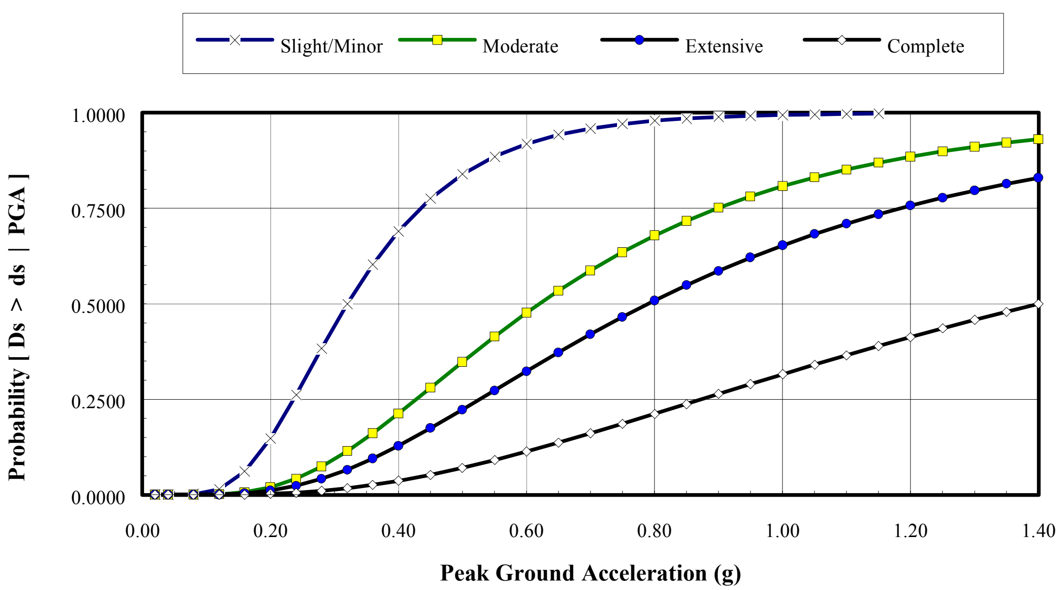


Figure 9.22 Fragility Curves at Various Damage States for Seismically Designed Railway Bridges Subject to Peak Ground Acceleration.

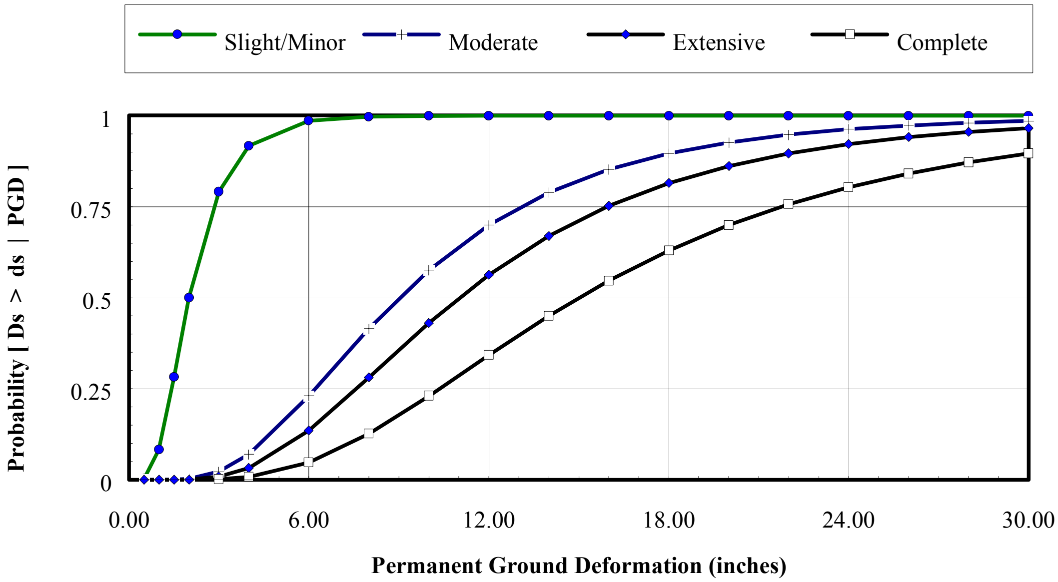
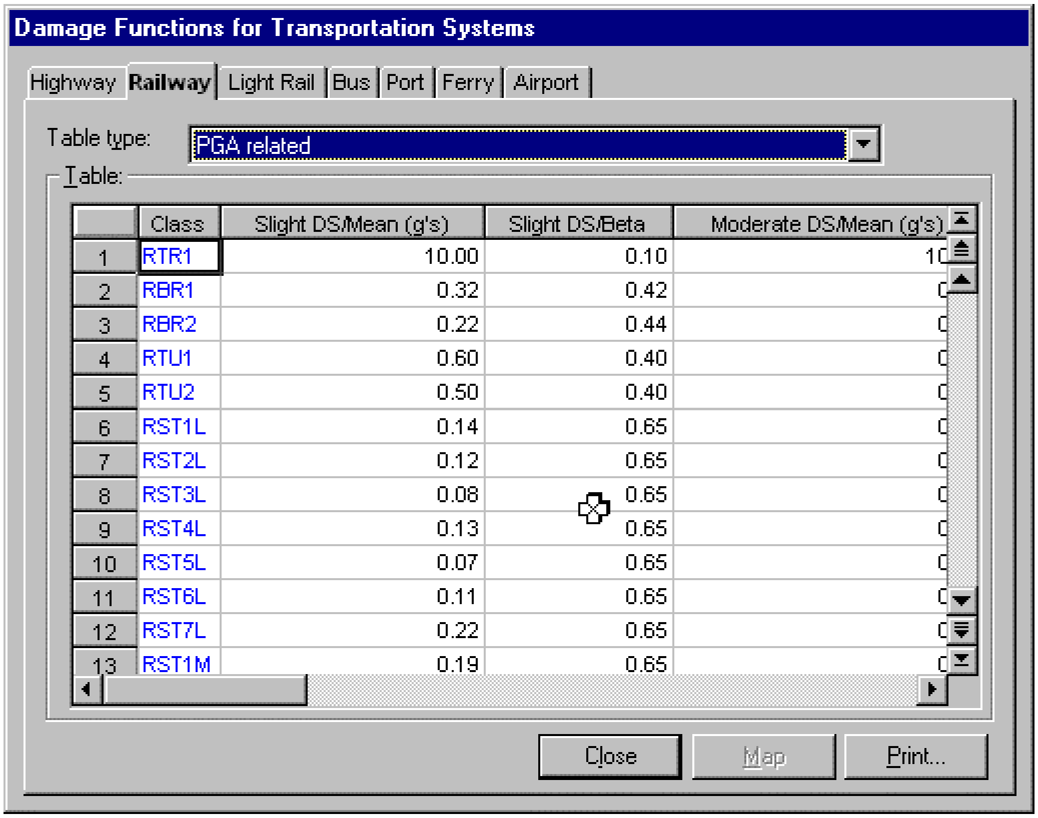


Figure 9.23 Fragility Curves at Various Damage States for Seismically Designed Railway Bridges Subject to Permanent Ground Deformation.

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	1C
2	RBR1	0.32	0.42	C
3	RBR2	0.22	0.44	C
4	RTU1	0.60	0.40	C
5	RTU2	0.50	0.40	C
6	RST1L	0.14	0.65	C
7	RST2L	0.12	0.65	C
8	RST3L	0.08	0.65	C
9	RST4L	0.13	0.65	C
10	RST5L	0.07	0.65	C
11	RST6L	0.11	0.65	C
12	RST7L	0.22	0.65	C
13	RST1M	0.19	0.65	C

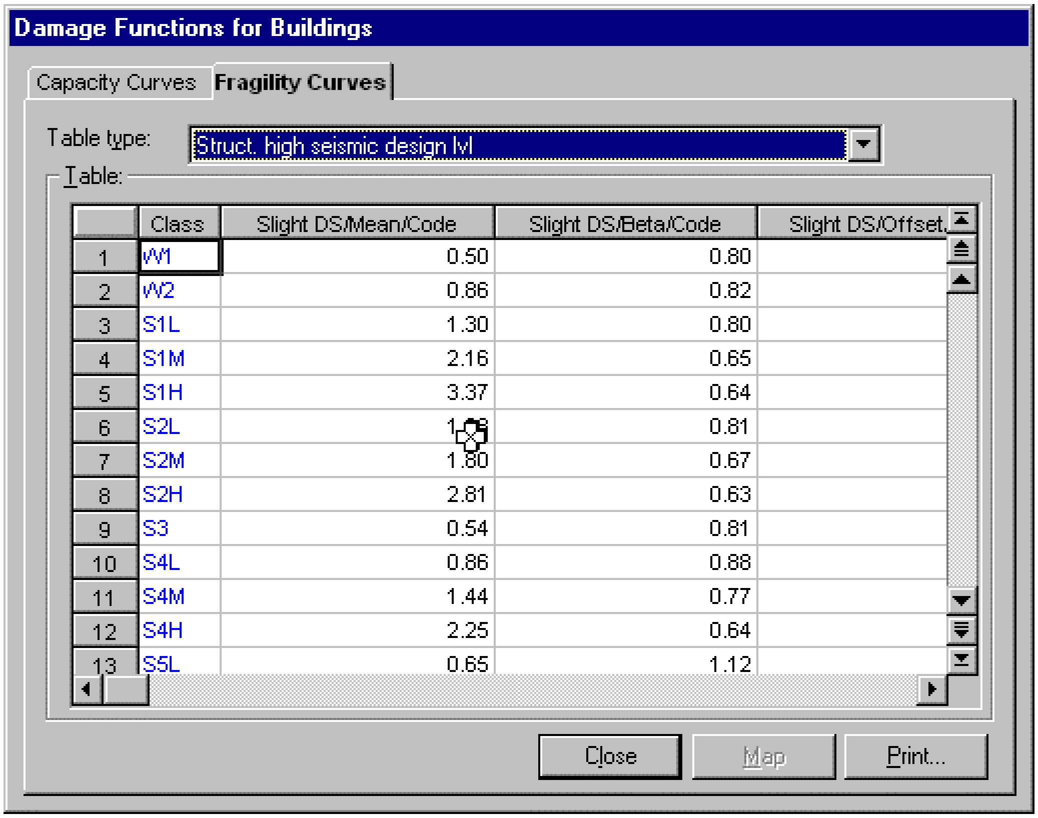
Figure 9.24 Parameters of lognormal damage functions, as viewed in HAZUS, for PGA induced damage to railway system components.

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	[illegible]	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.

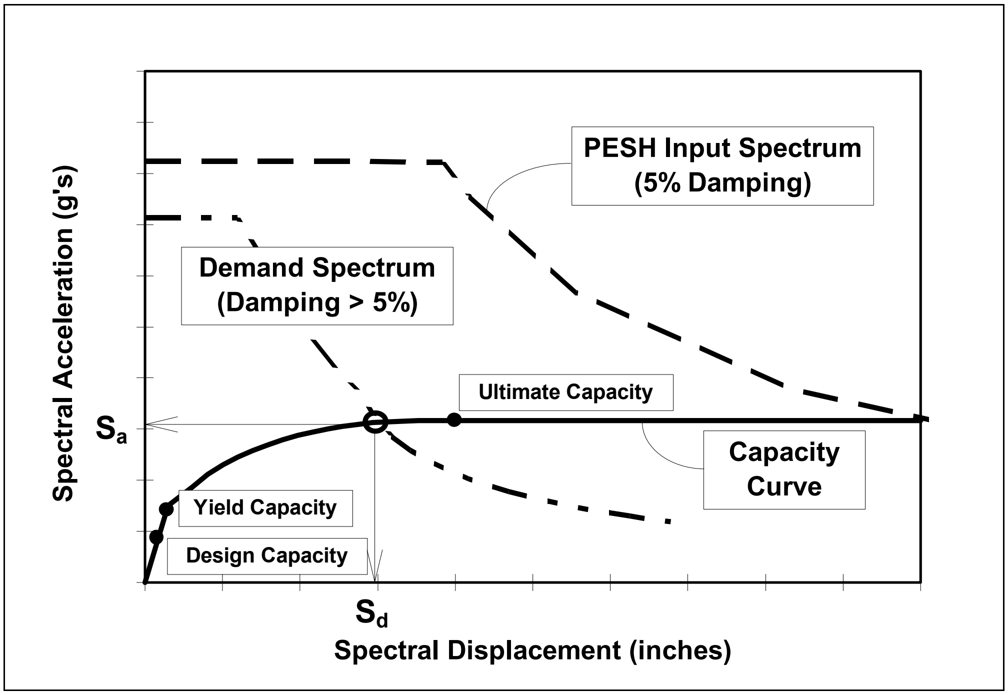
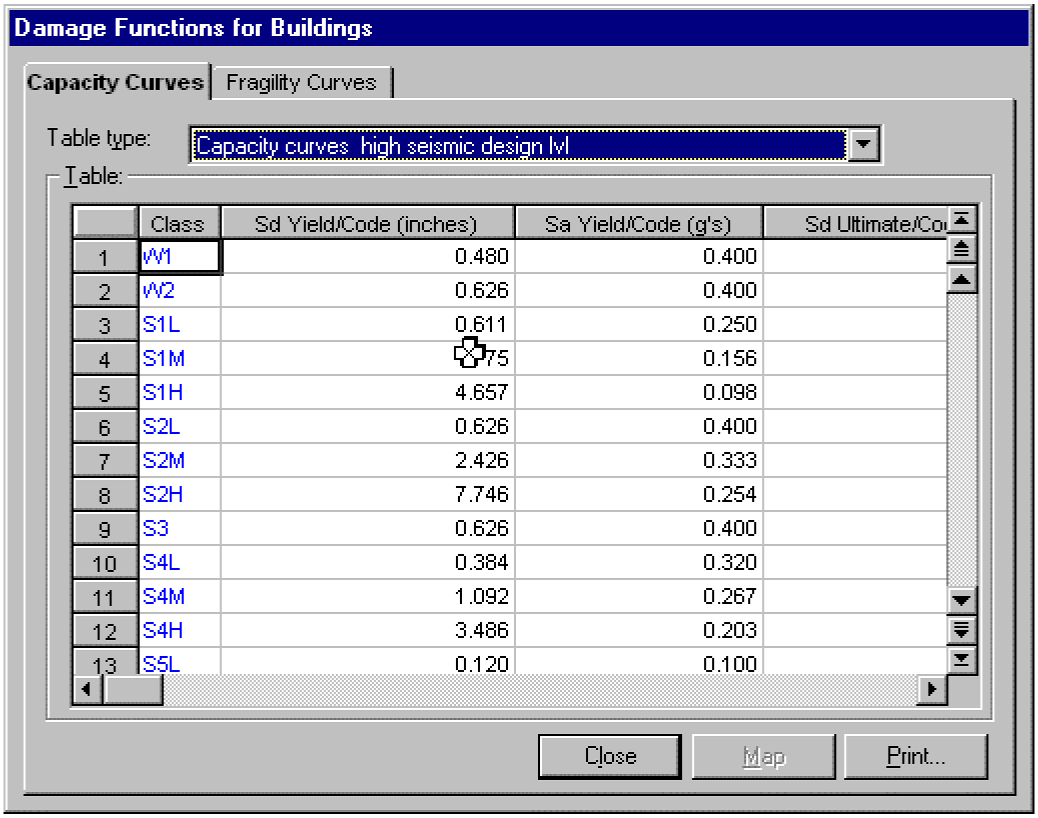


Figure 9.26 Example Capacity Curve and Spectral Demand.

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.



	Class	Sd Yield/Code (inches)	Sa Yield/Code (g's)	Sd Ultimate/Co
1	W1	0.480	0.400	
2	W2	0.626	0.400	
3	S1L	0.611	0.250	
4	S1M	[illegible]	0.156	
5	S1H	4.657	0.098	
6	S2L	0.626	0.400	
7	S2M	2.426	0.333	
8	S2H	7.746	0.254	
9	S3	0.626	0.400	
10	S4L	0.384	0.320	
11	S4M	1.092	0.267	
12	S4H	3.486	0.203	
13	S5L	0.120	0.100	

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.

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.

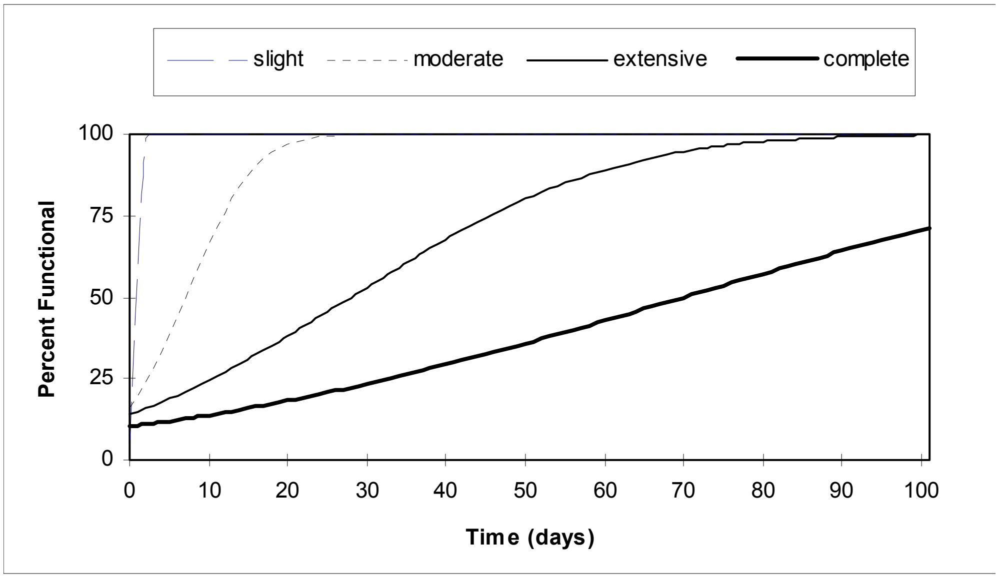


Figure 9.28 Restoration functions for a sample facility type.

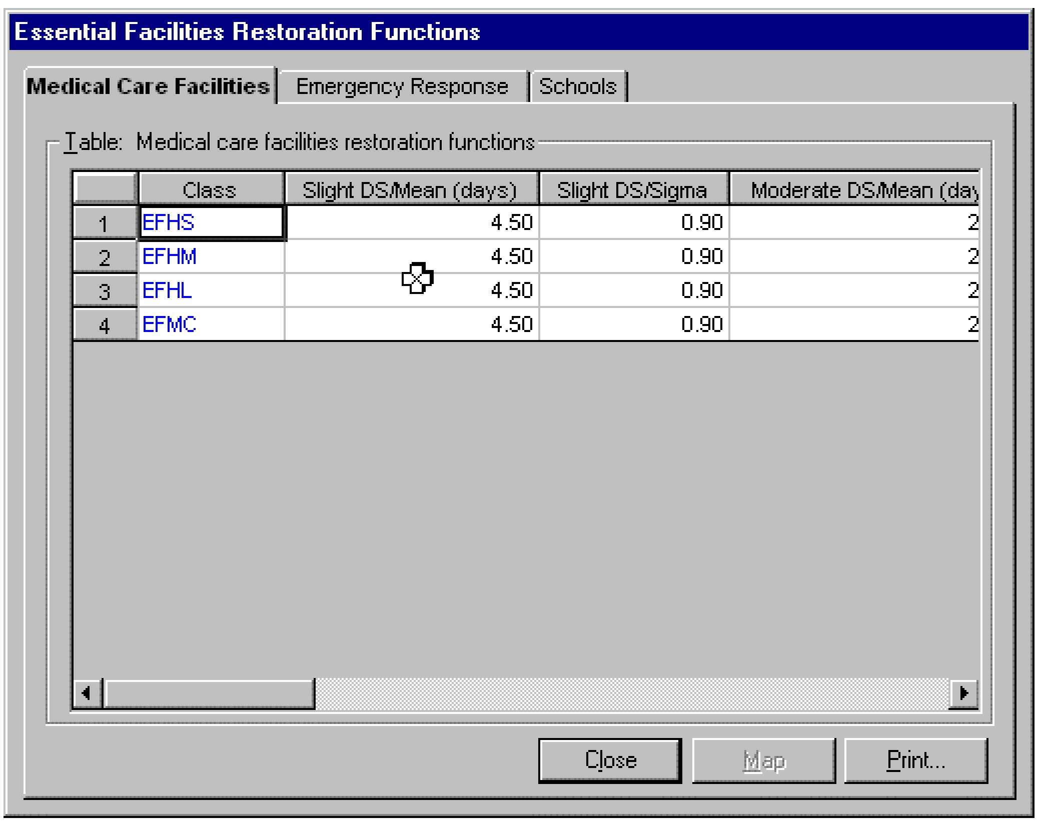


Figure 9.29 Example of window for reviewing and modifying restoration functions.

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 **HAZUS**, **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. Clicking on the **Induced physical damage** option in the window shown in Figure 9.16 will cause the following menu to appear.

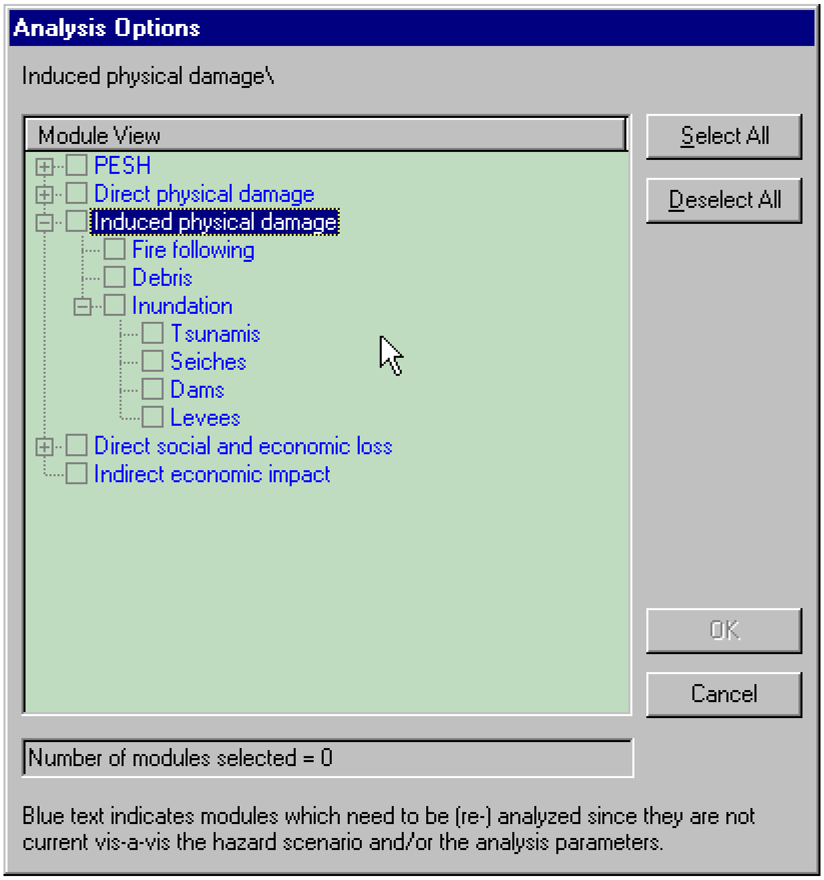


Figure 9.30 Menu for selecting Induced Physical Damage analysis options.

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.

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.

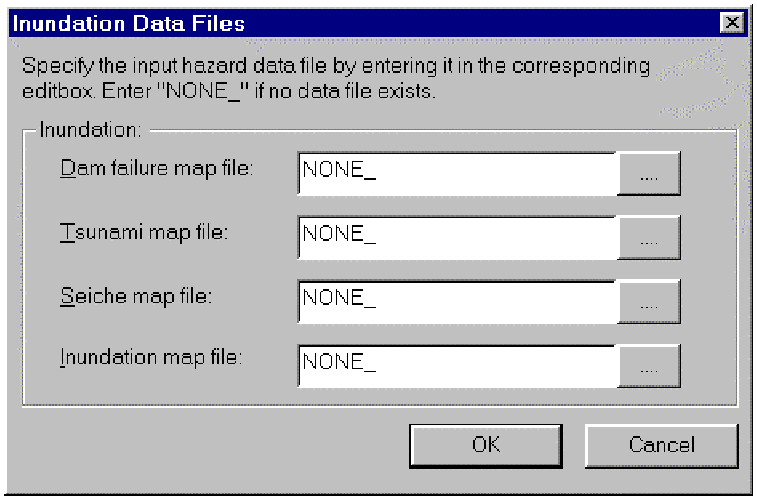


Figure 9.31 Entering inundation map files.

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, normal, 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.

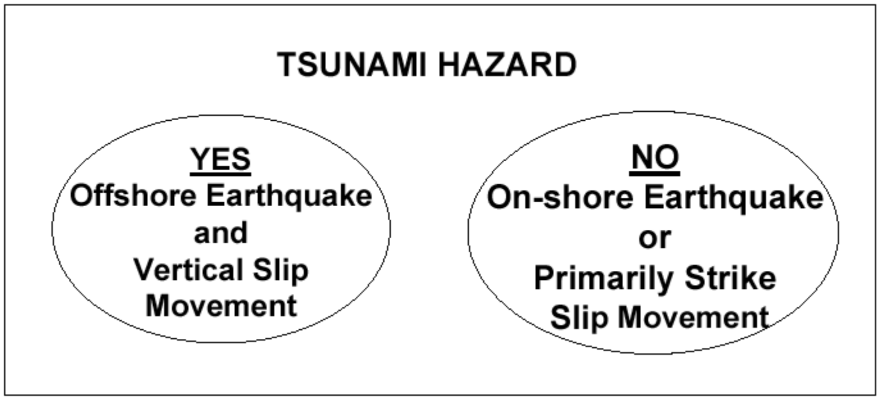


Figure 9.32 Evaluating the tsunami hazard.

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.

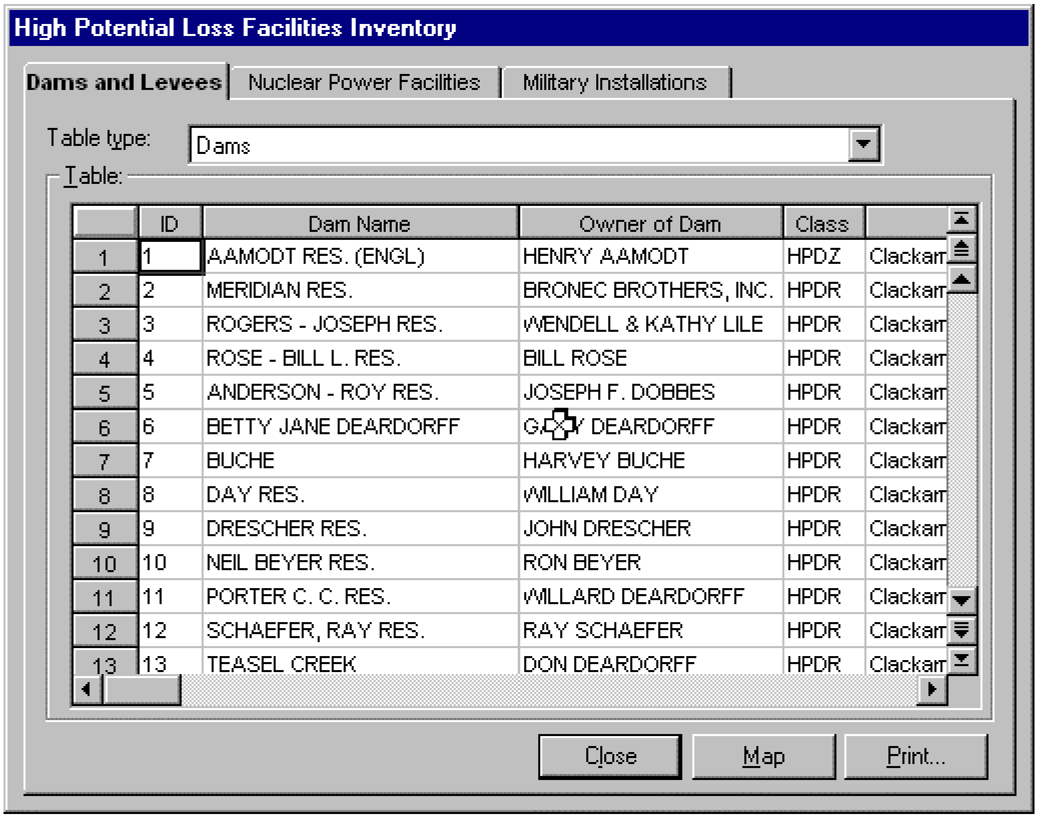


Figure 9.33 Default database of dams supplied with HAZUS.

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:

1. the lake volume must be greater than 500,000 acre-feet
2. 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 dam database, click in the dam database in the **Table of Content** to make it the active layer. Use the **Query** option found in the **HAZUS** menu bar. Once you specified the selection criteria(s), click the **New Set** button and all the dams that satisfy the selection features will be highlighted in the map. An example of a query is shown in Figure 9.34.

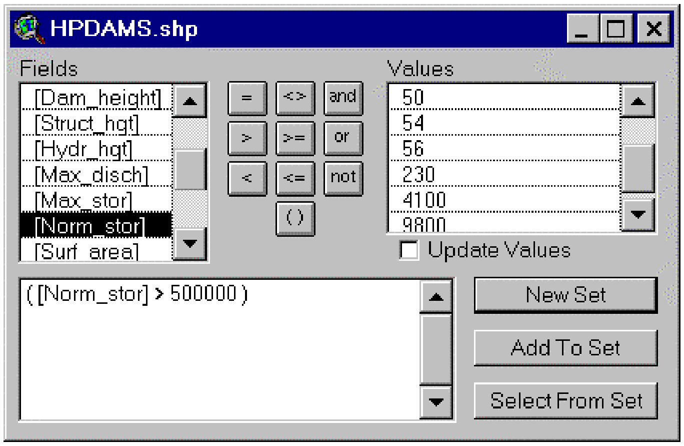


Figure 9.34 Identification of reservoirs with storage greater than 500,000 acre-feet.

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

To run the FFE module you only have to adjust the parameters shown in Figure 9.35.

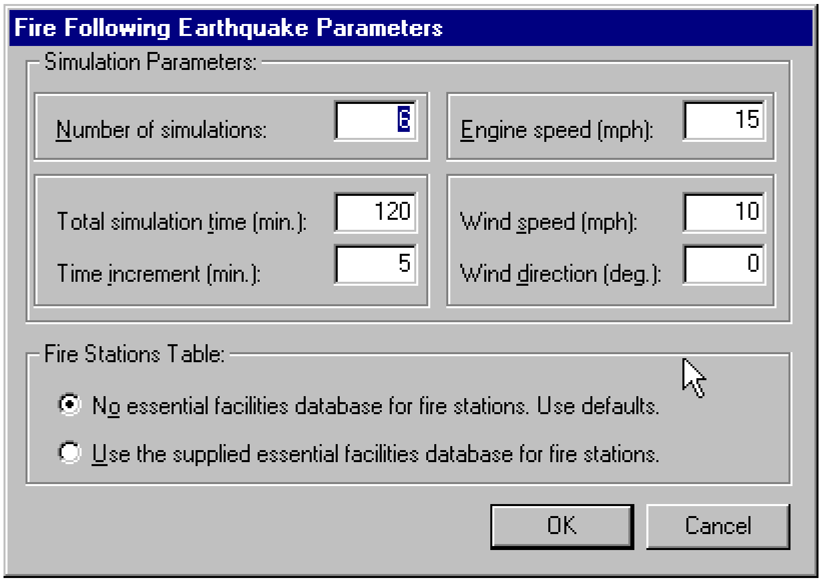


Figure 9.35 Parameter window for fire following earthquake module.

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. A default database listing the types of hazardous materials in your region and locations of sites where hazardous materials are stored can be accessed by using the **Inventory|Hazardous Materials** menu. 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).

9.5.5 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 spell 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.

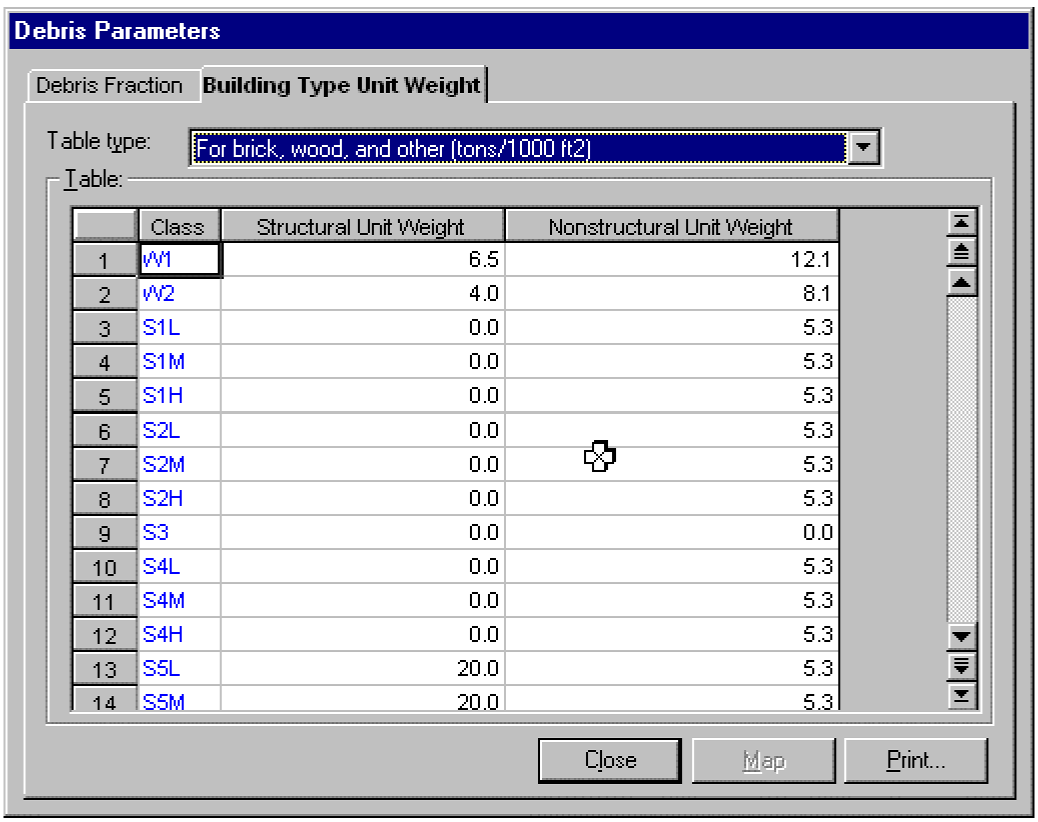
While estimates of debris could include debris due to collapsed bridges and overpasses as well as debris due to buildings, **HAZUS** ignores debris generated from collapsed bridges. Due to the simplifications that are introduced in the modeling of transportation systems, and in particular the lack of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

9.5.5.1 Debris Parameters

The debris module will provide 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 module. 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

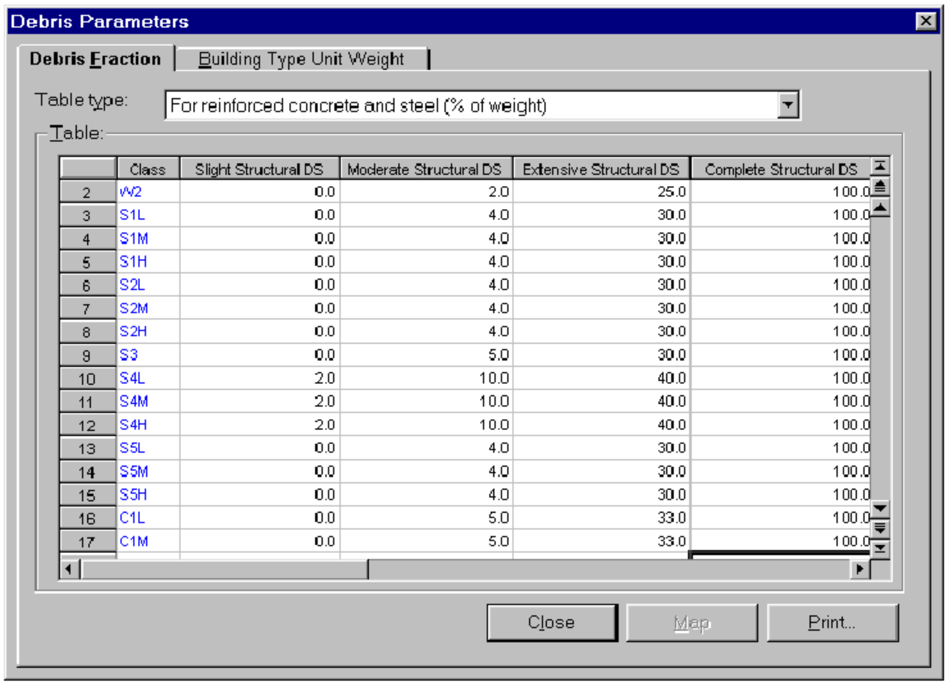
Estimates of debris can be generated using the default data supplied with **HAZUS**. Figure 9.36 shows the default values of debris weight for each model building type. Clicking on the Analysis|Parameters|Debris menu accesses this window. For each model building type there are two unit weight tables. 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.

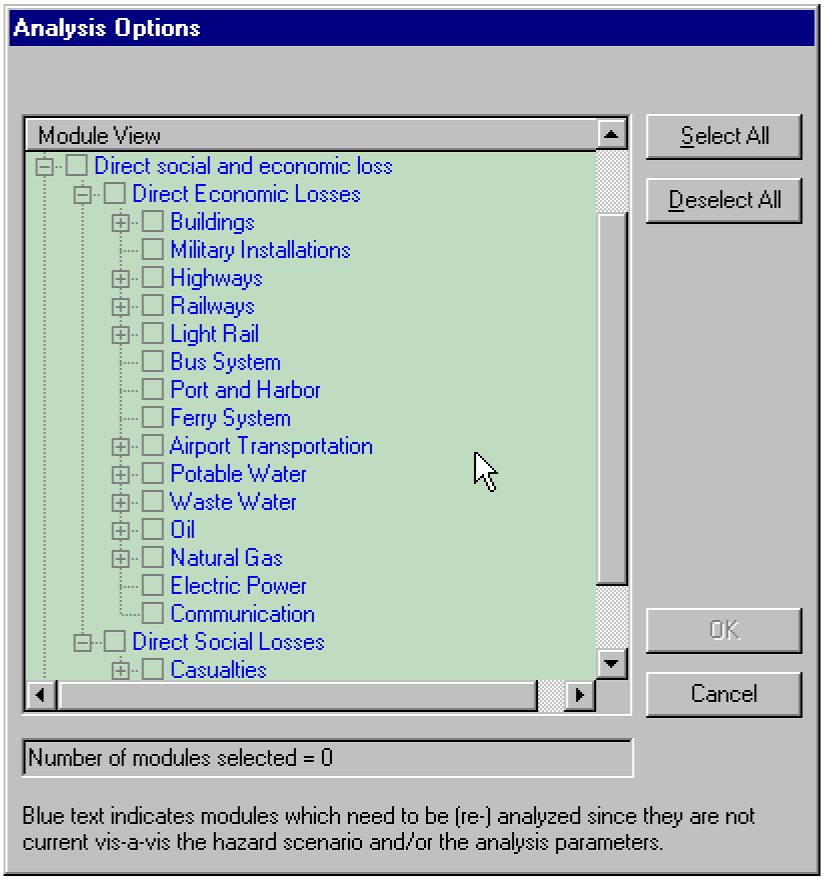


Figure 9.38 Window for selecting Direct Social and Economic Loss analysis options.

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. These social and economic analyses can only be run if the **direct physical damage** module is either run simultaneously, or if it has previously been run.

2.1.1 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)
- Education casualties (Severity 1, 2, 3 and 4)
- Hotel 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
- 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.

2..1.1.1 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 are a result 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.

2..1.1.2 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 = 1 in 2,000

Number of people in the study region who were in slightly damaged URML buildings = 50,000

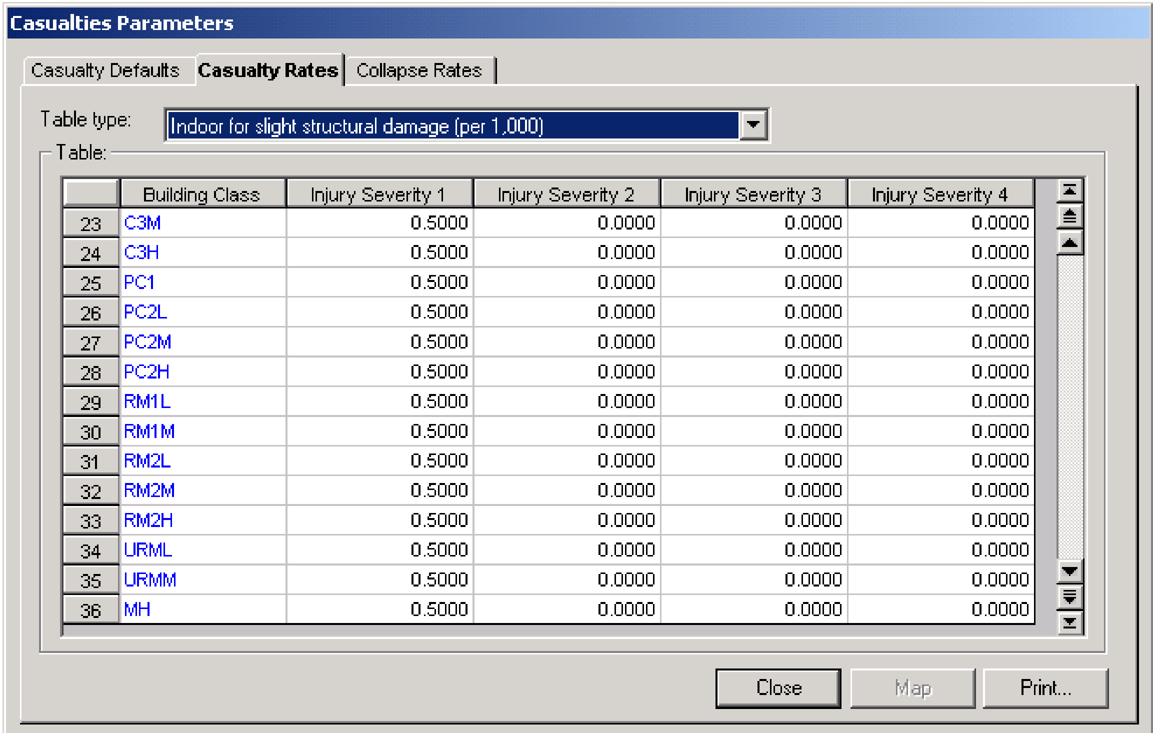
Severity 1 casualties = 50,000∗1/2,000 = 25 people

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.

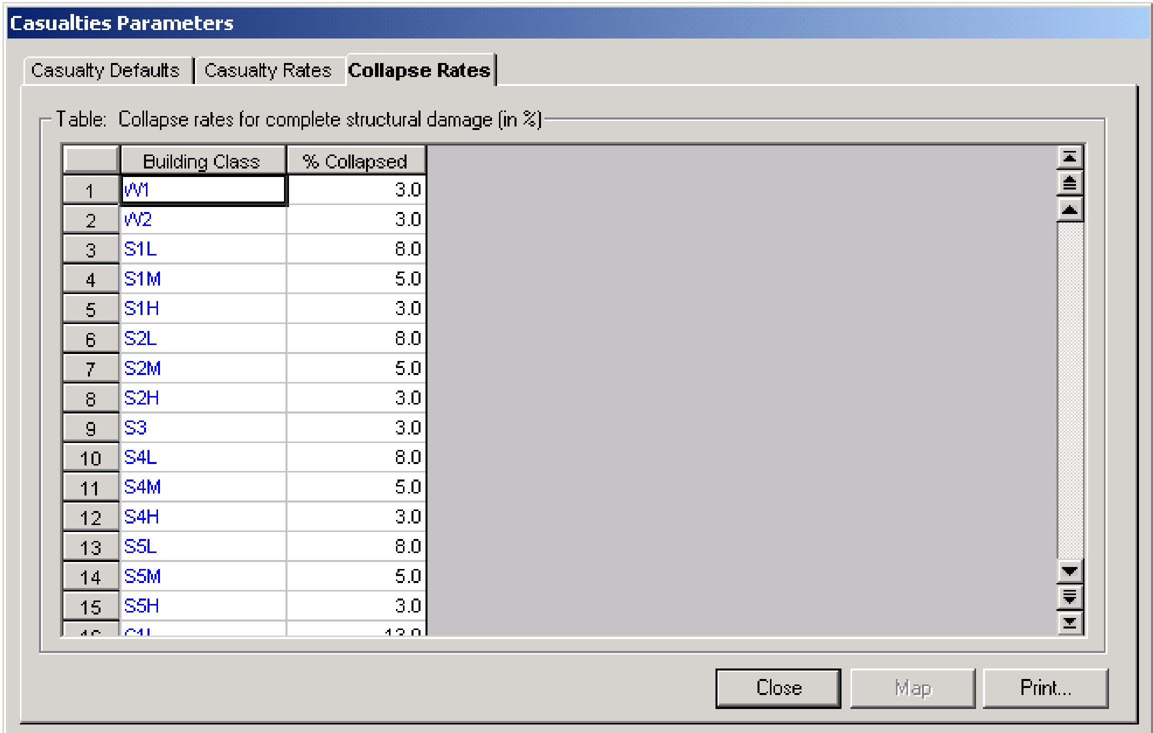


	Building Class	Injury Severity 1	Injury Severity 2	Injury Severity 3	Injury Severity 4
23	C3M	0.5000	0.0000	0.0000	0.0000
24	C3H	0.5000	0.0000	0.0000	0.0000
25	PC1	0.5000	0.0000	0.0000	0.0000
26	PC2L	0.5000	0.0000	0.0000	0.0000
27	PC2M	0.5000	0.0000	0.0000	0.0000
28	PC2H	0.5000	0.0000	0.0000	0.0000
29	RM1L	0.5000	0.0000	0.0000	0.0000
30	RM1M	0.5000	0.0000	0.0000	0.0000
31	RM2L	0.5000	0.0000	0.0000	0.0000
32	RM2M	0.5000	0.0000	0.0000	0.0000
33	RM2H	0.5000	0.0000	0.0000	0.0000
34	URML	0.5000	0.0000	0.0000	0.0000
35	URMM	0.5000	0.0000	0.0000	0.0000
36	MH	0.5000	0.0000	0.0000	0.0000

Figure 9.39 Casualty rates in number of casualties per 1,000 occupants by model building type for the slight structural damage state (indoors).

2..1.1.3 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.



	Building Class	% Collapsed
1	W1	3.0
2	W2	3.0
3	S1L	8.0
4	S1M	5.0
5	S1H	3.0
6	S2L	8.0
7	S2M	5.0
8	S2H	3.0
9	S3	3.0
10	S4L	8.0
11	S4M	5.0
12	S4H	3.0
13	S5L	8.0
14	S5M	5.0
15	S5H	3.0

Figure 9.40 Collapse rates for buildings as displayed in HAZUS.

2..1.1.4 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 estimate the commuters on or under bridges when an earthquake occurs. 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.

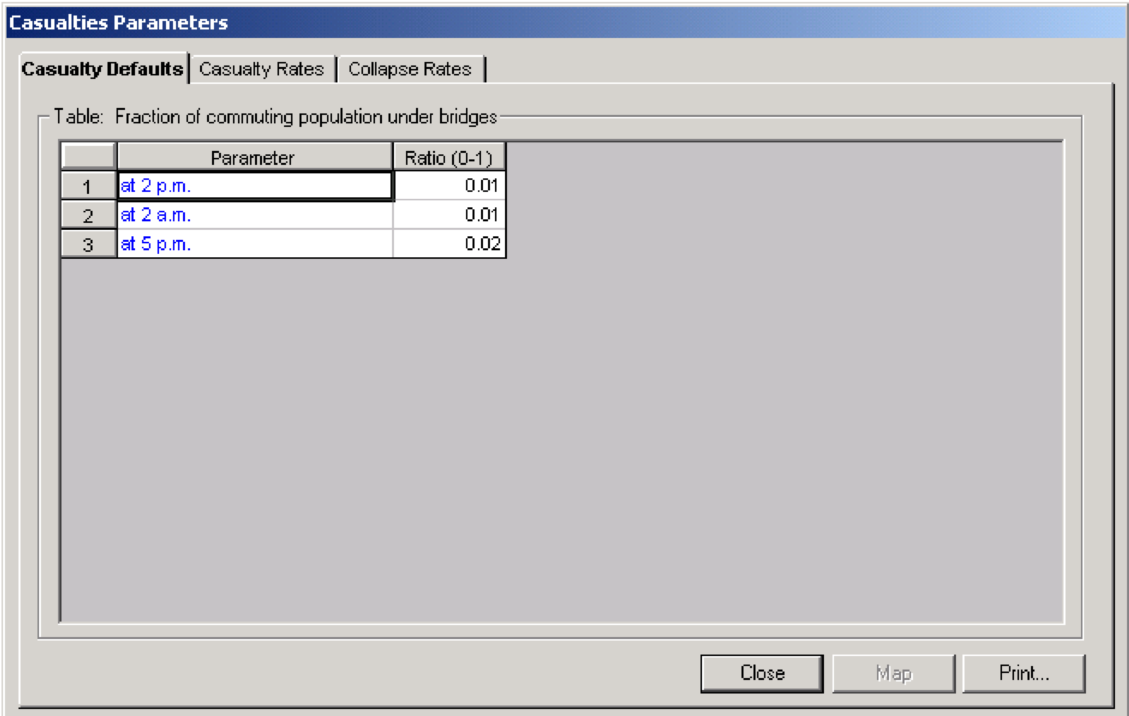


Figure 9.41 Commuter Distribution Factors for three times of day.

2.1.2 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. 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.

9.6.1.1 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.

9.6.1.1.1 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*.

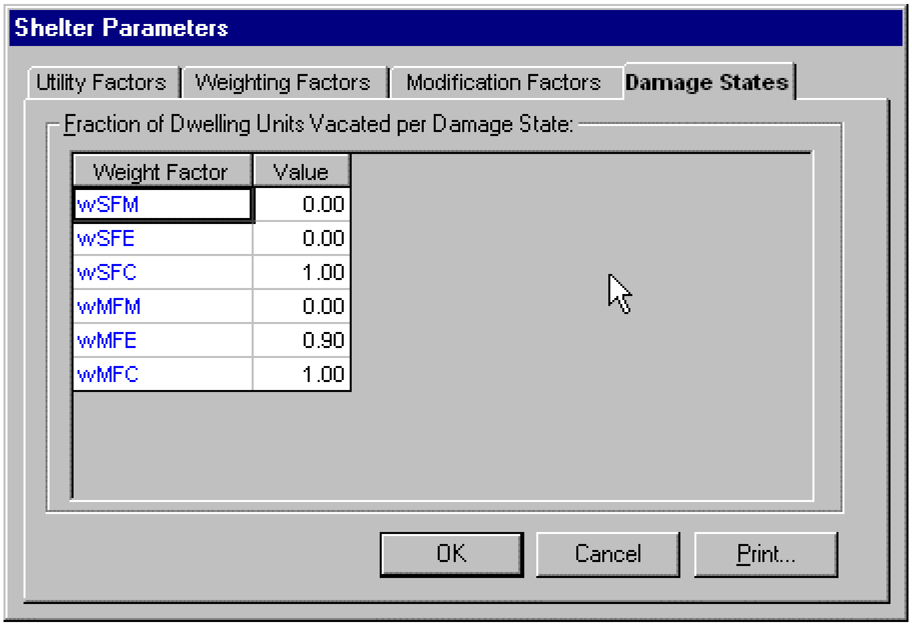


Figure 9.42 Default values for the fraction of dwelling units likely to be vacated if damaged.

9.6.1.1.2 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.

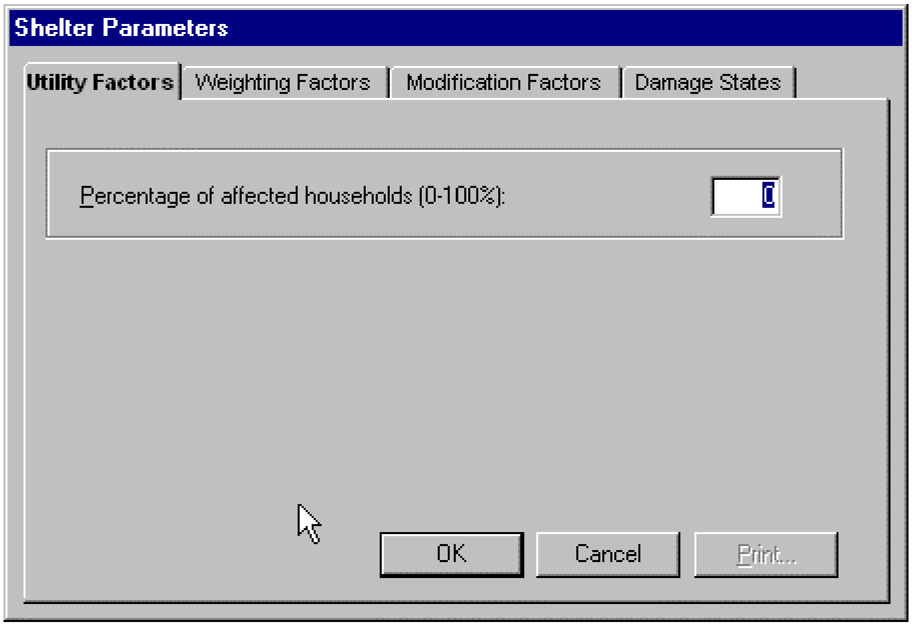


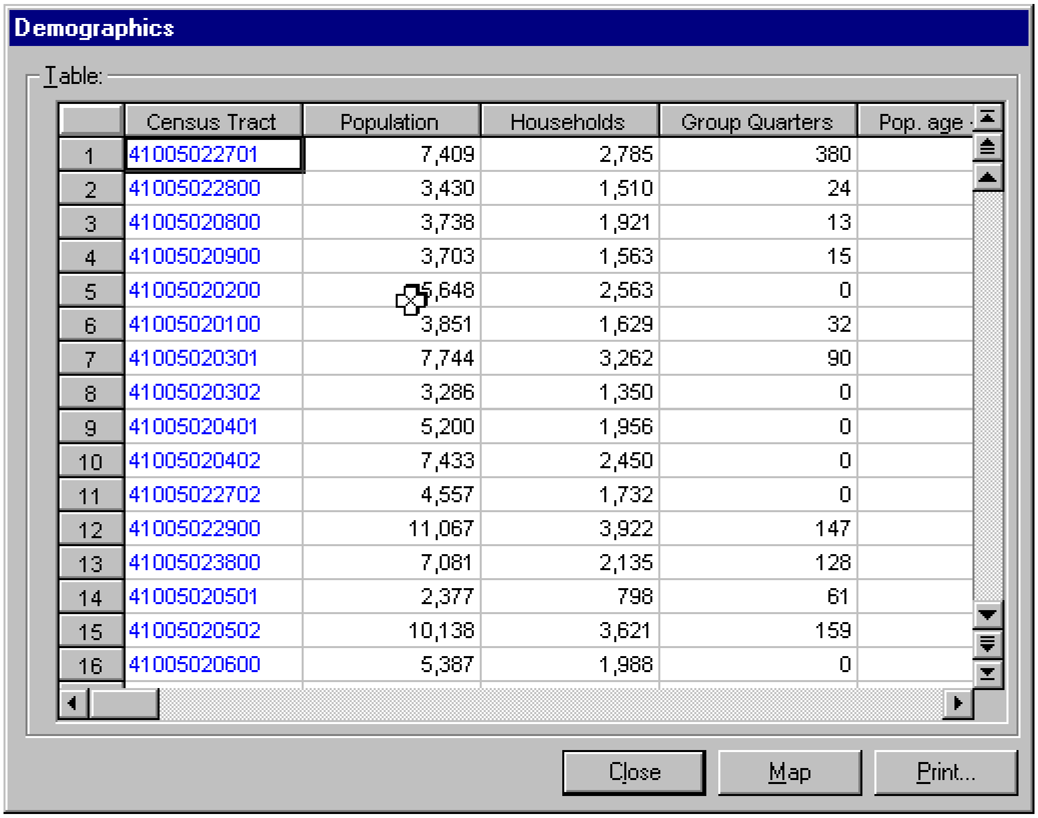
Figure 9.43 Utility factors in the shelter parameters window.

2..1.2.1 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 accomplished this. Note that to see this column you would need to click on the right arrow at the bottom of Figure 9.44.



Demographics

Table:

	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	

Close | Map | Print...

Figure 9.44 Demographic data supplied in HAZUS.

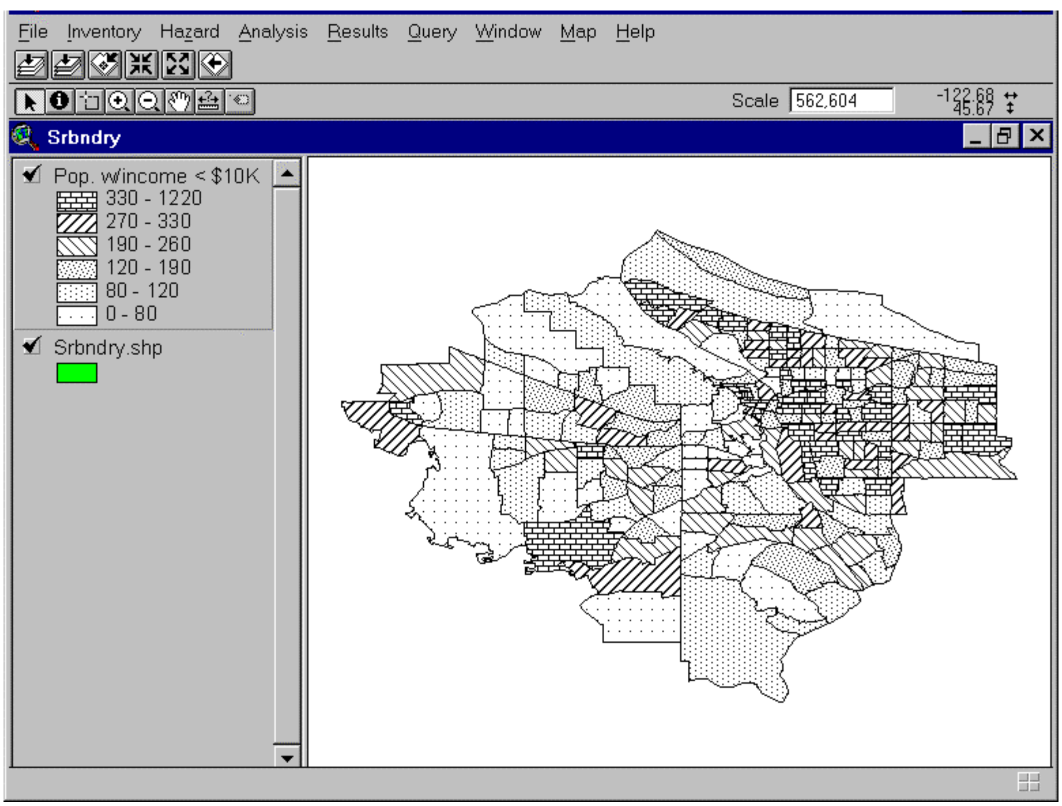


Figure 9.45 Map of households with incomes less than $10,000

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.

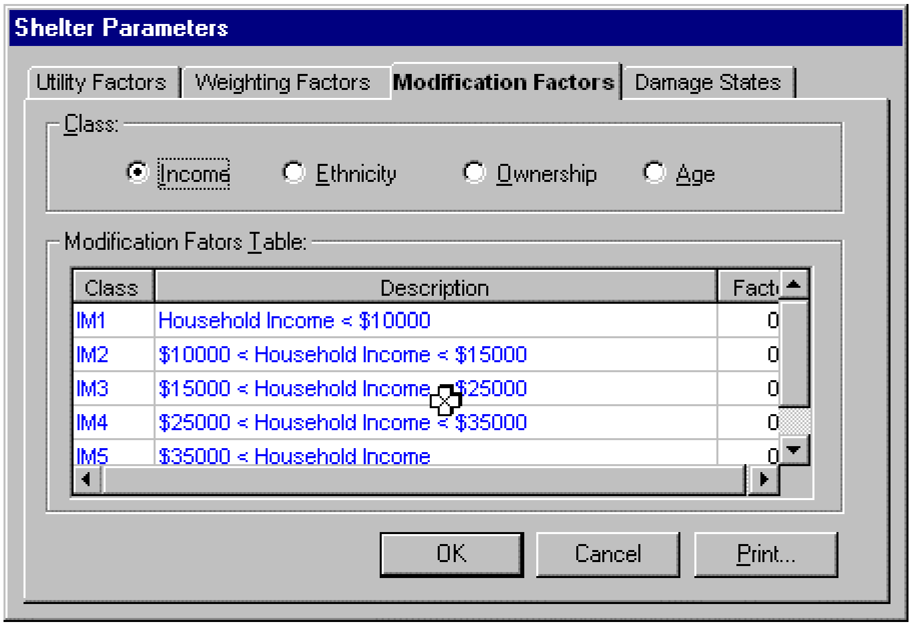


Figure 9.46 Fraction of households likely to seek public shelter as a function of household income.

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.

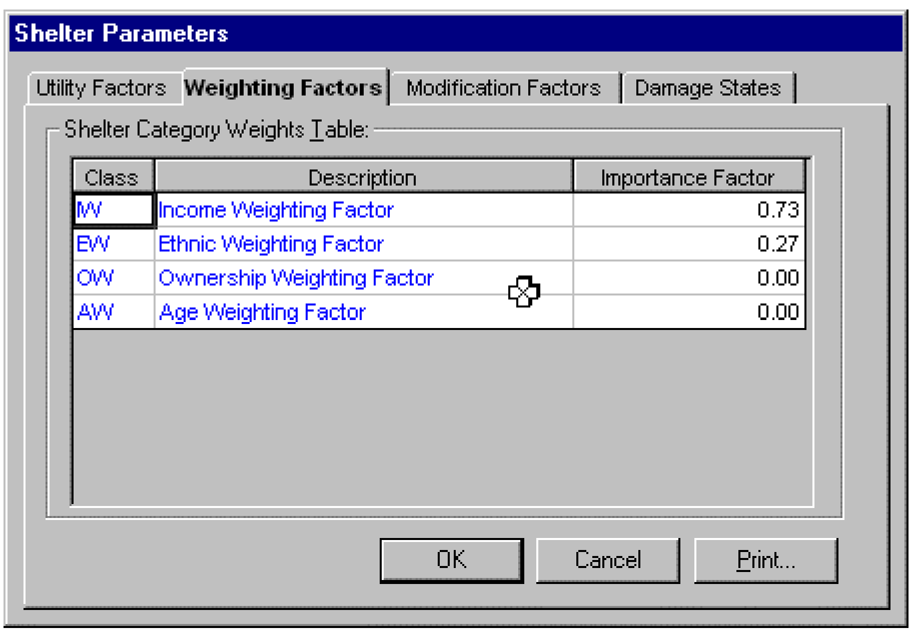


Figure 9.47 Importance Factors for determining shelter needs.

2.1.3 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 are impacts such as:

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, for example in the choice of or need for shelter, and require the deployment of large-scale psychological and counseling services. Some of these effects may be of long duration, and may affect children's behavior and adult family and work efficiency.

- 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 affect 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 such effects on the community or region under study, it is recommended that they begin by consulting 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.

2..1.3.1 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 consequential 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 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.

2..1.3.2 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. You will want to review the default data very carefully and modify the data to best represent the characteristics of your 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.

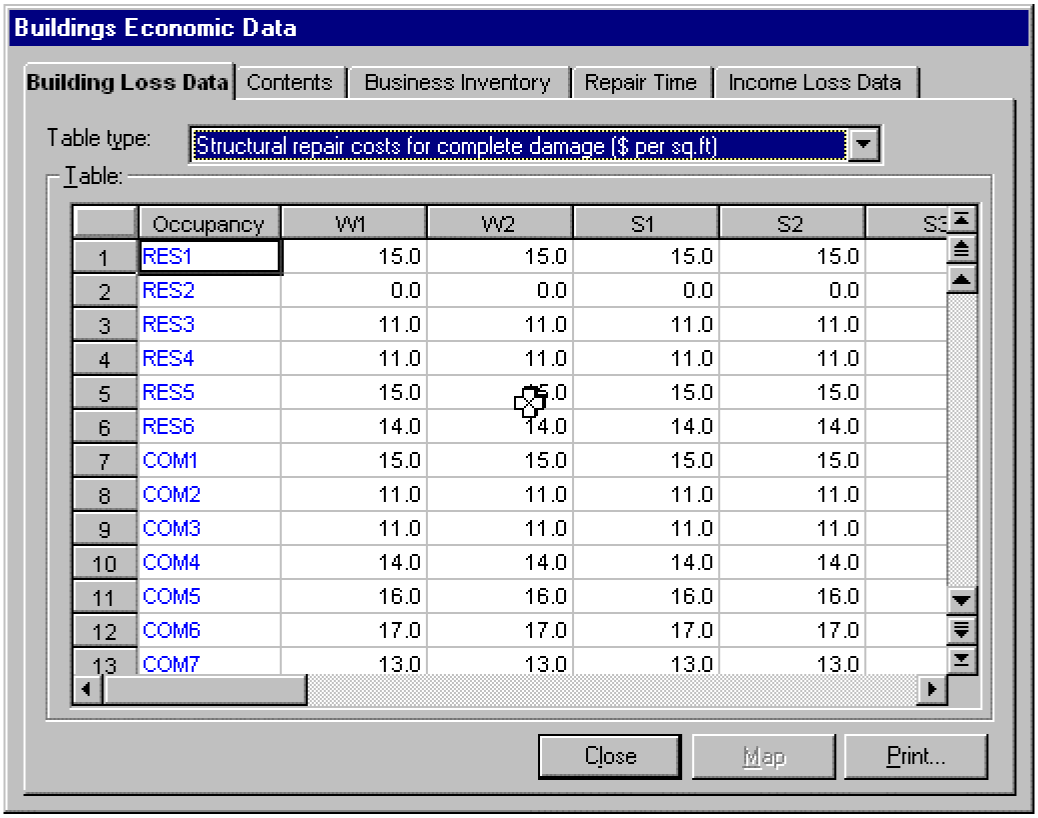


Figure 9.48 Economic data for estimating building repair costs, contents and business inventory losses, lost income and relocation costs.

9.6.1.1.3 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 <u>only be used to represent costs of large aggregations</u> 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 <u>building specific</u> cost estimates should be used.

9.6.1.1.4 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.

9.6.1.1.5 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.

9.6.1.1.6 Building Cleanup and Repair Time:

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

9.6.1.1.7 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 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.

9.6.1.1.8 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.

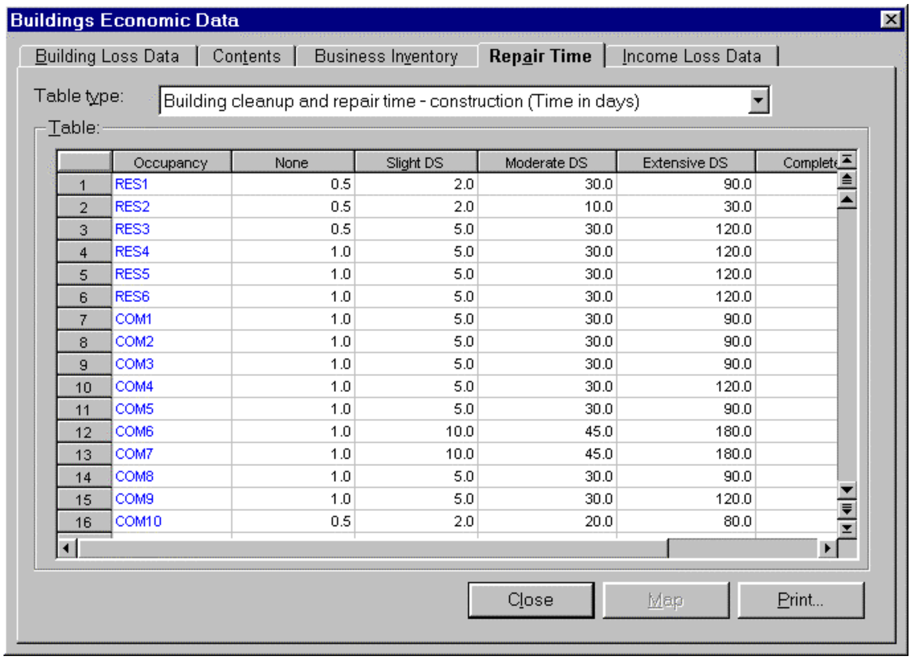
2..1.3.3 Repair and Clean-up Times

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

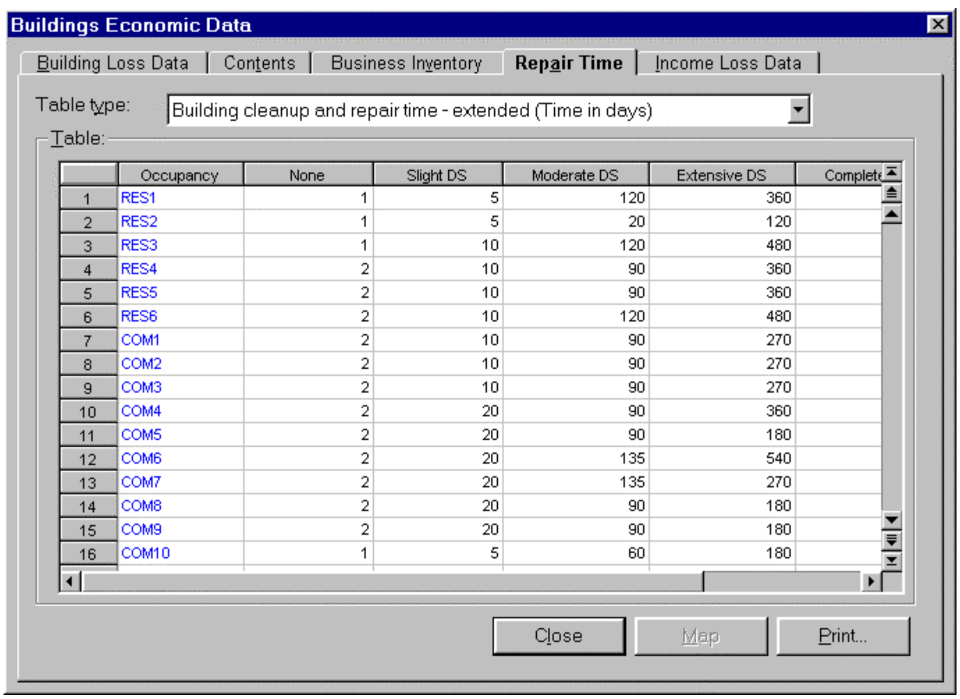
Default building repair and clean-up times are provided with **HAZUS**. These default values are broken into two parts: construction time and extended time. The construction time is the time to do the actual construction or repair. The extended time includes construction plus all of the additional delays 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	Complete
1	RES1	0.5	2.0	30.0	90.0	
2	RES2	0.5	2.0	10.0	30.0	
3	RES3	0.5	5.0	30.0	120.0	
4	RES4	1.0	5.0	30.0	120.0	
5	RES5	1.0	5.0	30.0	120.0	
6	RES6	1.0	5.0	30.0	120.0	
7	COM1	1.0	5.0	30.0	90.0	
8	COM2	1.0	5.0	30.0	90.0	
9	COM3	1.0	5.0	30.0	90.0	
10	COM4	1.0	5.0	30.0	120.0	
11	COM5	1.0	5.0	30.0	90.0	
12	COM6	1.0	10.0	45.0	180.0	
13	COM7	1.0	10.0	45.0	180.0	
14	COM8	1.0	5.0	30.0	90.0	
15	COM9	1.0	5.0	30.0	120.0	
16	COM10	0.5	2.0	20.0	80.0	

Figure 9.49 Default building cleanup and repair times.

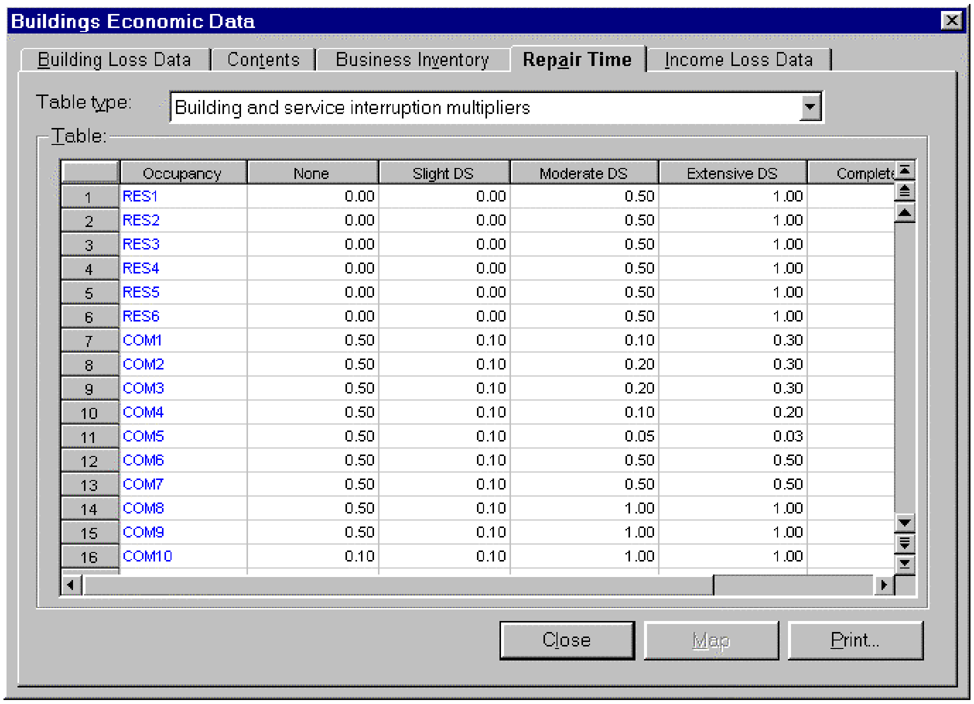


	Occupancy	None	Slight DS	Moderate DS	Extensive DS	Complete
1	RES1	1	5	120	360	
2	RES2	1	5	20	120	
3	RES3	1	10	120	480	
4	RES4	2	10	90	360	
5	RES5	2	10	90	360	
6	RES6	2	10	120	480	
7	COM1	2	10	90	270	
8	COM2	2	10	90	270	
9	COM3	2	10	90	270	
10	COM4	2	20	90	360	
11	COM5	2	20	90	180	
12	COM6	2	20	135	540	
13	COM7	2	20	135	270	
14	COM8	2	20	90	180	
15	COM9	2	20	90	180	
16	COM10	1	5	60	180	

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.



	Occupancy	None	Slight DS	Moderate DS	Extensive DS	Complete
1	RES1	0.00	0.00	0.50	1.00	
2	RES2	0.00	0.00	0.50	1.00	
3	RES3	0.00	0.00	0.50	1.00	
4	RES4	0.00	0.00	0.50	1.00	
5	RES5	0.00	0.00	0.50	1.00	
6	RES6	0.00	0.00	0.50	1.00	
7	COM1	0.50	0.10	0.10	0.30	
8	COM2	0.50	0.10	0.20	0.30	
9	COM3	0.50	0.10	0.20	0.30	
10	COM4	0.50	0.10	0.10	0.20	
11	COM5	0.50	0.10	0.05	0.03	
12	COM6	0.50	0.10	0.50	0.50	
13	COM7	0.50	0.10	0.50	0.50	
14	COM8	0.50	0.10	1.00	1.00	
15	COM9	0.50	0.10	1.00	1.00	
16	COM10	0.10	0.10	1.00	1.00	

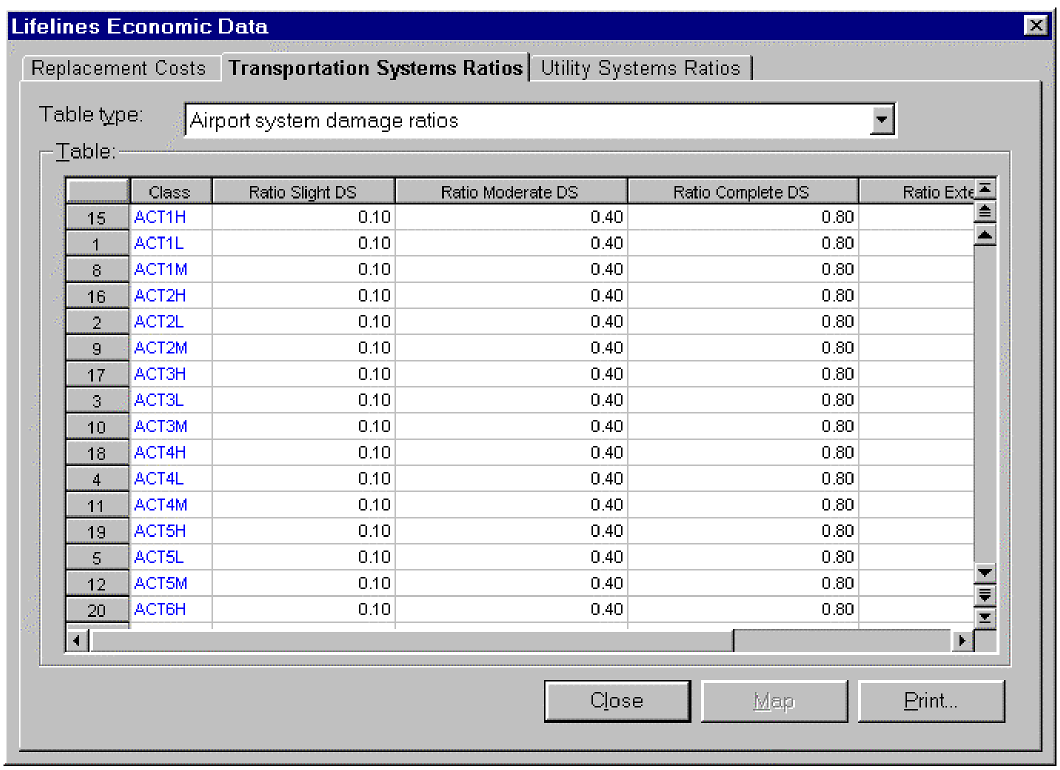
Figure 9.51 Default building and service interruption time multipliers.

Application of the interruption multipliers to the extended building clean 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.

2..1.3.4 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	Ratio Exte
15	ACT1H	0.10	0.40	0.80	
1	ACT1L	0.10	0.40	0.80	
8	ACT1M	0.10	0.40	0.80	
16	ACT2H	0.10	0.40	0.80	
2	ACT2L	0.10	0.40	0.80	
9	ACT2M	0.10	0.40	0.80	
17	ACT3H	0.10	0.40	0.80	
3	ACT3L	0.10	0.40	0.80	
10	ACT3M	0.10	0.40	0.80	
18	ACT4H	0.10	0.40	0.80	
4	ACT4L	0.10	0.40	0.80	
11	ACT4M	0.10	0.40	0.80	
19	ACT5H	0.10	0.40	0.80	
5	ACT5L	0.10	0.40	0.80	
12	ACT5M	0.10	0.40	0.80	
20	ACT6H	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.

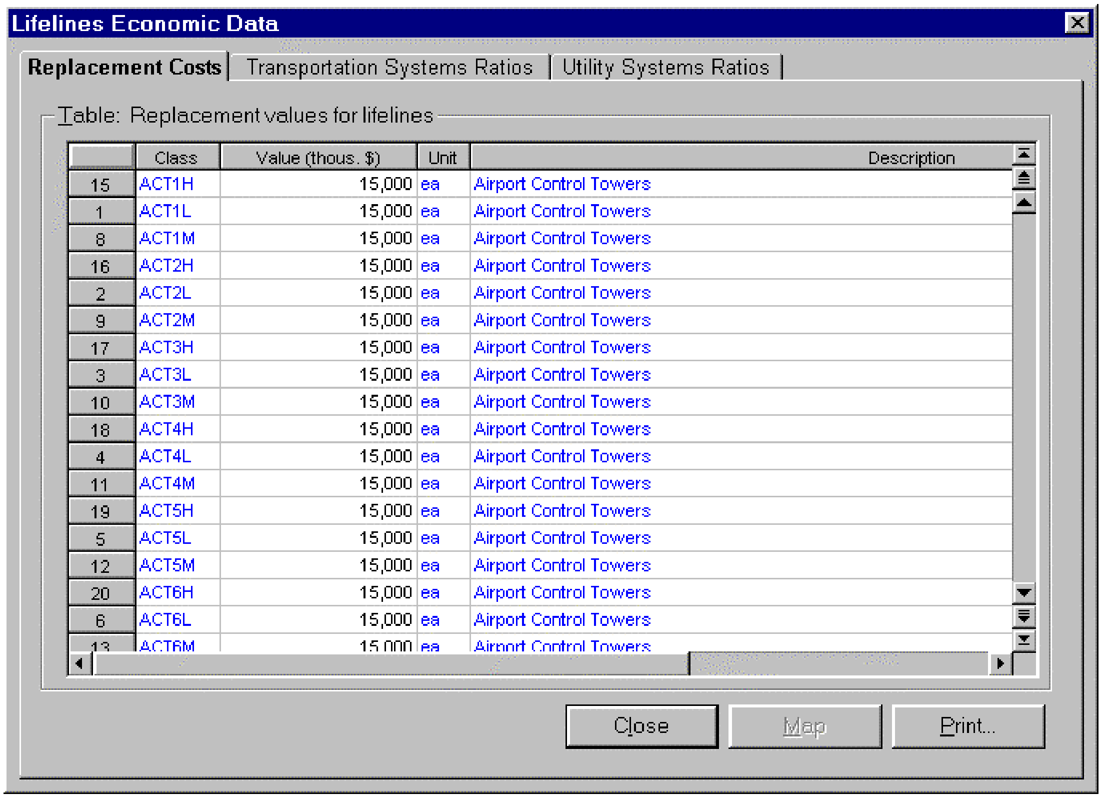


Figure 9.53 Default replacement costs for lifeline components.

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 their 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).

2.1.4 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.

2.1.5 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 access the 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*.

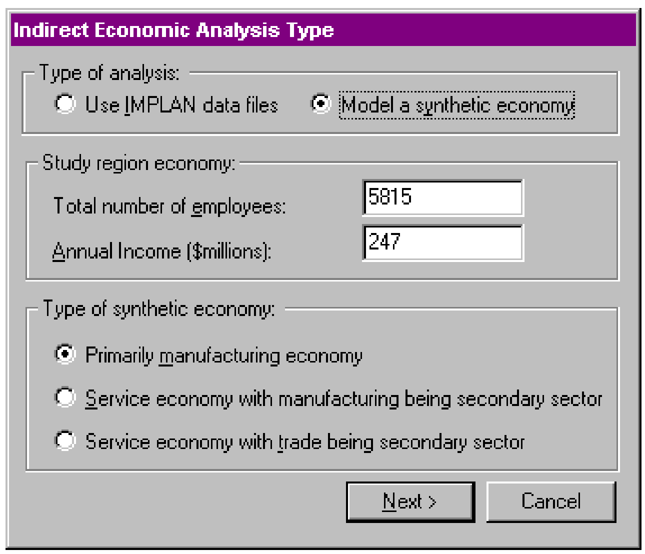
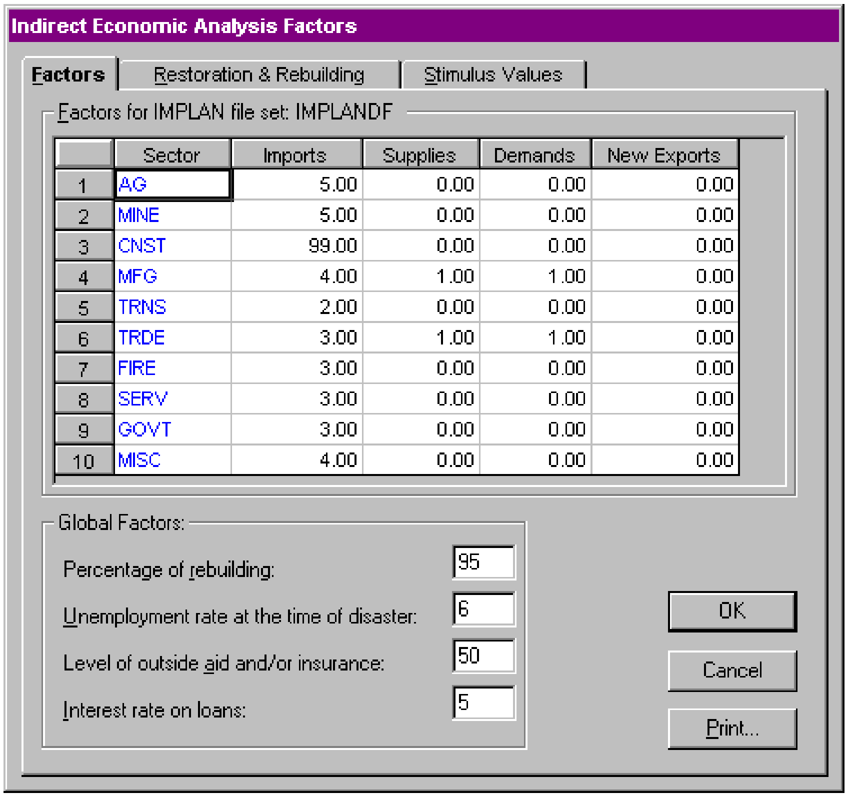


Figure 9.54 Setting parameters for synthetic economy.

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 **Next>** button in Figure 9.54, the window in Figure 9.55 will appear. Figures 9.55 through 9.57 allow you to modify economic factors that relate to the general capacity and the economy's ability to restore itself following the earthquake. 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



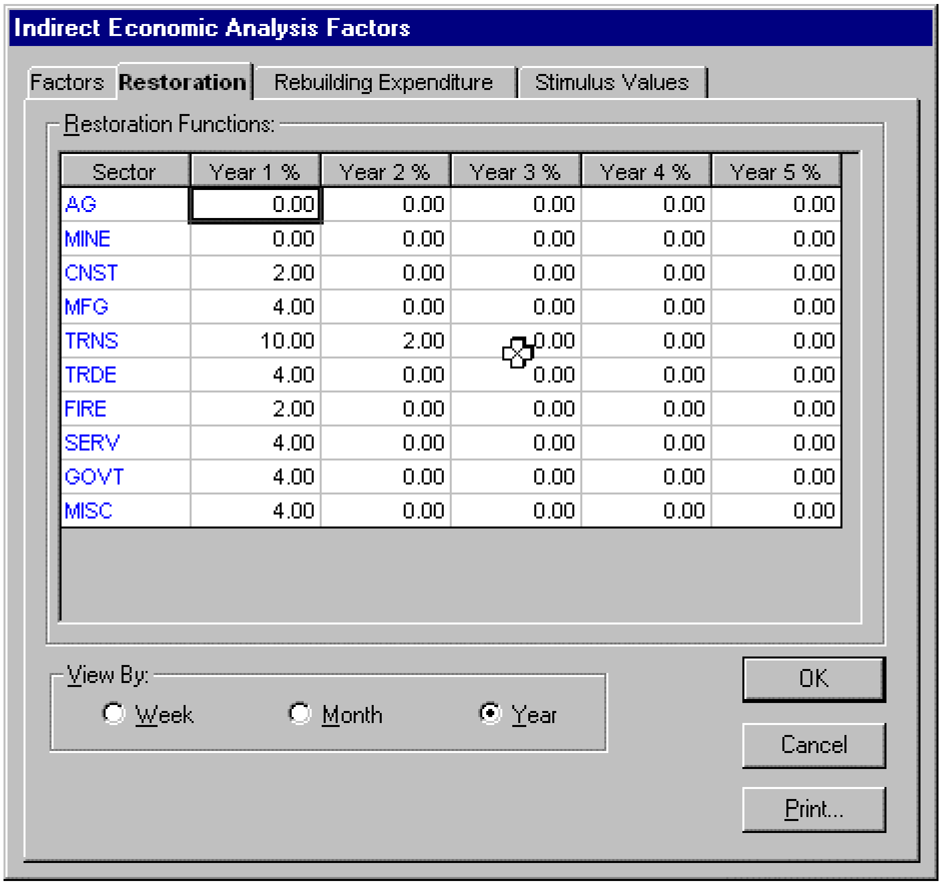
	Sector	Imports	Supplies	Demands	New Exports
1	AG	5.00	0.00	0.00	0.00
2	MINE	5.00	0.00	0.00	0.00
3	CNST	99.00	0.00	0.00	0.00
4	MFG	4.00	1.00	1.00	0.00
5	TRNS	2.00	0.00	0.00	0.00
6	TRDE	3.00	1.00	1.00	0.00
7	FIRE	3.00	0.00	0.00	0.00
8	SERV	3.00	0.00	0.00	0.00
9	GOVT	3.00	0.00	0.00	0.00
10	MISC	4.00	0.00	0.00	0.00

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

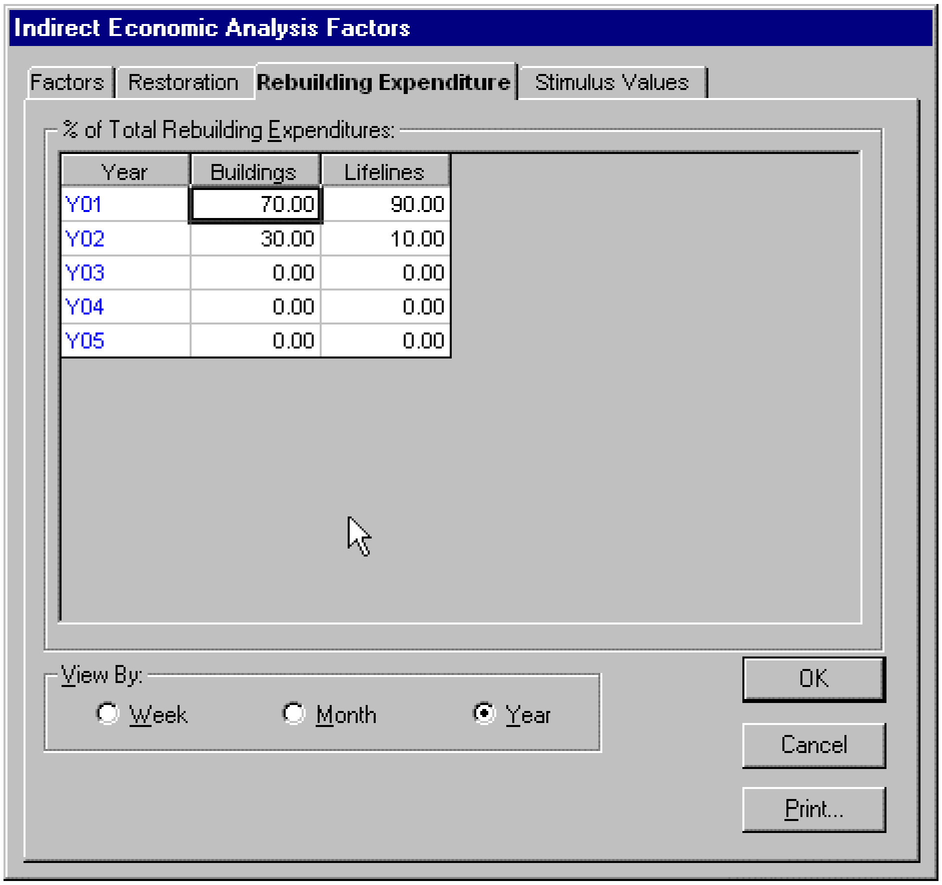


Figure 9.57 Setting the indirect economic rebuilding factors

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.

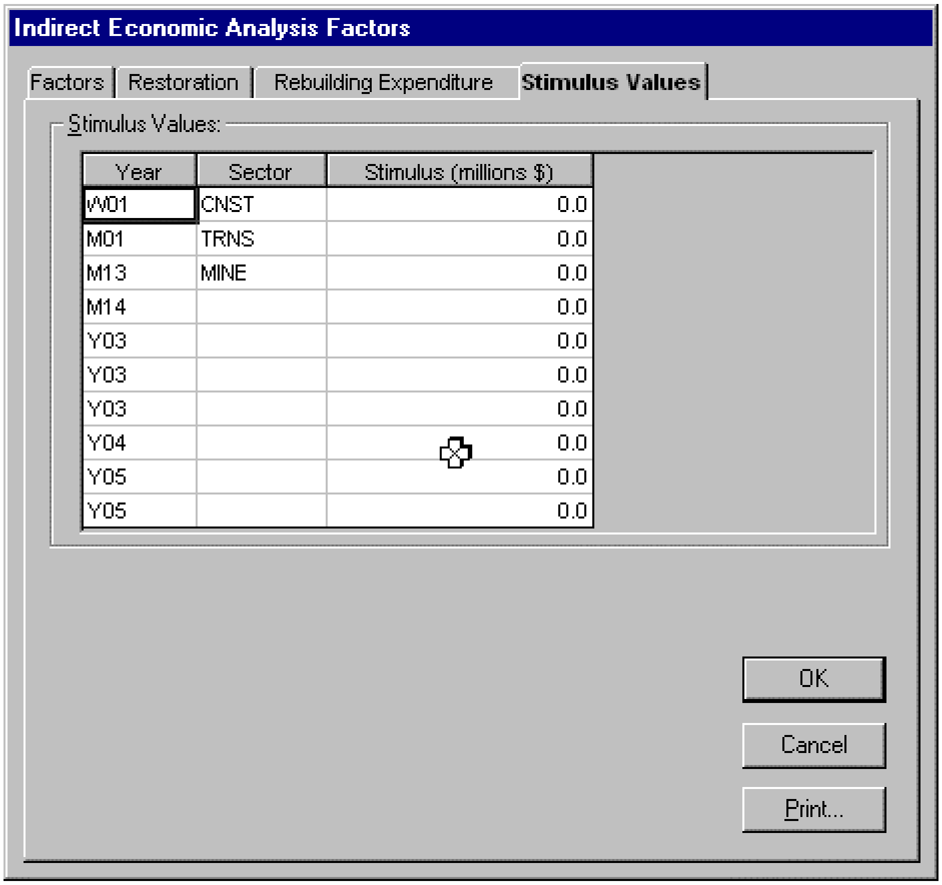


Figure 9.58 Setting the stimulus values.

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.

HAZUS includes the capability of inputting a higher resolution timeframe for the restorations factors, the rebuilding factors and the stimulus values. In **HAZUS** 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.

2.1.6 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.

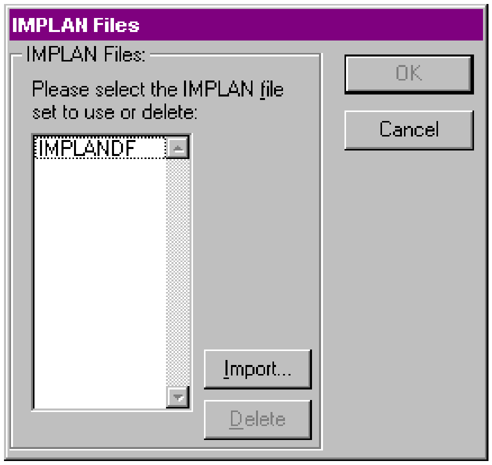


Figure 9.59 Screen for importing IMPLAN files.

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.

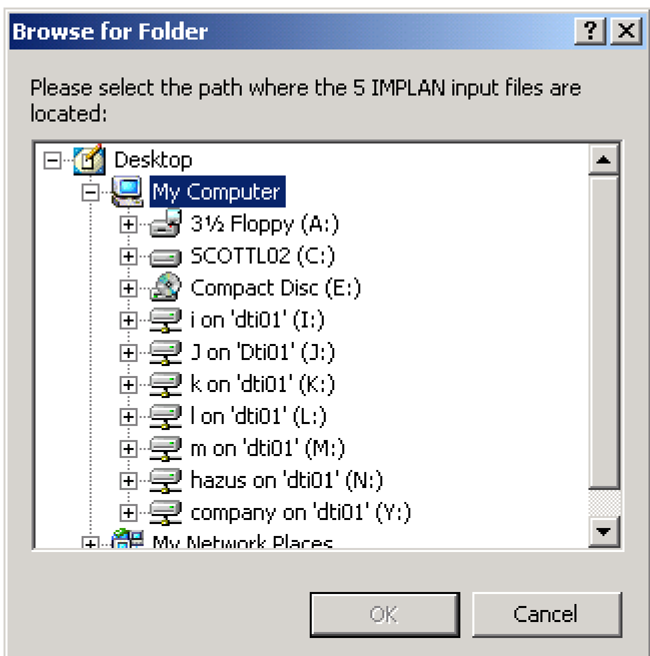


Figure 9.60 Locating IMPLAN files.

Use the **Import** button to import **IMPLAN** files into **HAZUS**. Use the window in Figure 9.60 to locate the directory that contains the required **IMPLAN files**. This returns you to the **IMPLAN** Files screen in Figure 9.59. Note that **HAZUS** only prompts you for the directory that contains the required files. All five files should be located in the same directory. Chapter 16 of the HAZUS Technical Manual provides the information of the files required by the module.

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

The user can modify inputs depending on the time and resources 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 tables such as Tables 9.10 and 9.11, to record inputs and results.

Table 9.10 Sample Table of Sensitivity Analysis Scenarios

Scenario Name	Inputs 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						
•						
•						

Chapter 10. Viewing, Reporting and Ground Truthing the Results

10.1 Guidance for Reporting Loss Results

There is no single format that is appropriate for presentation of loss study results. The format will depend on the use of the results and the intended audience. The audience can vary from the general public to technical experts. Decision makers such as city council members and other government officials may require only summaries of losses for a region. Emergency response planners may want to see the geographical distribution of all losses and damage for several different earthquake scenarios. **HAZUS** provides a great deal of flexibility in presenting results. Results can be presented in a tabular or map form - which maps or tables are selected for reports will depend on the application. In any case, the users of the results should be involved from the beginning in determining the types and formats of the results that best suit their needs.

In previous loss studies, authors of reports have had the difficult task of trying to combine the study results with the theory of how they were calculated. Consequently, reports often seemed overly technical, reducing their readability and usefulness for many audiences. **HAZUS** users can refer to the *Technical Manual* that describes all of the theories and equations that provide the basis of any loss estimate. Thus reports do not need to, and probably should not, include technical discussions of theory. Instead, reports should focus on describing results in non-technical language that is easily understood by the intended audience.

While no particular format for presenting results can be recommended, several general statements about reporting of results can be made. Reports should serve to clarify the meaning of the loss estimates. As an example, the reporting of economic loss should indicate whether both direct and indirect losses are included in the estimates. The report should indicate whether losses are due only to structural and non-structural damage or if they also include monetary losses resulting from loss of function. Casualty reports should indicate that casualties include only those that result from building damage and bridge collapse and do not include injuries and deaths from fires, flood, hazardous material releases or medical causes such as heart attacks. It should be clarified that in most cases losses are not calculated for specific buildings or facilities, but instead are based on the performances of entire classes of buildings and lifelines. These are just a few examples of the types of clarifications that should appear in reports.

Reports should also clarify for the reader what assumptions were made in developing the scenario and inventory and in calculating losses. For example, were losses based on default inventories or were default inventories augmented? Were default repair costs and repair times used? If not, what values were used? Were soils maps provided or were results based on a default soil type? What assumptions were made in selecting the scenario earthquake? Is it based on an historical event? Is it based on a specified probability of occurrence (e.g. 10% chance in 200 years)? What types of assumptions were made about design and construction quality?

A criticism of past studies is that there has been little qualitative or quantitative treatment of uncertainty. Discussions with users of previous studies have indicated that users need information about where errors in prediction are most likely to occur. While this methodology does not explicitly include a technique for carrying the uncertainty of each variable through the entire calculation from PESH input to loss estimates, sensitivity analyses are useful for providing bounds on loss estimates (see Section 9.8). At a minimum, reports should make some statement about the uncertainty of the input values.

10.2 Module Outputs

Each of the modules of **HAZUS** provides the user with a series of outputs. The outputs can be in a numerical or graphical form. Some of the modules yield intermediate results that are used as inputs to other modules. For example, the PESH module determines ground motion at different locations for a specified earthquake scenario. This information by itself may not be very useful for hazard mitigation and emergency planning. However, the results of the PESH module are used as an input to determine the damage to structures in the Direct Physical Damage module. In the following sections, summaries of the outputs of the modules are provided.

10.3 Potential Earth Science Hazards

HAZUS provides information about the expected ground shaking response for a specified event in the given study region. The user may specify a deterministic scenario event. For the purposes of emergency response and preparedness, a scenario event is commonly used to estimate earthquake consequences and losses. The user can also opt for a pseudo-probabilistic approach that can be used to compute expected annual losses. This type of approach may be useful for comparing mitigation strategies. Finally the user can use an existing ground motion map prepared by an expert.

Table 10.1 summarizes the module outputs for these three options. In all three cases, the user is provided with ground shaking in the study region characterized in terms of peak ground acceleration (PGA) and spectral accelerations (5% damping) at two specific structural periods (0.3 and 1.0 seconds).

Table 10.1 PESH Module Outputs - Ground Motion/Site Effects

Component	Description of Output	Measure
Deterministic Event	**HAZUS** determines census tract ground motion and develops region-wide ground motion contour maps based on a user-defined scenario event.	a) Census Tract Ground Shaking b) PGA Contour Maps c) Spectral Contour Maps
USGS Probabilistic Seismic Hazard Maps	**HAZUS** includes spectral contour maps at two seismic hazard levels: 2% probability of exceedance in 50 years and 10% probability of exceedance in 50 years	a) PGA Contour Maps b) Spectral Contour Maps
User-Supplied Ground Shaking Maps	The user supplies region-wide ground motion contour maps which are used as the ground motion inputs to **HAZUS**	a) Census Tract Ground Shaking b) PGA Contour Maps c) Spectral Contour Maps

For identified susceptible areas, **HAZUS** provides information concerning the probability of an expected level of permanent ground deformations (PGD) due to the specified scenario event. In this methodology, permanent ground deformation is defined as liquefaction, landsliding and surface fault rupture. PGD are important in estimating losses to and functionality of lifelines. Table 10.2 summarizes the ground deformation outputs of the PESH module. PGD are reported in terms of contour maps of ground deformations (in meters) or site specific PGD.

Table 10.2 PESH Module Outputs - Ground Deformation

Component	Description of Output	Measure
Liquefaction	**HAZUS** determines the probability of and expected level of permanent ground deformations for liquefaction susceptible sites during the deterministic, probabilistic, or user-defined event.	a) PGD Contour Maps b) Location-Specific PGD
Landsliding	**HAZUS** determines the probability of and expected level of permanent ground deformations for landsliding susceptible sites during the deterministic, probabilistic, or user-defined event.	a) PGD Contour Maps b) Location-Specific PGD
Surface Fault Rupture	**HAZUS** determines the probability of and expected level of permanent ground deformations for surface fault rupture susceptible sites during the deterministic, probabilistic, or user-defined event.	a) PGD Contour Maps b) Location-Specific PGD

Outputs of the PESH module can be accessed from the **Results|Ground Motion** menu (See Figure 10.1). Ground motion maps can be viewed in two forms: census tract-based or contour maps. To generate census tract-based maps, HAZUS evaluates the ground motion at the census tract centroid and then assigns the value to the census tract. The census tract- based information is used to derive the damage and loss estimates for the general building stock. Contour maps that are generated by **HAZUS** are for display purposes only. Contour maps that are digitized and entered by the user can be used for further computations. From the **Ground Motion or Failure** menu (see Figure 10.1), you can plot a variety of maps by choosing one of the options**: Ground Motion (By Census Tracts)** or **Contours or Ground Failure Maps**. For the **Ground Motion (By Census Tracts)** option, as shown in Figure 10.2, you can generate acceleration, displacement, velocity, PGV or PGA maps by clicking on the appropriate column of data and then clicking on the **Map** button. Examples of these maps are found in Figures 10.3 and 10.4. For the **Contours or Ground Failure Maps** option, you may plot any of the parameters shown in Figure 10.5 provided that you have already run the specific analysis that you want to plot. Click on your choice in Figure 10.5, followed by the **Map** button.

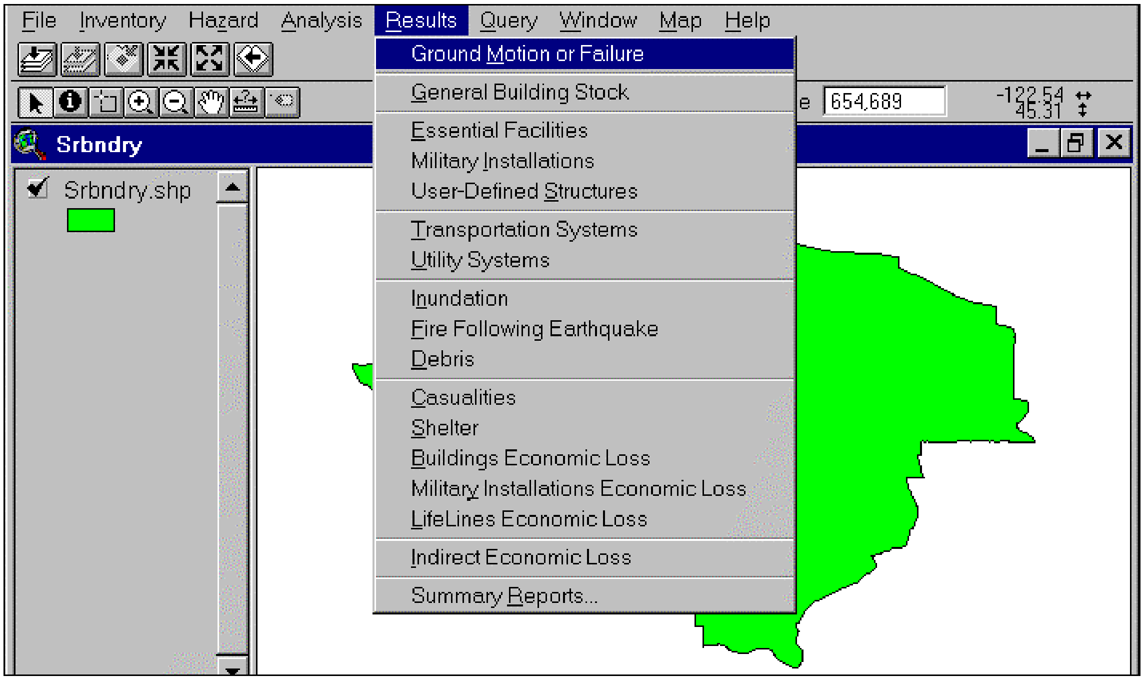
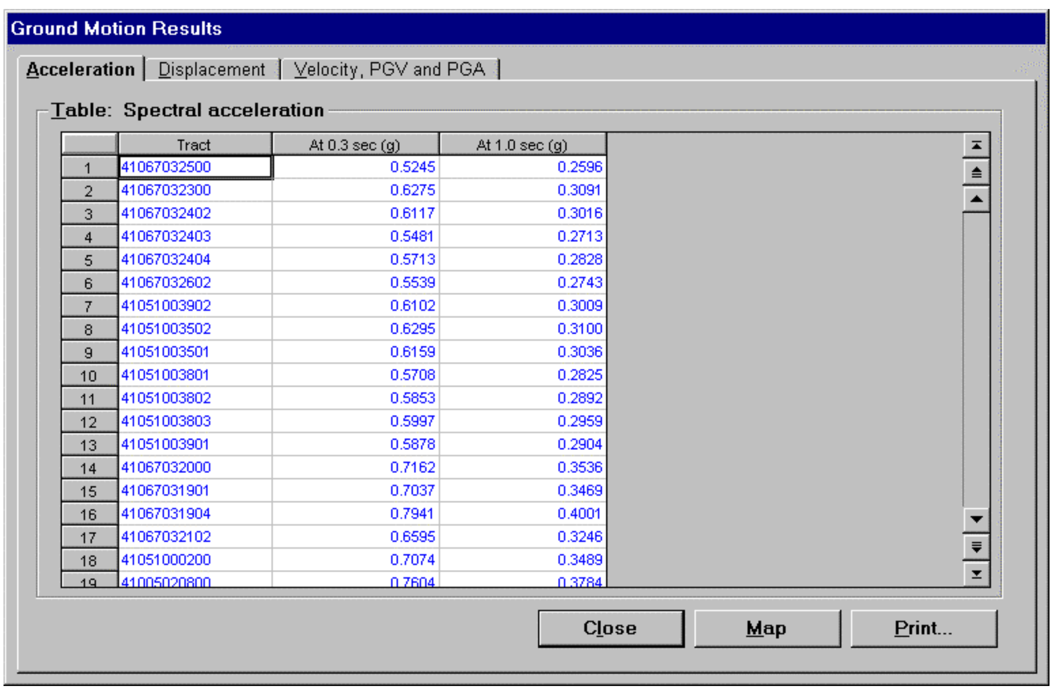


Figure 10.1 Accessing PESH module results.



	Tract	At 0.3 sec (g)	At 1.0 sec (g)
1	41067032500	0.5245	0.2596
2	41067032300	0.6275	0.3091
3	41067032402	0.6117	0.3016
4	41067032403	0.5481	0.2713
5	41067032404	0.5713	0.2828
6	41067032602	0.5539	0.2743
7	41051003902	0.6102	0.3009
8	41051003502	0.6295	0.3100
9	41051003501	0.6159	0.3036
10	41051003801	0.5708	0.2825
11	41051003802	0.5853	0.2892
12	41051003803	0.5997	0.2959
13	41051003901	0.5878	0.2904
14	41067032000	0.7162	0.3536
15	41067031901	0.7037	0.3469
16	41067031904	0.7941	0.4001
17	41067032102	0.6595	0.3246
18	41051000200	0.7074	0.3489
19	41005020800	0.7604	0.3784

Figure 10.2 Selecting site-specific data generated in the PESH module

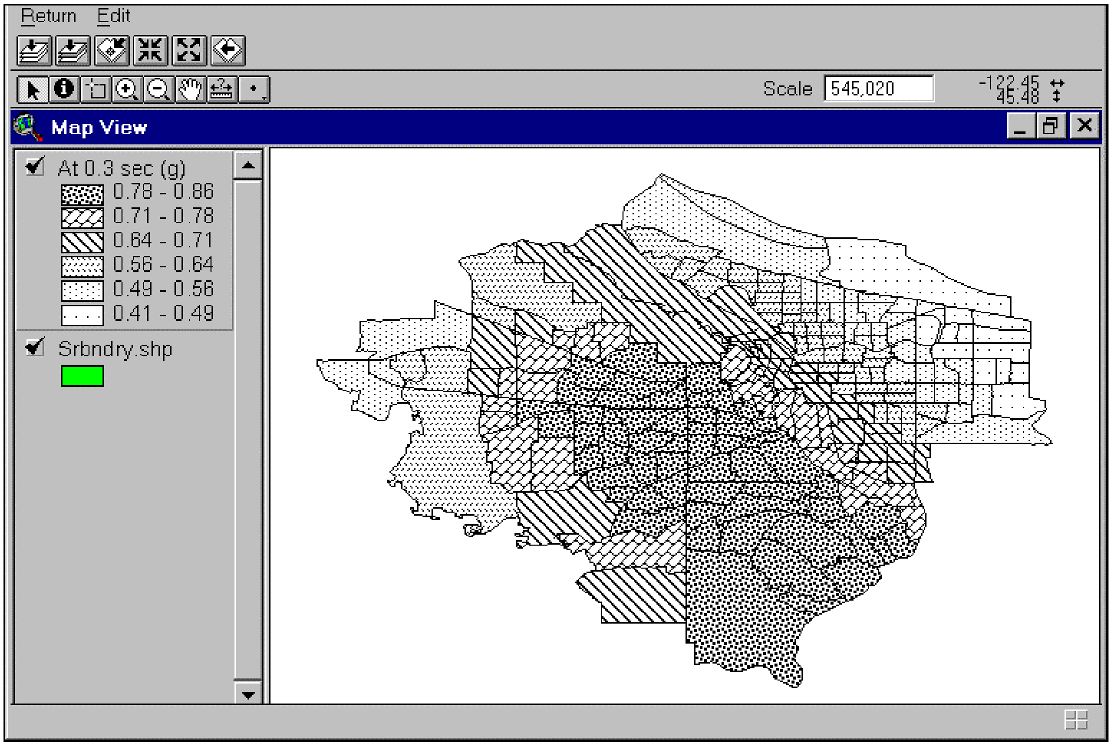


Figure 10.3 Map of 0.3 second spectral acceleration by census tract

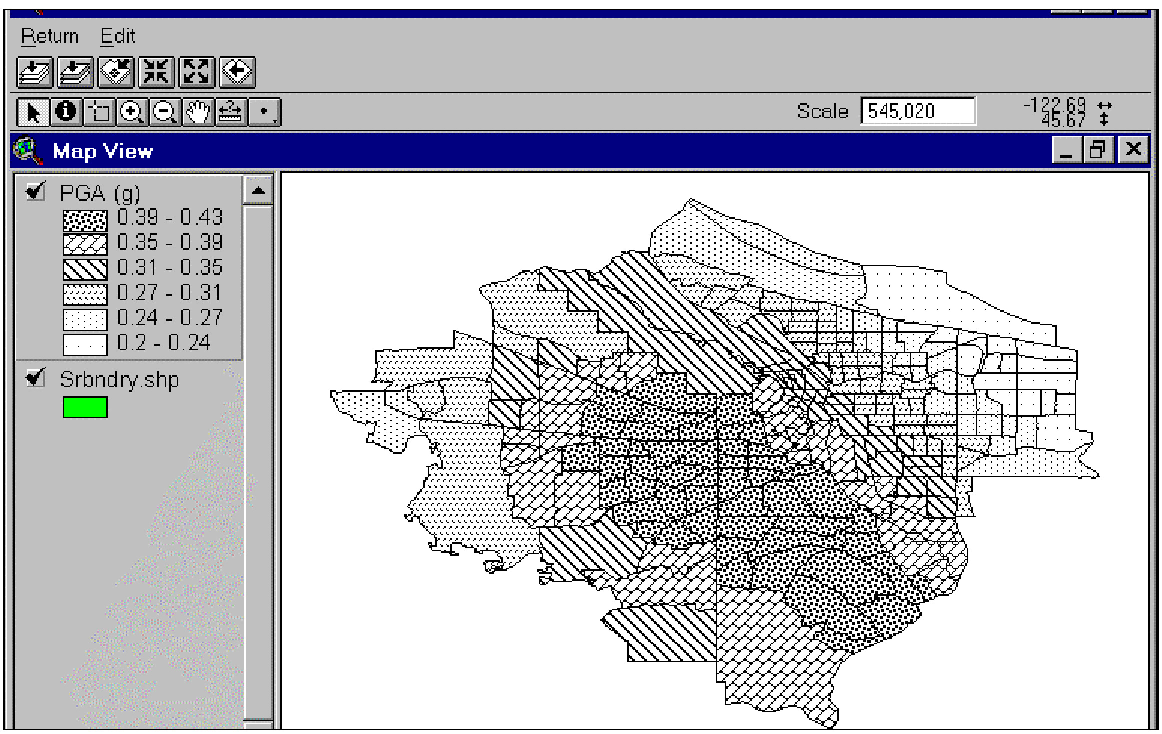


Figure 10.4 Map of peak ground acceleration by census tract.

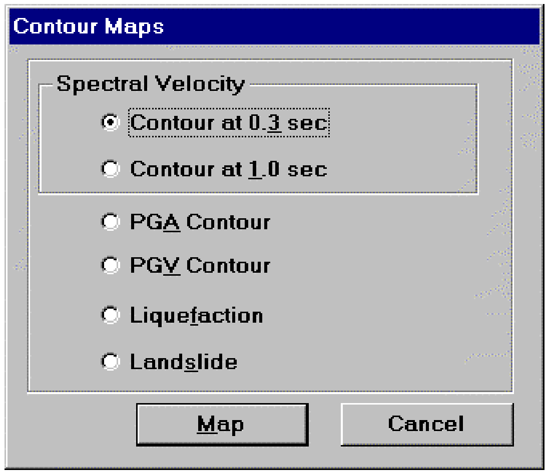


Figure 10.5 Window to select PESH contours for mapping.

10.3.1 Ground Motion Descriptions

Many of the earlier regional loss estimation studies and methods have based losses on MMI and isoseismal maps (maps showing areas of constant MMI). In **HAZUS**, PGA, PGV and SA characterize ground shaking. The use of spectral acceleration allows **HAZUS** to account for possible amplification of building motion and consequently damage due to sympathetic response of a building to the earthquake motions. Sympathetic response of a building (or amplification of building shaking) is similar to what you experience when on a swing. If you pump your legs at a certain frequency, the swing will go very high and very fast. If the ground motion shakes the building at a certain frequency the building will experience amplification of its motions. Fast shaking excites short buildings and slower shaking excites tall buildings. Presenting ground motion in terms of spectral velocity and spectral acceleration gives information about the frequency of the ground shaking. This in turn can be used to determine which buildings (tall or short) are most excited and thus most damaged by a particular earthquake.

10.4 Direct Physical Damage - General Building Stock

The direct physical damage module of **HAZUS** provides information about the level of damage to the study region's general building stock. Damage to the general building stock is not evaluated on a building-by-building basis. Instead, damage is estimated and reported for groups of buildings in each census tract. Damage to the general building stock is defined in terms of the probability that a specific model building type will reach or exceed a specified level of damage when subjected to a given level of ground motion. Damage estimates are then converted in other modules into monetary losses and social losses such as casualties and shelter demands (see, for example, Figure 10.6).

Losses such as the costs of reconstruction, the length of business interruption, the number of people needing shelter and the severity of injuries and number of casualties all depend on the severity of the damage. While estimation of social and economic losses is the ultimate goal of a loss study, some knowledge of the geographical distribution of damage may be helpful in planning for post-earthquake response or in determining strategies for mitigation, for example, if the scenario identifies a particular area where a large number of buildings are likely to collapse, planning for rescue efforts in this area may be important.

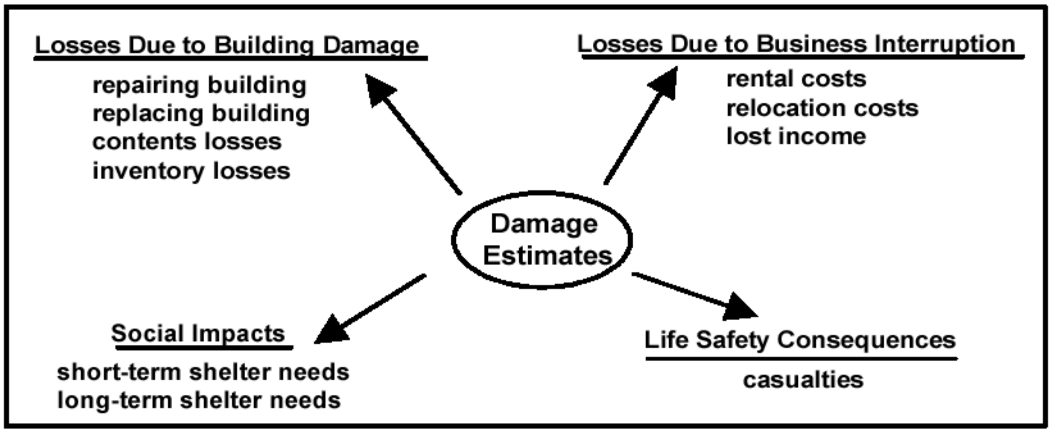


Figure 10.6 Losses calculated from damage estimates.

Damage is described by five damage states (none, slight, moderate, extensive and complete) that are defined in detail in Section 9.4.2. Estimates of earthquake damage are provided in terms of damage state probabilities or building count. For a specified earthquake, the user is provided with the probability of a structural type experiencing a certain level of damage. For example, for a given earthquake, wood frame structures may have a probability of 0.9 of experiencing no damage and a probability of 0.1 of experiencing slight damage. As shown in Table 10.3, damage state probabilities are provided for structural as well as non-structural damage, where as building counts are only provided for structural damage. To provide the most flexibility to the user, the module delivers damage state probabilities for model building types, specific occupancy classes and general occupancy classes. Results are available in a tabular or map format.

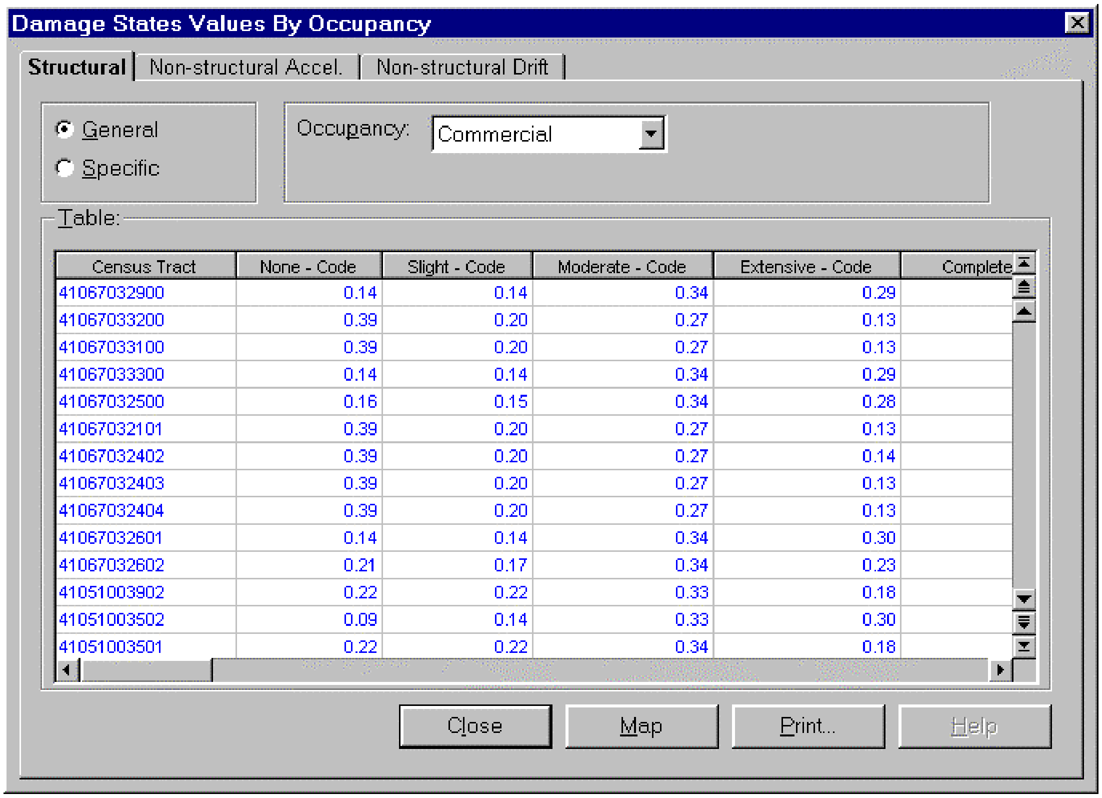
Table 10.3 Direct Physical Damage Module Outputs - General Building Stock

Component	Description of Output	Measure
Model Building Type	**HAZUS** determines the damage state probability for each model building type (36) by census tract in the study region. Results are presented for each design level and construction quality bias. Damage state probabilities are determined for i) structural elements, ii) non-structural drift-sensitive elements, and iii) non-structural acceleration-sensitive elements.	a) Structural Damage State Probabilities b) Non-structural Damage State Probabilities c) Structural Damage State Building Counts
General Building Type	**HAZUS** determines the damage state probability for each general building type (7) by census tract in the study region. Results are presented for each design level and construction quality bias. Damage state probabilities are determined for i) structural elements, ii) non-structural drift-sensitive elements, and iii) non-structural acceleration-sensitive elements.	a) Structural Damage State Probabilities b) Non-structural Damage State Probabilities c) Structural Damage State Building Counts
Specific Occupancy Class	**HAZUS** determines the damage state probability for each specific occupancy (28) by census tract in the study region. Results are presented for each construction quality bias. Damage state probabilities are determined for i) structural elements, ii) non-structural drift-sensitive elements, and iii) non-structural acceleration-sensitive elements.	a) Structural Damage State Probabilities b) Non-structural Damage State Probabilities c) Structural Damage State Occupancy Counts
General Occupancy Class	**HAZUS** determines the damage state probability for each general occupancy (6) by census tract in the study region. Damage state probabilities are determined for I) structural elements, ii) non-structural drift-sensitive elements, and iii) non-structural acceleration-sensitive elements.	a) Structural Damage State Probabilities b) Non-structural Damage State Probabilities c) Structural Damage State Occupancy Counts

The **Results|General Building Stock** menu option is used to assess the output of the damage module. Results are provided in a tabular format (see Figures 10.7 and 10.8) or in a map form (Figures 10.9 through 10.11). In both cases the following information can be displayed:

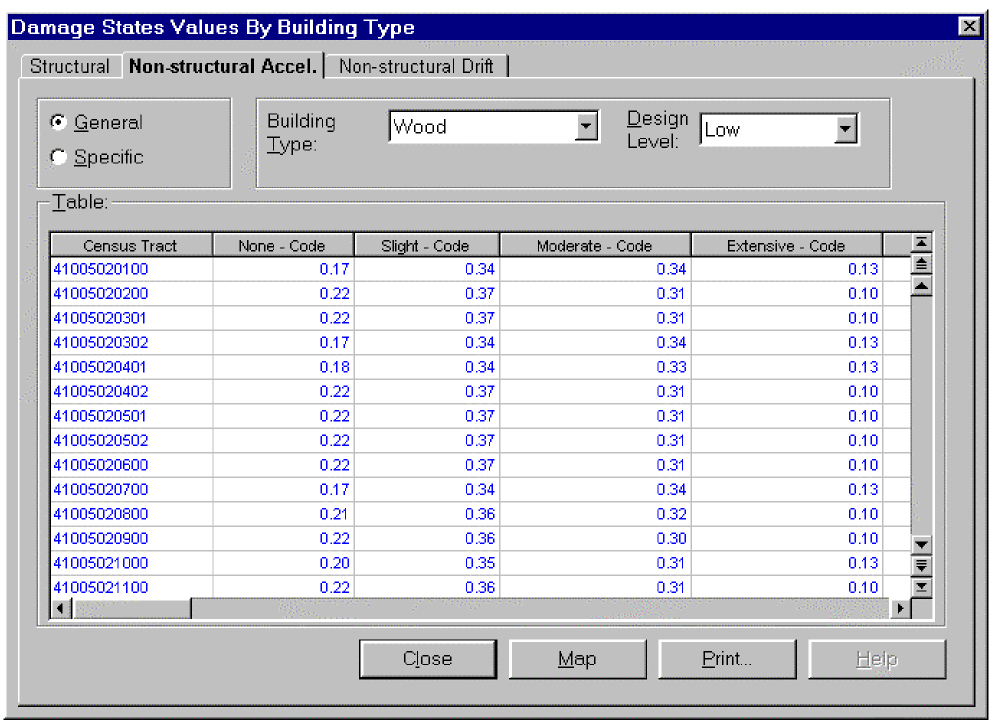
Probability of none, slight, moderate, extensive or complete structural damage, acceleration sensitive non- structural damage or drift sensitive non- structural damage. Probability of at least slight, at least moderate, at least extensive for structural or either type of non-structural damage.

To thematically map a given value, select its column by clicking on the header, and then clicking **Map**. Click on **Return|Return to Table** to go back to the dialog that displays tabular results.



Census Tract	None - Code	Slight - Code	Moderate - Code	Extensive - Code	Complete
41067032900	0.14	0.14	0.34	0.29	
41067033200	0.39	0.20	0.27	0.13	
41067033100	0.39	0.20	0.27	0.13	
41067033300	0.14	0.14	0.34	0.29	
41067032500	0.16	0.15	0.34	0.28	
41067032101	0.39	0.20	0.27	0.13	
41067032402	0.39	0.20	0.27	0.14	
41067032403	0.39	0.20	0.27	0.13	
41067032404	0.39	0.20	0.27	0.13	
41067032601	0.14	0.14	0.34	0.30	
41067032602	0.21	0.17	0.34	0.23	
41051003902	0.22	0.22	0.33	0.18	
41051003502	0.09	0.14	0.33	0.30	
41051003501	0.22	0.22	0.34	0.18	

Figure 10.7 Damage state probabilities by general occupancy.



Census Tract	None - Code	Slight - Code	Moderate - Code	Extensive - Code
41005020100	0.17	0.34	0.34	0.13
41005020200	0.22	0.37	0.31	0.10
41005020301	0.22	0.37	0.31	0.10
41005020302	0.17	0.34	0.34	0.13
41005020401	0.18	0.34	0.33	0.13
41005020402	0.22	0.37	0.31	0.10
41005020501	0.22	0.37	0.31	0.10
41005020502	0.22	0.37	0.31	0.10
41005020600	0.22	0.37	0.31	0.10
41005020700	0.17	0.34	0.34	0.13
41005020800	0.21	0.36	0.32	0.10
41005020900	0.22	0.36	0.30	0.10
41005021000	0.20	0.35	0.31	0.13
41005021100	0.22	0.36	0.31	0.10

Figure 10.8 Damage state probabilities by general building type.

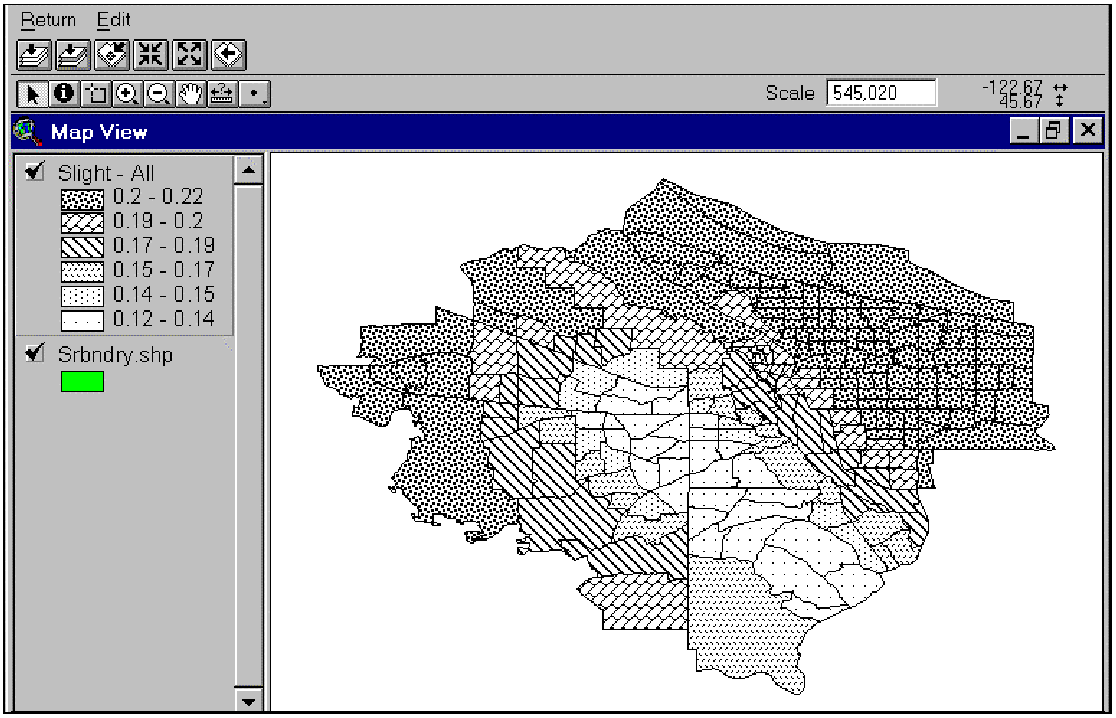


Figure 10.9 Map of probability of slight structural damage for commercial occupancy.

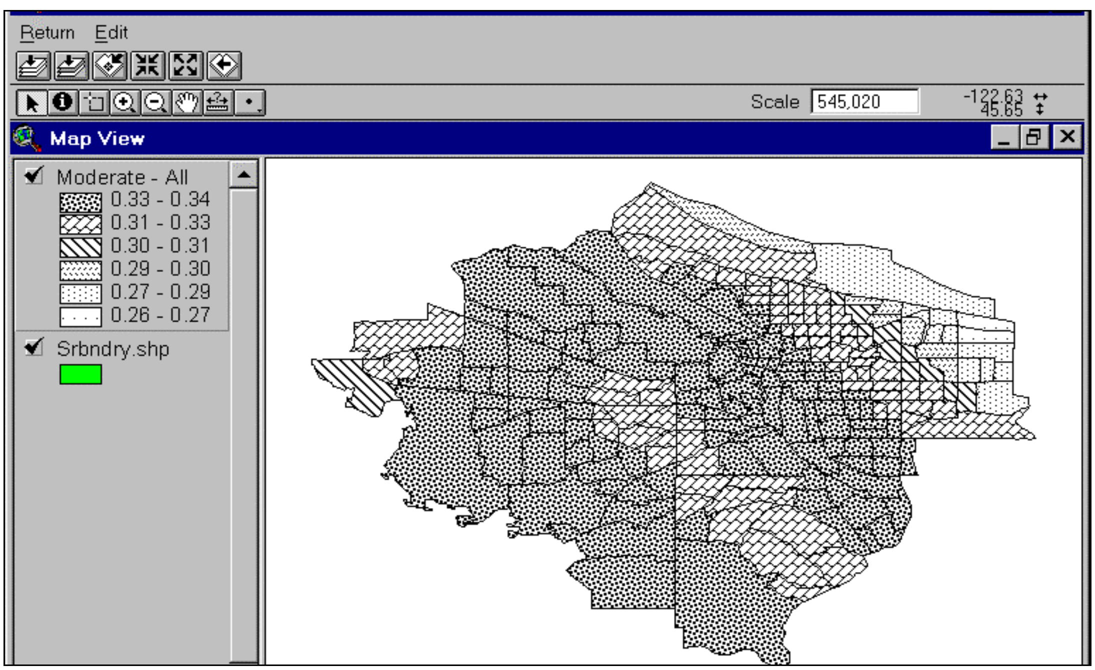


Figure 10.10 Map of moderate structural damage for retail trade (COM 1).

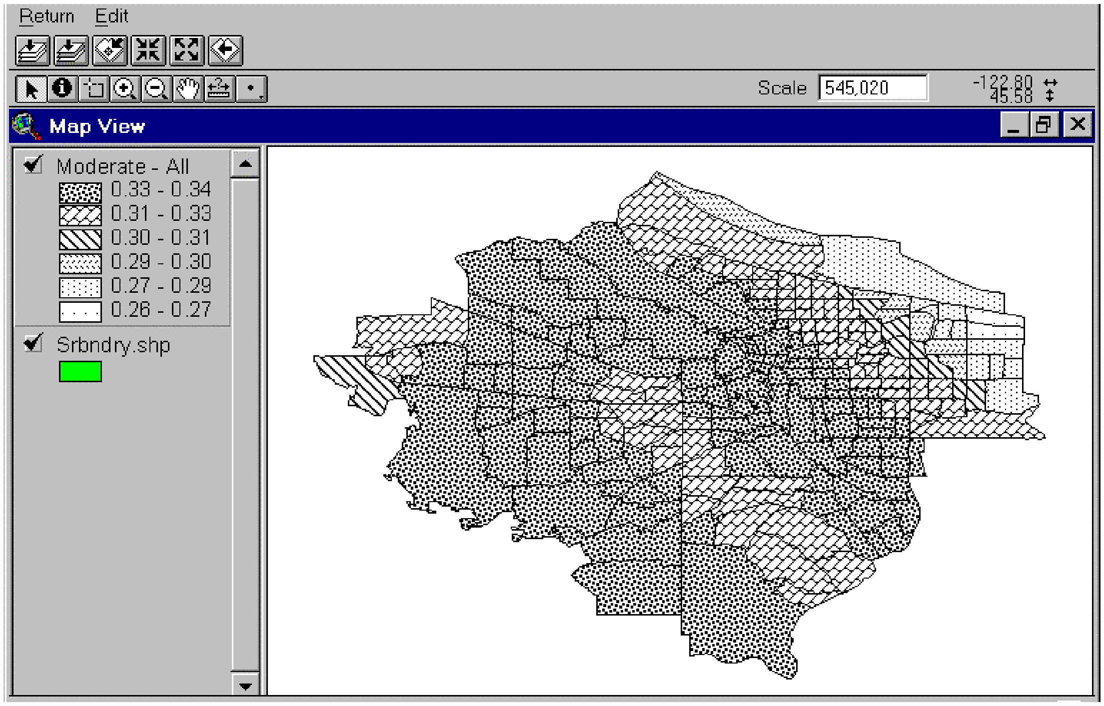


Figure 10.11 Map of moderate non-structural drift sensitive damage for retail trade (COM 1).

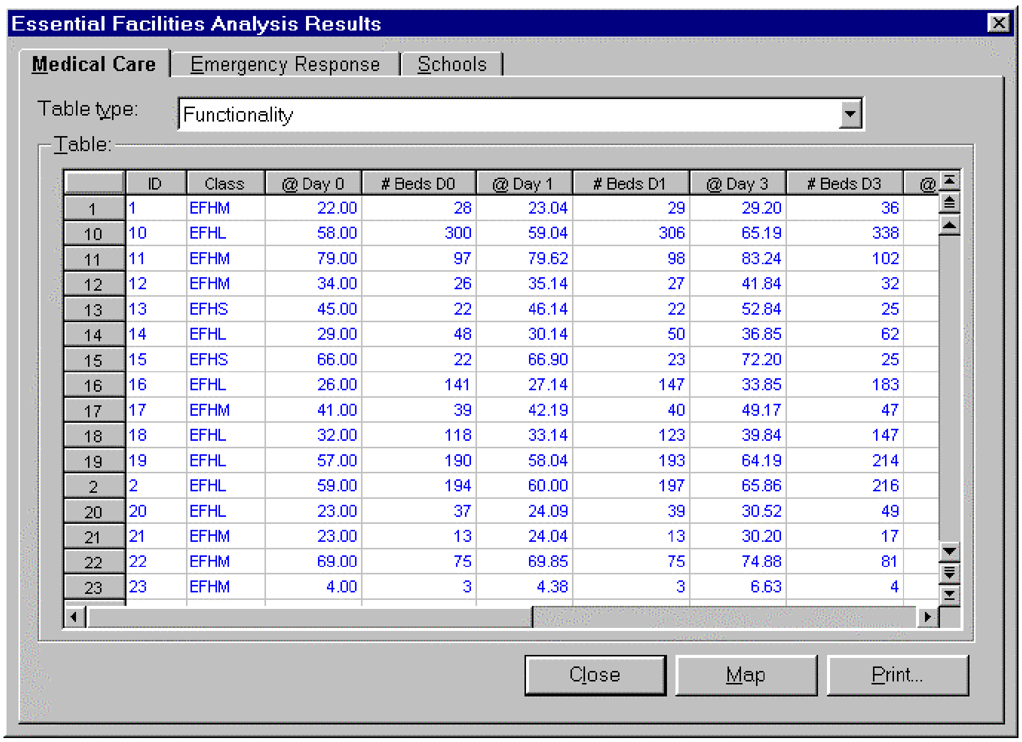
10.5 Direct Physical Damage - Essential Facilities

HAZUS provides information about the damage state probability of the study region's essential facilities. In contrast to the general building stock, where damage probabilities are calculated for groups of buildings, for essential facilities the damage probabilities are estimated for each individual facility. As with the general building stock, the damage states are none, slight, moderate, extensive and complete. Both structural and non-structural damage is considered. As can be seen in Table 10.4, damage state probabilities are estimated for health care facilities, police and fire stations, emergency operation centers and schools. In addition, loss of beds and facility functionality is computed as a function of time for health care facilities.

Output of the essential facilities damage module can be obtained by using the **Results|Essential Facilities** menu. As with the general building stock, results are provided in a tabular format or in a map form. An example of the functionality of health care facilities is found in Figure 10.12. To thematically map a given value, select its column by clicking on the header, and then clicking **Map**. Click on **Return|Return to Table** to go back to the dialog that displays tabular results.

Table 10.4 Direct Physical Damage Module Outputs - Essential Facilities

Facility Type	Description of Output	Measure
Health Care Facilities	**HAZUS** determines the damage state probabilities for each health care facility in the study region. Damage state probabilities are determined for i) structural elements, ii) non-structural drift-sensitive elements, and iii) non-structural acceleration-sensitive elements. The expected reduction in available beds for each facility is also determined.	a) Structural Damage State Probabilities b) Non-structural Damage State Probabilities c) Loss of Beds and Facility Functionality
Police/Fire Stations Emergency Operations Centers Schools	**HAZUS** determines the damage state probabilities for each facility in the study region. Damage state probabilities are determined for i) structural elements, ii) non-structural drift-sensitive elements, and iii) non-structural acceleration-sensitive elements.	a) Structural Damage State Probabilities b) Non-structural Damage State Probabilities c) Functionality @ Day 1



	ID	Class	@ Day 0	# Beds D0	@ Day 1	# Beds D1	@ Day 3	# Beds D3	@
1	1	EFHM	22.00	28	23.04	29	29.20	36	
10	10	EFHL	58.00	300	59.04	306	65.19	338	
11	11	EFHM	79.00	97	79.62	98	83.24	102	
12	12	EFHM	34.00	26	35.14	27	41.84	32	
13	13	EFHS	45.00	22	46.14	22	52.84	25	
14	14	EFHL	29.00	48	30.14	50	36.85	62	
15	15	EFHS	66.00	22	66.90	23	72.20	25	
16	16	EFHL	26.00	141	27.14	147	33.85	183	
17	17	EFHM	41.00	39	42.19	40	49.17	47	
18	18	EFHL	32.00	118	33.14	123	39.84	147	
19	19	EFHL	57.00	190	58.04	193	64.19	214	
2	2	EFHL	59.00	194	60.00	197	65.86	216	
20	20	EFHL	23.00	37	24.09	39	30.52	49	
21	21	EFHM	23.00	13	24.04	13	30.20	17	
22	22	EFHM	69.00	75	69.85	75	74.88	81	
23	23	EFHM	4.00	3	4.38	3	6.63	4	

Figure 10.12 Functionality of health care facilities.

10.6 High Potential Loss Facilities

High potential loss facilities tend to be unique and complex facilities that would require in-depth evaluation by structural and geotechnical engineers to assess their vulnerability to earthquakes. These types of facilities are often designed to codes and standards that exceed those for general building stock. Thus, the vulnerability curves that are used for general building stock may be inappropriate for high potential loss facilities. It is likely that the user/engineer will need to define vulnerability curves that are specific to these facilities. Furthermore, often the owners of these facilities have already performed in-depth, site-specific seismic hazard analyses. For these reasons, **HAZUS** is limited to providing information concerning the location of the study region's high potential loss facilities (see Table 10.5). This can serve as a first step in developing mitigation and preparedness efforts. You may opt to perform a vulnerability analysis of a specific facility, and include the results of the special study with the results of the methodology. Locations of and details about high potential loss facilities are found in the **Inventory|High Potential Loss Facilities|Inventory Data** menu. Results for military facilities are obtained through the **Results|Military Installations** menu.

Table 10.5 Direct physical damage module outputs - high potential loss facilities

Component	Description of Output	Measure
Dams	**HAZUS** provides the locations of dams in the study region.	List of and locations of dams
Nuclear Facilities	**HAZUS** provides the locations of nuclear power facilities in the study region.	List of and locations of nuclear power facilities
Military facilities	**HAZUS** determines the damage state probabilities for each facility in the study region. Damage state probabilities are determined for i) structural elements, ii) non-structural drift-sensitive elements, and iii) non-structural acceleration-sensitive elements.	a) Structural Damage State Probabilities b) Non-structural Damage State Probabilities

10.7 Direct Physical Damage - Lifelines

Lifeline systems are vital to the functionality of a community. Damage to these systems after an earthquake can be devastating in terms of the health and safety of the citizens. After the Great Hanshin earthquake in 1995, the water supply system was so severely damaged that people had to rely on trucked-in water. Damage to railway and road systems prevented emergency response personnel from bringing food, water and other supplies into the region. Over 900,000 households were without electricity and 800,000 households without gas in the middle of winter. Damage to roads and blockages of roads due to collapsed buildings prevented police, fire fighters and rescuers from fighting fires and attending to the trapped and injured.

Losses to the community that result from damage to lifelines can be much greater than the costs of repairing the systems. For example, damage to the Kobe harbor, one of the busiest in Japan, stopped the import and export of materials that were essential to the operation of many manufacturing plants in Japan. Factories were forced to close down for lack of materials. Recovery of the region will depend to a great degree on how quickly lifelines can be restored to full functionality. Therefore, assessment of the vulnerability of lifeline systems is a very important part of developing regional emergency preparedness and response plans.

In **HAZUS**, damage to lifeline systems is described in terms of damage to components. Detailed systems analyses are not performed, although simplified system analyses are performed for water systems and electric power. Damage is reported in terms of the probability of reaching or exceeding a specified level of damage when subjected to a given level of ground motion or permanent ground deformation. Associated with each damage state is a restoration curve that is used to evaluate the time required to bring the system back to full functionality.

A probability of functionality is defined as the probability, given an initial level of damage after the earthquake, of the component operating at a certain capacity after a specified period of time. For example, a highway bridge might be found to have the following probabilities of damage, based upon experiencing 0.6g peak ground acceleration and 12 inches of permanent ground deformation.

No damage	3% chance
Slight damage	9% chance
Moderate damage	20% chance
Extensive damage	44% chance
Complete damage	24% chance

Based upon this estimate of damage, the expected functionality of the bridge would be

14% functional after one day,
26% functional after 3-days,
34% functional after 7 days,
39% functional after 30 days, and
60% functional after a 3-month restoration period.

Another interpretation of these results is that after one day, 14% of the bridges of this type would be functional and after 3 months, 60% of these bridges would be functional. Interdependency of the components on overall transportation system functionality is not addressed by the methodology. Lifelines are divided into transportation systems and utility systems. Table 10.6 summarizes the outputs for each of the seven transportation lifeline systems.

Table 10.6 Direct Physical Damage Module Outputs - Transportation Systems

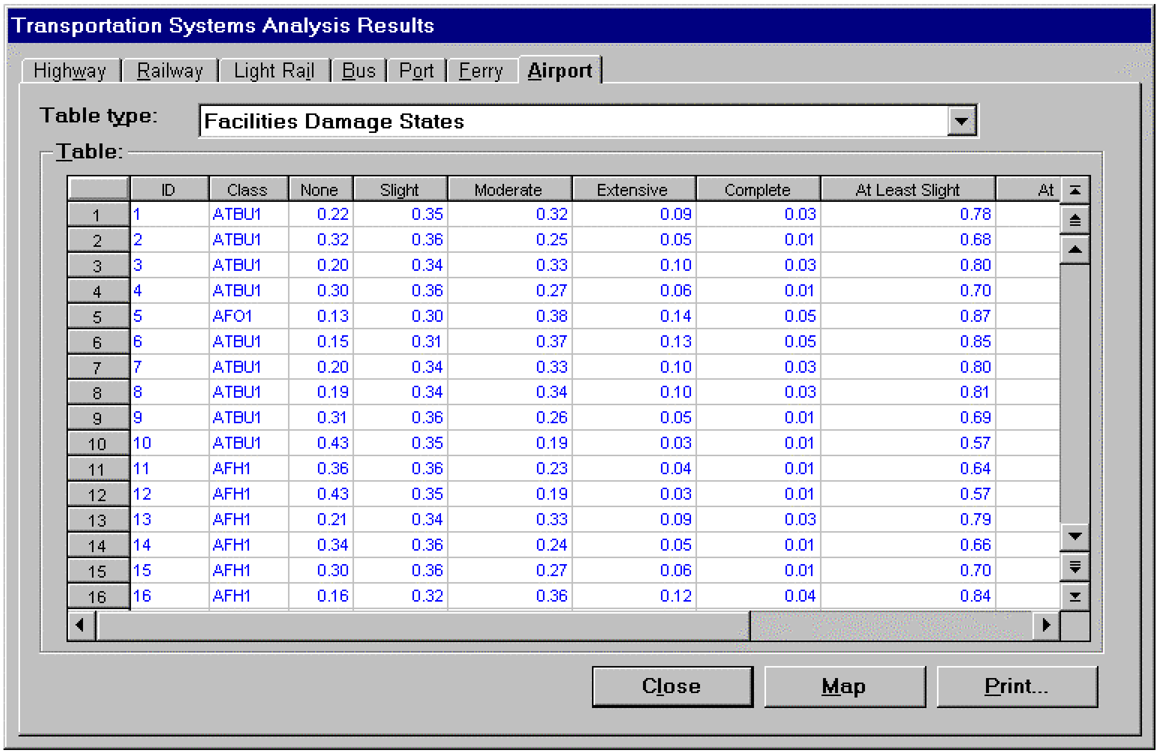
System	Description of Output	Measure
Highway System Railway System Light Rail Bus Ferry Port Airport	a) **HAZUS** determines the damage state probability for each transportation system component in the study region. b) **HAZUS** determines the probability of functionality for each transportation system component at discrete time intervals.	a) Component Damage State Probabilities b) Component Probability of Functionality

Table 10.7 summarizes the outputs of **HAZUS** for the study region's utility system components. A simplified system analysis is performed for potable water systems and electric power systems. These analyses make simplified assumptions about the serviceability of the systems based on the number of pipe leaks and breaks or the functionality of medium voltage substations.

Table 10.7 Direct Physical Damage Module Outputs - Utility Systems

System	Description of Output	Measure
Potable Water	a) **HAZUS** determines the damage state probabilities for each potable water component in the study region. b) **HAZUS** determines the probability of functionality for each potable water component at discrete time intervals. c) **HAZUS** supports simplified potable water system analysis for the study region.	a) Component Damage State Probabilities b) Component Probability of Functionality c) # of Households without water
Waste Water Natural Gas Crude and Refined Oil Pipeline Communication	a) **HAZUS** determines the damage state probabilities for each system component in the study region. b) **HAZUS** determines the probability of functionality for each system component at discrete time intervals.	a) Component Damage State Probabilities b) Component Probability of Functionality
Electric Power	a) **HAZUS** determines the damage state probabilities for each electric power component in the study region. b) **HAZUS** determines the probability of functionality for each electric power component at discrete time intervals. c) **HAZUS** supports simplified system analysis for the study region.	a) Component Damage State Probabilities b) Component Probability of Functionality c) # of Households without power

Output of the lifeline module can be viewed in terms of damage states or in terms of functionality and can be displayed in a tabular or map format. Figure 10.13 shows a table of the damage to airport facilities for the study region. For each of the airports in the study region (identified by ID number), the probability of being in one of the five damage states is tabulated. For airport facility number 1, the probability of no damage is 0.22, slight damage is 0.35 and moderate damage is 0.32. This information can be mapped, as shown in Figure 10.14, by clicking on the **Map** button. Each airport facility is identified by a symbol. The shape (or color) of the symbol is associated with a range of probabilities. For example, if the symbol is square, the probability of slight damage is between 0.34 and 0.35. Users familiar with ArcView, have the option of zooming in on any area and viewing that area more closely as shown in Figure 10.15.



	ID	Class	None	Slight	Moderate	Extensive	Complete	At Least Slight	At
1	1	ATBU1	0.22	0.35	0.32	0.09	0.03	0.78	
2	2	ATBU1	0.32	0.36	0.25	0.05	0.01	0.68	
3	3	ATBU1	0.20	0.34	0.33	0.10	0.03	0.80	
4	4	ATBU1	0.30	0.36	0.27	0.06	0.01	0.70	
5	5	AFO1	0.13	0.30	0.38	0.14	0.05	0.87	
6	6	ATBU1	0.15	0.31	0.37	0.13	0.05	0.85	
7	7	ATBU1	0.20	0.34	0.33	0.10	0.03	0.80	
8	8	ATBU1	0.19	0.34	0.34	0.10	0.03	0.81	
9	9	ATBU1	0.31	0.36	0.26	0.05	0.01	0.69	
10	10	ATBU1	0.43	0.35	0.19	0.03	0.01	0.57	
11	11	AFH1	0.36	0.36	0.23	0.04	0.01	0.64	
12	12	AFH1	0.43	0.35	0.19	0.03	0.01	0.57	
13	13	AFH1	0.21	0.34	0.33	0.09	0.03	0.79	
14	14	AFH1	0.34	0.36	0.24	0.05	0.01	0.66	
15	15	AFH1	0.30	0.36	0.27	0.06	0.01	0.70	
16	16	AFH1	0.16	0.32	0.36	0.12	0.04	0.84	

Figure 10.13 Output of the lifeline module: damage to airport facilities.

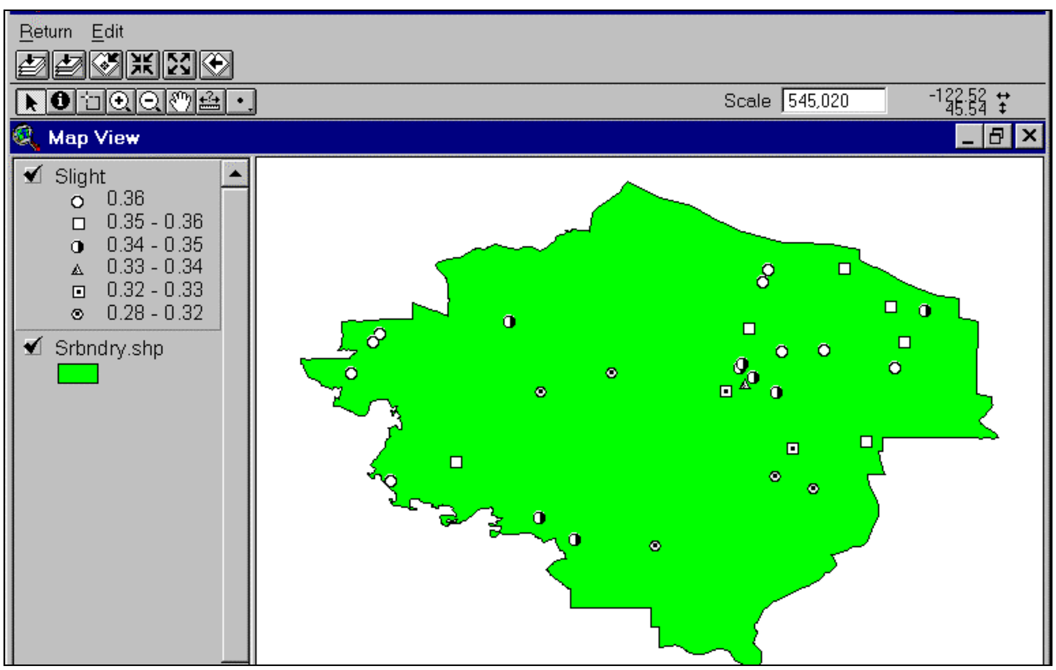


Figure 10.14 Output of the lifeline module: map of probability of slight damage to airport facilities for entire study region.

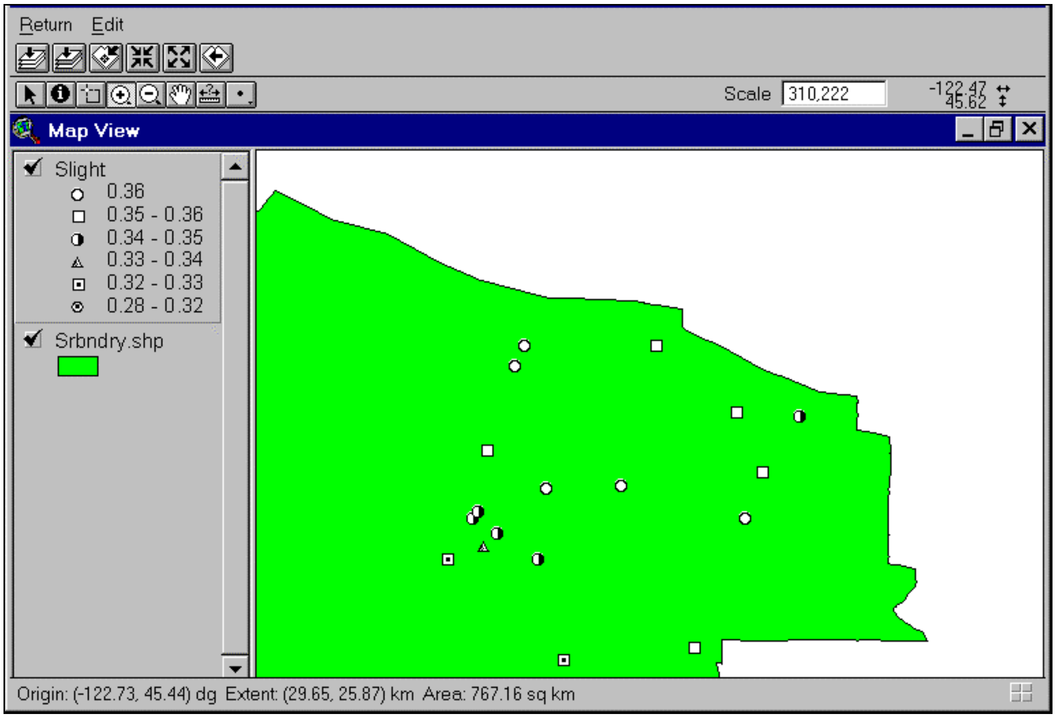
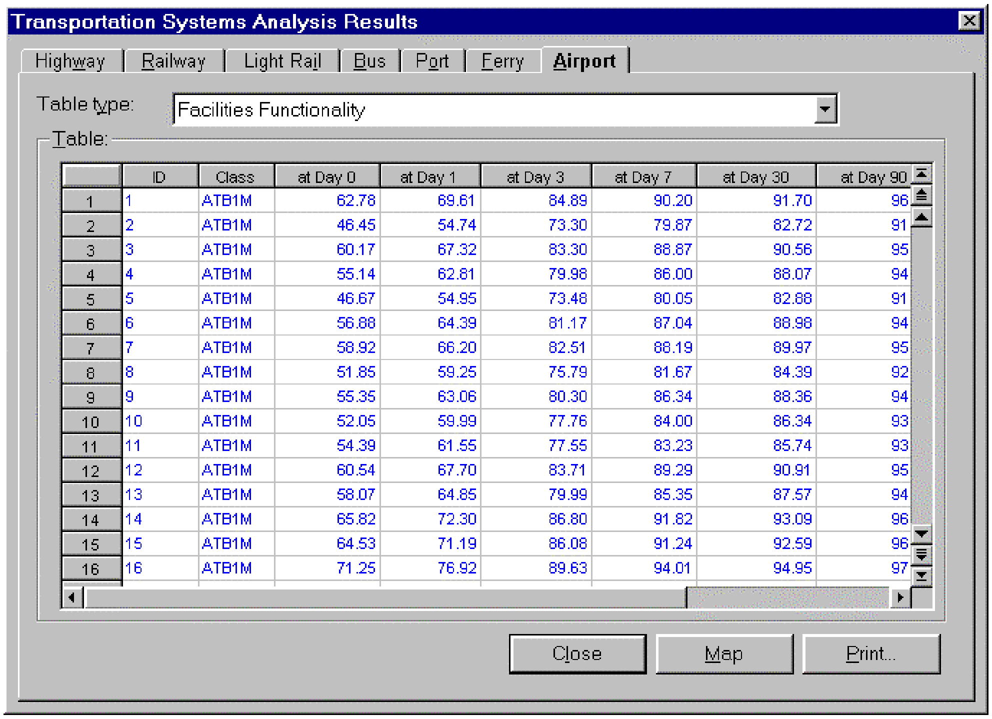


Figure 10.15 Map of probability of slight damage to airport facilities for a portion of the study region.

Figure 10.16 shows a table of the functionality of airport facilities at specified periods after the occurrence of the scenario earthquake. According to this table, facility number 1 would be functional with a 63% probability immediately after the earthquake, and functional with a 96% probability after 90 days. Functionality can be mapped, as shown in Figure 10.17, by clicking on the **Map** button. Facilities are mapped as "operational" or "non-operational". The user must specify a "confidence level" above which the facility is considered operational. In Figure 10.18 the "confidence level" is chosen to be 75%, indicating that if the probability of functionality is greater than 75%, the facility will be considered operational. Based on this definition of operational, many of the airport terminals near the epicenter will be non-operational the day after the earthquake.



	ID	Class	at Day 0	at Day 1	at Day 3	at Day 7	at Day 30	at Day 90
1	1	ATB1M	62.78	69.61	84.89	90.20	91.70	96
2	2	ATB1M	46.45	54.74	73.30	79.87	82.72	91
3	3	ATB1M	60.17	67.32	83.30	88.87	90.56	95
4	4	ATB1M	55.14	62.81	79.98	86.00	88.07	94
5	5	ATB1M	46.67	54.95	73.48	80.05	82.88	91
6	6	ATB1M	56.88	64.39	81.17	87.04	88.98	94
7	7	ATB1M	58.92	66.20	82.51	88.19	89.97	95
8	8	ATB1M	51.85	59.25	75.79	81.67	84.39	92
9	9	ATB1M	55.35	63.06	80.30	86.34	88.36	94
10	10	ATB1M	52.05	59.99	77.76	84.00	86.34	93
11	11	ATB1M	54.39	61.55	77.55	83.23	85.74	93
12	12	ATB1M	60.54	67.70	83.71	89.29	90.91	95
13	13	ATB1M	58.07	64.85	79.99	85.35	87.57	94
14	14	ATB1M	65.82	72.30	86.80	91.82	93.09	96
15	15	ATB1M	64.53	71.19	86.08	91.24	92.59	96
16	16	ATB1M	71.25	76.92	89.63	94.01	94.95	97

Figure 10.16 Output of the lifeline module: functionality of airport facilities reported by number of days since the occurrence of the earthquake.

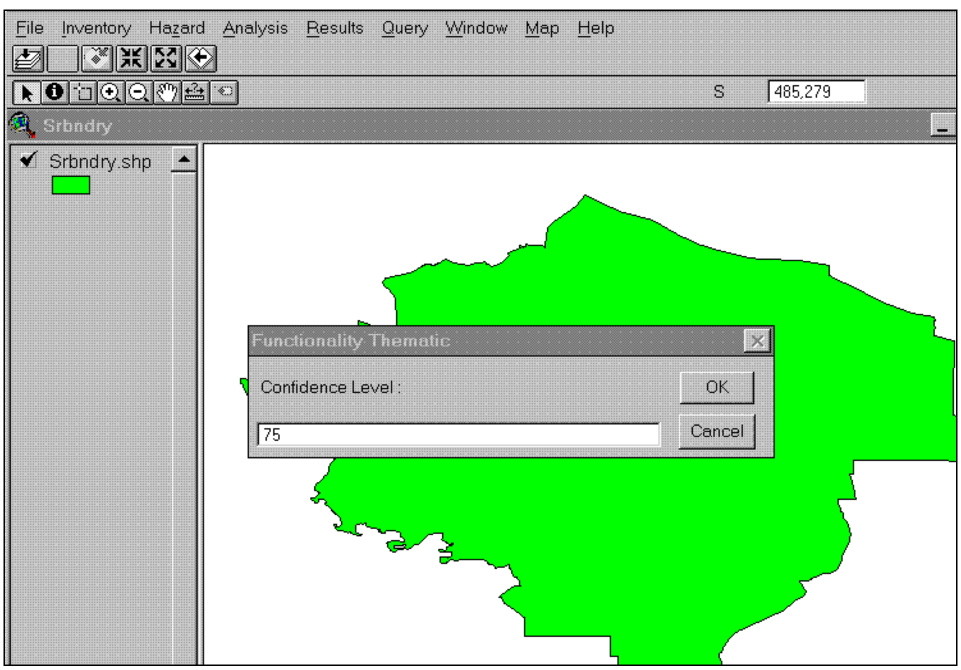


Figure 10.17 Selection of confidence level.

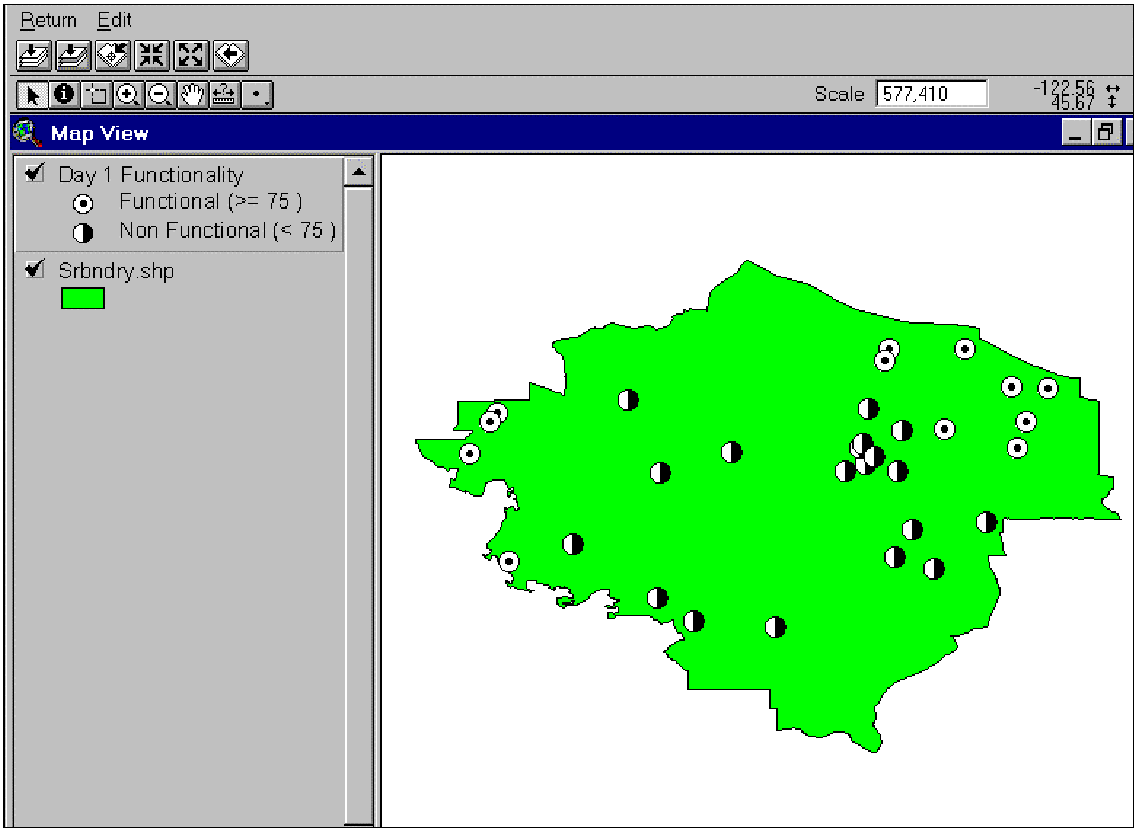


Figure 10.18 Output of the lifeline module: map functionality of airport terminal buildings.

10.8 Induced Physical Damage

HAZUS includes information about earthquake-related flooding to enable users to design programs to reduce the likelihood of dam or levee failure and to prepare to cope with those floods that may occur. Development of inundation maps requires an understanding of the downstream topography and the involvement of an experienced hydrologist. In the case of tsunamis, inundation models are complex and are in many cases still in the development stage; therefore, **HAZUS** does not produce inundation maps. Instead, as a first step in assessing the risk to a study region, all dams and levees are identified. The existing national inventory of dams that is provided with the software includes a hazard classification (low, significant, high) based on the downstream urban development and potential economic loss. The potential for tsunamis and seiches are assessed (by the user outside **HAZUS**) without any estimate of size or consequence. Table 10.8 summarizes the outputs that are available from **HAZUS**.

Table 10.8 Induced Physical Damage Module Outputs - Inundation

Component	Description of Output	Measure
Tsunami	a) The methodology provides rules to determine if tsunamis are a threat to the study region. b) The user can import existing tsunami inundation maps and overlay with population and economic value maps.	a) Qualify Potential Threat b) Exposed Population Exposed Value ($)
Seiche	a) The methodology provides rules to determine if seiches are a threat on any body of water in the study region. b) The user can import existing seiche inundation maps and overlay with population and economic value maps.	a) Qualify Potential Threat b) Exposed Population Exposed Value ($)
Dam Failure	a) **HAZUS** displays the location of all dams in the study region and (for the default database) ranks the potential impact of the dam failure. b) The user can import existing dam failure inundation maps and overlay with population and economic value maps.	a) List of and Locations of Dams and Quantification of Potential Hazard b) Exposed Population Exposed Value ($)
Levee Failure	a) **HAZUS** displays the location of the levees in the study region. b) The user can import existing levee failure inundation maps and overlay with population and economic value maps.	a) List of and Locations of Levees b) Exposed Population Exposed Value ($)

For all four inundation types, **HAZUS** has the ability to import existing inundation maps. These can then be overlaid with population density maps or maps of inventory to estimate exposed population and exposed inventory. The output of the inundation module is a display of the inundation maps that were specified in the data window shown in Figure 9.32. An example is shown in Figure 10.19. To access this map, use the **Map|Inundation Maps|Dams** menu. This map can be overlaid with population data to obtain an understanding of the exposed population, as shown in Figure 10.20. Alternatively, you can view a table of population, value and area exposure by census tract using the **Results|Inundation** menu (see Figure 10.21). This output is only available if an inundation map has been specified. Highlighting the appropriate column and clicking on the Map button can map any one of the outputs in Figure 10.21.

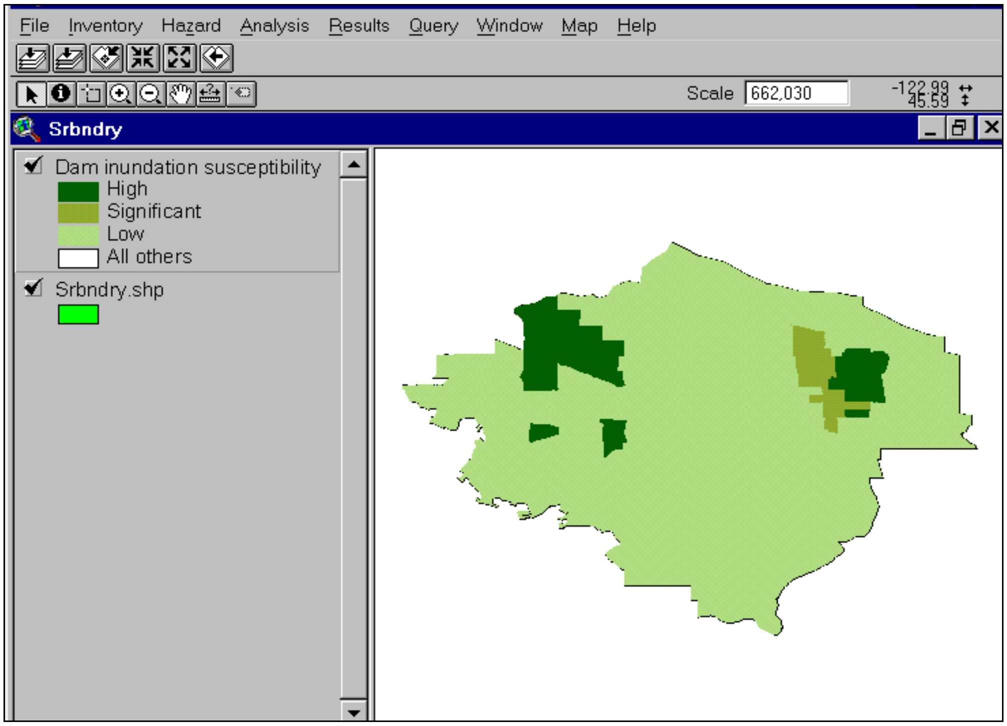


Figure 10.19 Display of inundation potential map.

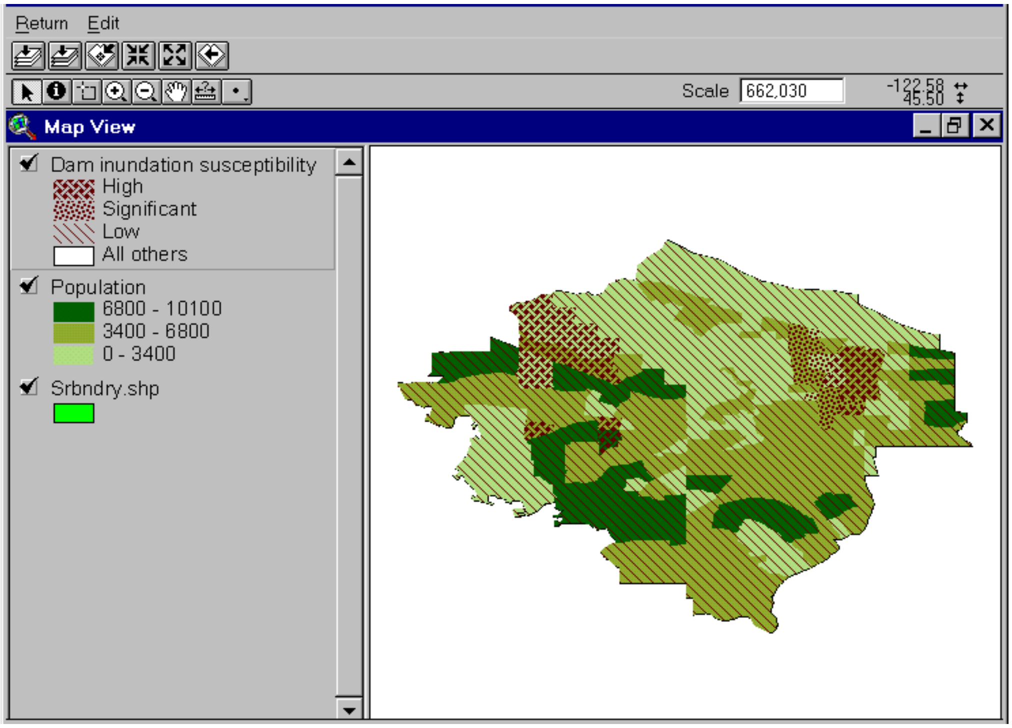


Figure 10.20 Population data overlaid with the inundation potential map.

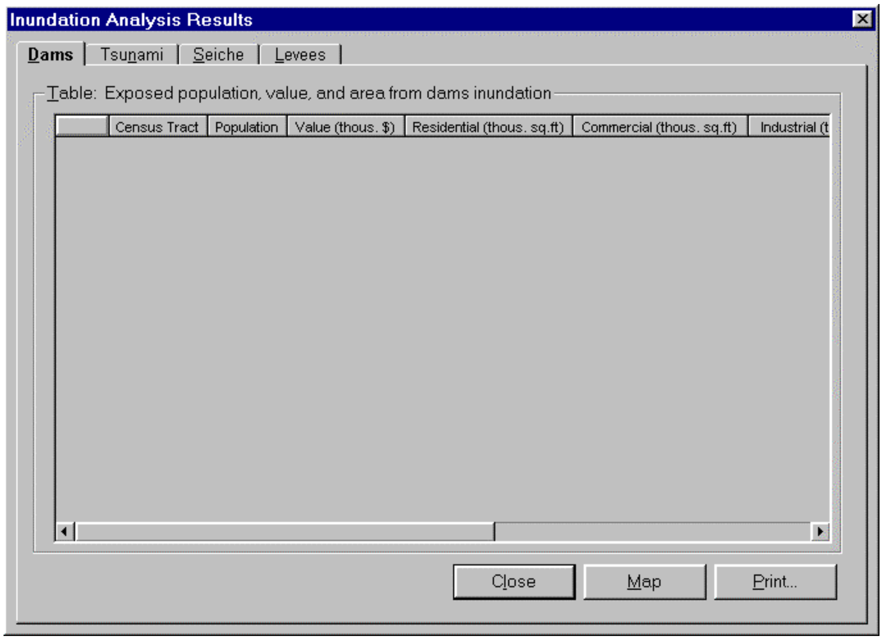


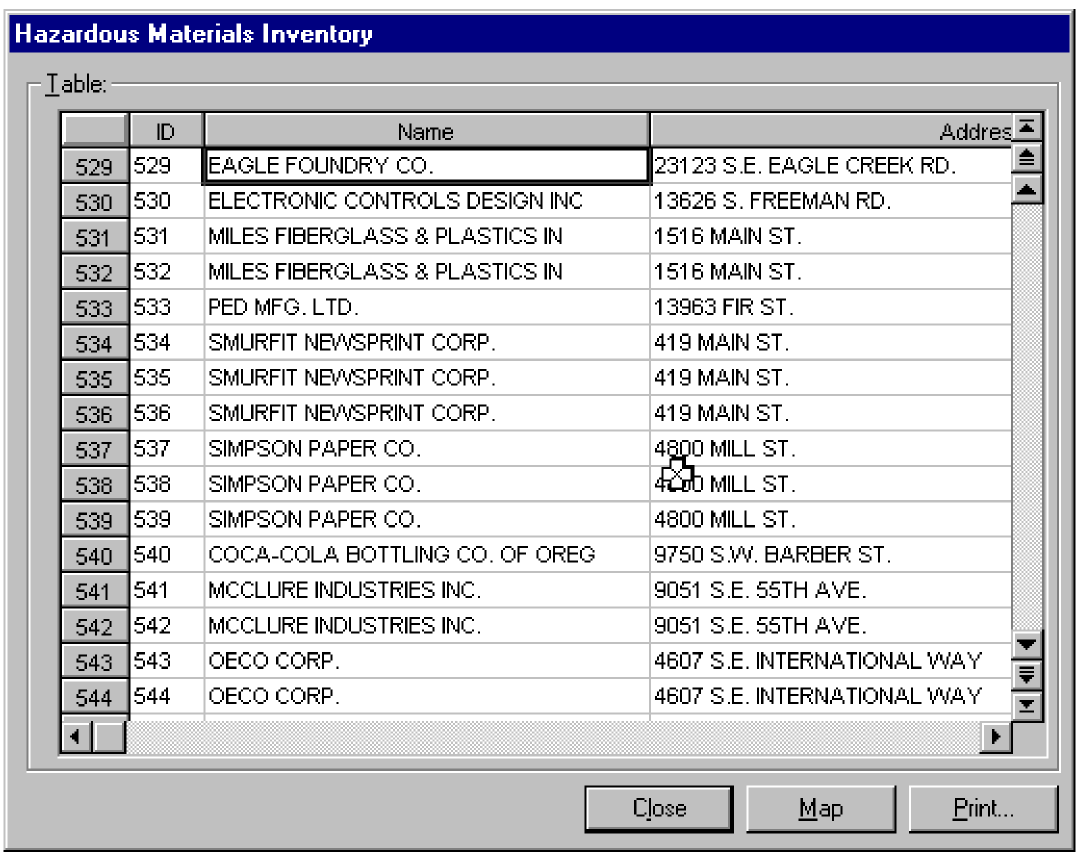
Figure 10.21 Tabulation of exposed population, value and area resulting from inundation map.

Assessment of the consequences of a hazardous materials release requires an understanding of the amounts and types of materials that are released as well as, in some cases, a model of a gaseous plume. A single facility may house many toxic and hazardous materials. Without visiting a facility, assessing the vulnerability of the structure and auditing how materials are stored, it is impossible to give a meaningful estimate of risk. Therefore **HAZUS** does not perform any analysis on hazardous. Locations of hazardous materials facilities can be mapped and overlaid with ground motion, population and inventory maps. This can provide a preliminary assessment of consequences, which can then be followed up with detailed site-specific studies. In addition, the hazardous facility database can be sorted in a variety of ways allowing the user to view only certain types of materials, facilities with large amounts, highly vulnerable facilities, etc. Table 10.9 summarizes the information available from the hazardous materials module.

Table 10.9 Induced Physical Damage Module - Hazardous Material Release

Component	Description	Measure
Hazardous Materials Facilities	a) **HAZUS** provides the location of the hazardous material facilities located in the study region. b) **HAZUS** provides the types and amounts of hazardous materials stored at each location and the health hazard associated with each chemical. c) The user can overlay a map of hazardous material facilities with ground shaking, population, and economic value maps to interrogate the consequences of release at a particular site.	a) List of and Locations of Facilities Containing Hazardous Materials b) Type/Amount of Material Stored at Each Facility

There us no output for the hazardous materials module. The inventory information can be accessed using **Inventory|Hazardous Materials.** Form Hazardous Material database you can get a listing of the materials and plots of locations of sites as shown in Figures 10.22 and 10.23. Clicking the Map button at the bottom of Figure 10.22 generated the output shown in Figure 10.23. The information in the small box at the left-hand side of Figure 10.23 was retrieved using the information tool (**i**) in the ArcView Main menu. By using the information tool and clicking on any one of the sites, you can access all of the stored data for that site.



	ID	Name	Addres
529	529	EAGLE FOUNDRY CO.	23123 S.E. EAGLE CREEK RD.
530	530	ELECTRONIC CONTROLS DESIGN INC	13626 S. FREEMAN RD.
531	531	MILES FIBERGLASS & PLASTICS IN	1516 MAIN ST.
532	532	MILES FIBERGLASS & PLASTICS IN	1516 MAIN ST.
533	533	PED MFG. LTD.	13963 FIR ST.
534	534	SMURFIT NEWSPRINT CORP.	419 MAIN ST.
535	535	SMURFIT NEWSPRINT CORP.	419 MAIN ST.
536	536	SMURFIT NEWSPRINT CORP.	419 MAIN ST.
537	537	SIMPSON PAPER CO.	4800 MILL ST.
538	538	SIMPSON PAPER CO.	4[illegible]0 MILL ST.
539	539	SIMPSON PAPER CO.	4800 MILL ST.
540	540	COCA-COLA BOTTLING CO. OF OREG	9750 S.W. BARBER ST.
541	541	MCCLURE INDUSTRIES INC.	9051 S.E. 55TH AVE.
542	542	MCCLURE INDUSTRIES INC.	9051 S.E. 55TH AVE.
543	543	OECO CORP.	4607 S.E. INTERNATIONAL WAY
544	544	OECO CORP.	4607 S.E. INTERNATIONAL WAY

Figure 10.22 Default hazardous material database.

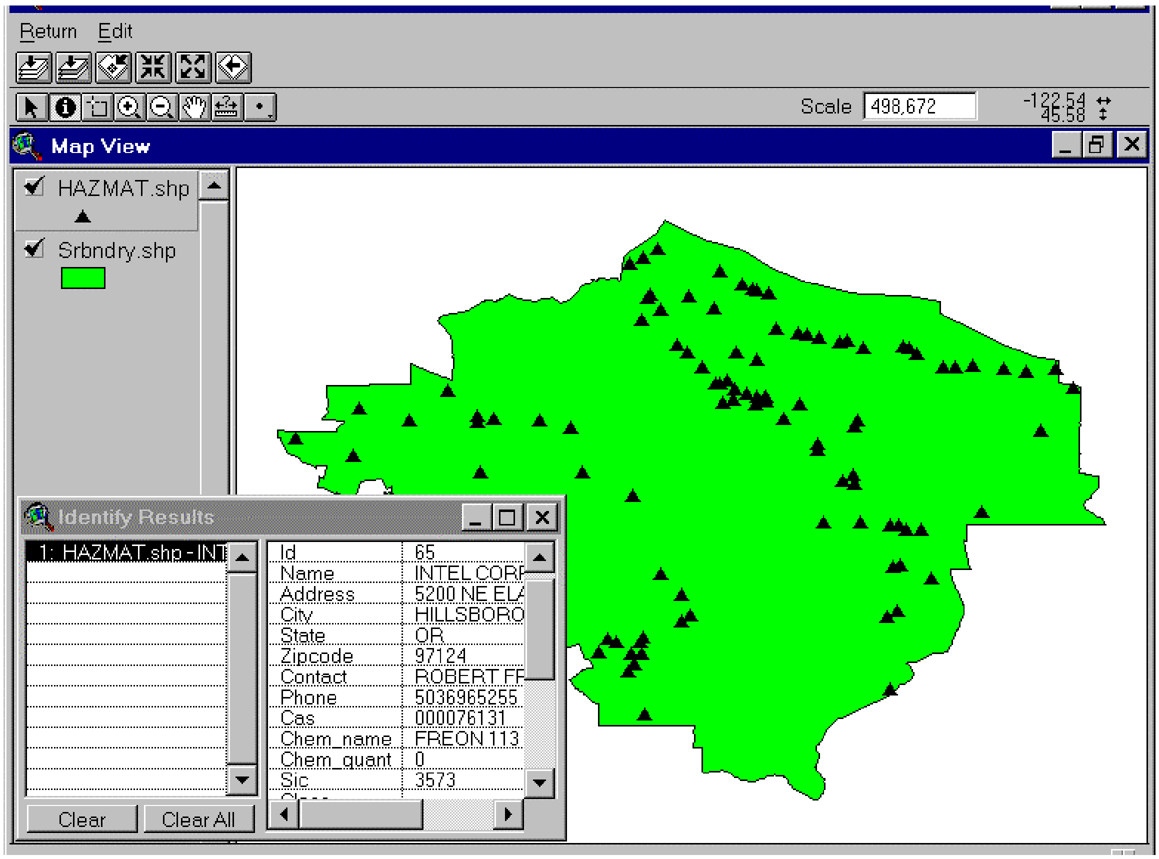


Figure 10.23 Map of default hazardous materials database

Another feature of **HAZUS** is that you can query the database and plot specific types of data. In Figure 10.27, all of the sites at which ammonia or chlorine are stored have been identified and are plotted as large triangles. This was done using the **Query** menu.

To create such a map, follow these steps. Plot the hazardous materials database for your region using the **Map** button at the bottom of the window shown in Figure 10.22. Then click on the **Return** menu at the upper left-hand corner of the map. Click on **Return to Table**. Close the table using the **Close** button at the bottom of the window (see Figure 10.22). Click on the **Query|Query** menu and the dialog box shown in Figure 10.24 will appear. By double clicking on different selection parameters and using various pull down menus, you can create a query from the table called HAZMAT.

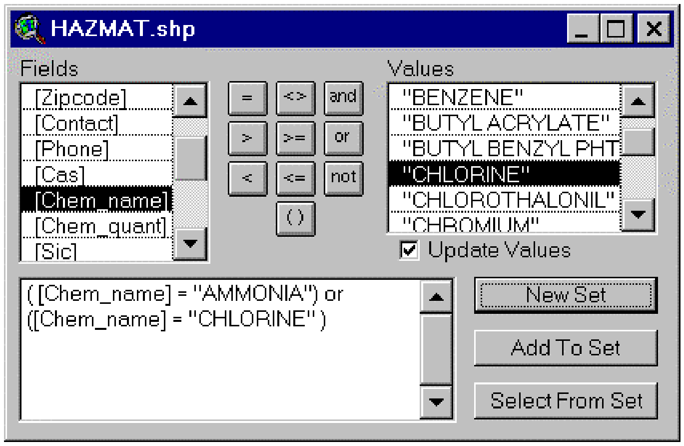


Figure 10.24 Developing a query to identify sites that store ammonia or chlorine.

The facilities that satisfy the selection criteria will appear highlighted on the inventory map as shown in Figure 10.25.

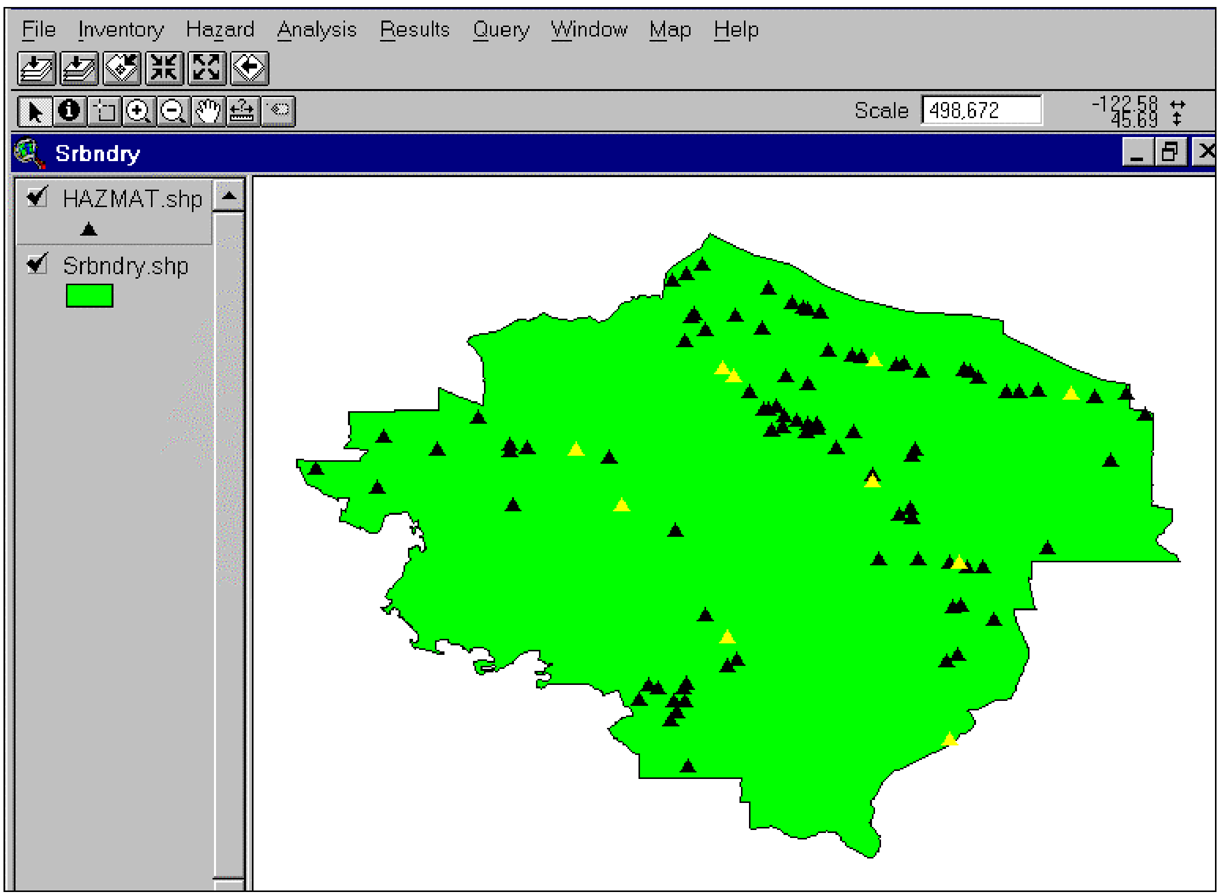


Figure 10.25 The result of the query

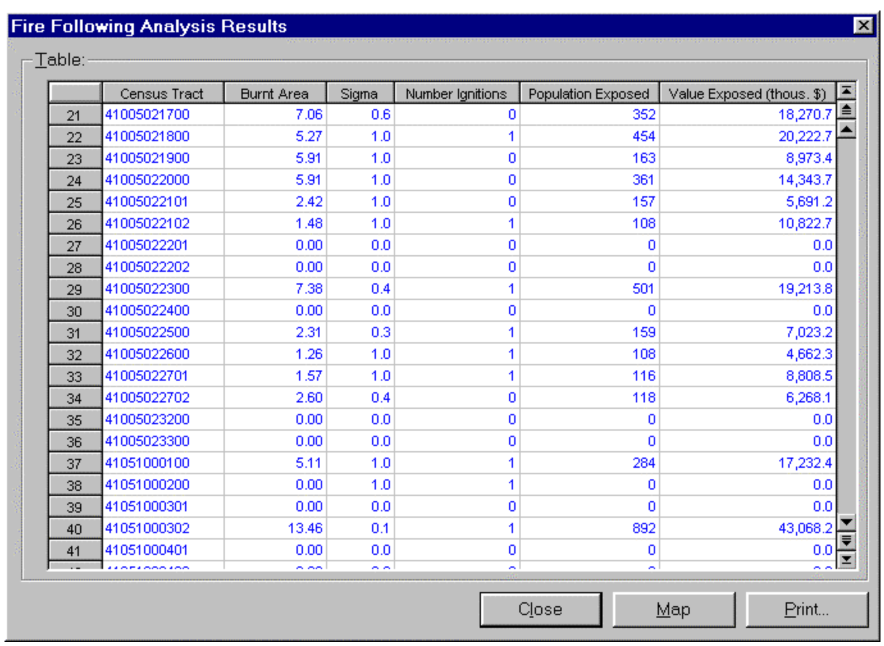
A complete Fire Following Earthquake Model requires extensive input including the types and density of fuel, the number of fire fighting apparatus, the functionality of the water system, the occurrence of hazardous materials releases, wind conditions, and others. To simplify the input, **HAZUS** limits the analysis to an estimate of the number of ignitions, an estimate of the size of the potential burned area, and estimates of exposed population and exposed inventory.

Table 10.10 Induced Physical Damage Module Outputs - Fire Following Earthquake

Component	Description of Output	Measure
Ignition	a) **HAZUS** determines the expected number of fire ignitions by census tract for the study region.	a) Number of ignitions
Burned Area	a) **HAZUS** determines the expected burned area by census tract for the study region. b) Expected burned area is combined with population and economic value to estimate exposed population and inventory.	a) Percentage of Burned Area b) Exposed Population Exposed Value ($)

The outputs from Fire Following Earthquake Model are presented in **HAZUS** in a table as shown in Figure 10.26. For each census tract in the study region, the following values are displayed:

Best estimates of the percent of the census tract that has been burned
Standard deviation of the estimate of percent of burned area
Number of ignitions in the census tract
The population in the census tract that is exposed to fire (% burned area X total population in census tract)
The value of inventory (in dollars) in the census tract fire exposed to fire (% burned area X total building value in census tract)



	Census Tract	Burnt Area	Sigma	Number Ignitions	Population Exposed	Value Exposed (thous. $)
21	41005021700	7.06	0.6	0	352	18,270.7
22	41005021800	5.27	1.0	1	454	20,222.7
23	41005021900	5.91	1.0	0	163	8,973.4
24	41005022000	5.91	1.0	0	361	14,343.7
25	41005022101	2.42	1.0	0	157	5,691.2
26	41005022102	1.48	1.0	1	108	10,822.7
27	41005022201	0.00	0.0	0	0	0.0
28	41005022202	0.00	0.0	0	0	0.0
29	41005022300	7.38	0.4	1	501	19,213.8
30	41005022400	0.00	0.0	0	0	0.0
31	41005022500	2.31	0.3	1	159	7,023.2
32	41005022600	1.26	1.0	1	108	4,662.3
33	41005022701	1.57	1.0	1	116	8,808.5
34	41005022702	2.60	0.4	0	118	6,268.1
35	41005023200	0.00	0.0	0	0	0.0
36	41005023300	0.00	0.0	0	0	0.0
37	41051000100	5.11	1.0	1	284	17,232.4
38	41051000200	0.00	1.0	1	0	0.0
39	41051000301	0.00	0.0	0	0	0.0
40	41051000302	13.46	0.1	1	892	43,068.2
41	41051000401	0.00	0.0	0	0	0.0

Figure 10.26 Output of fire following earthquake module.

Highlighting the column and then clicking on the Map button will map any of the columns in Figure 10.26. The "Burnt Area (%)" column has been mapped in Figure 10.27. A summary report of the output of the Fire Following Earthquake Model can also be printed to the screen or to a printer.

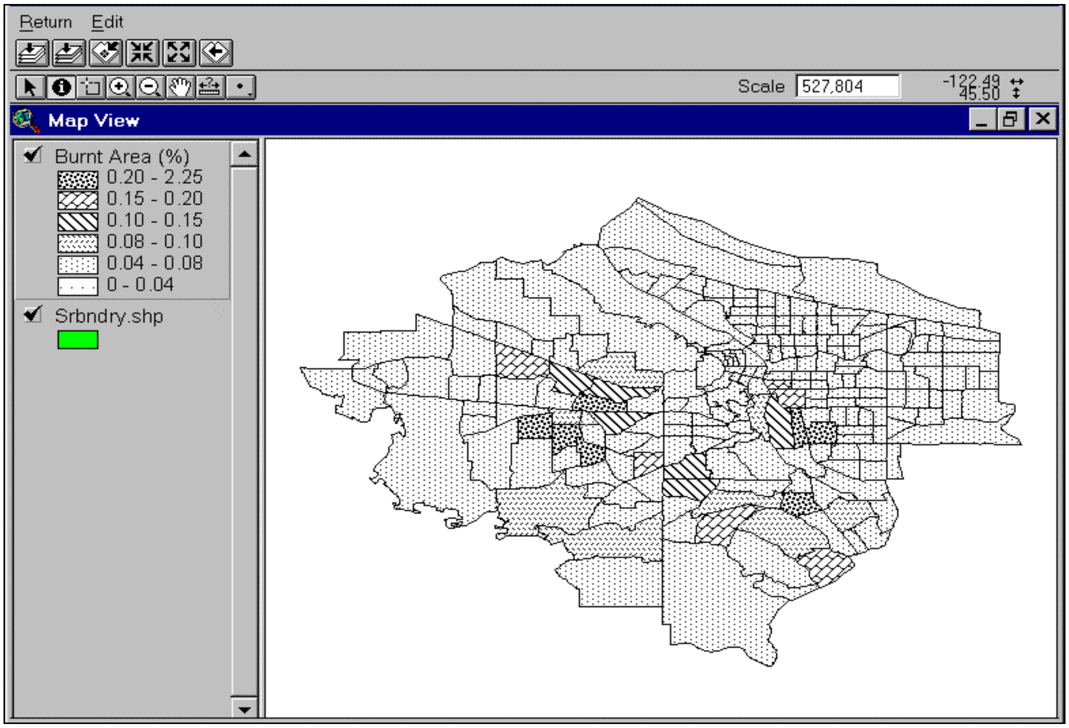


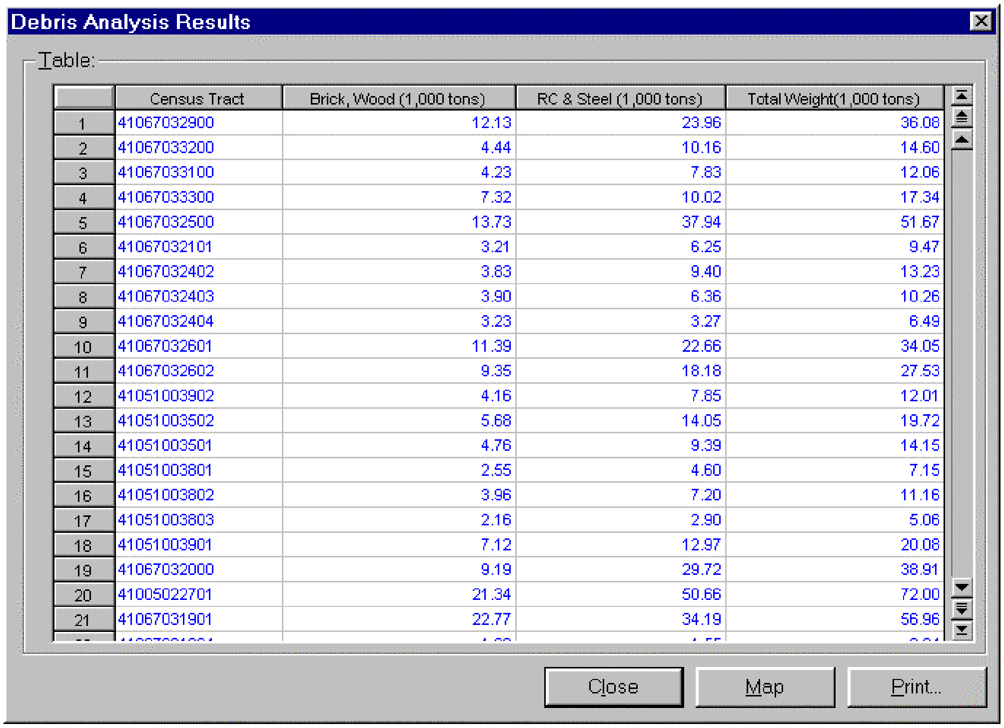
Figure 10.27 Map of percent of each census tract burned.

HAZUS provides information about the debris generated during the seismic event to enable users to prepare and to rapidly and efficiently manage debris removal and disposal. As shown in Table 10.11, two types of debris are identified: (1) reinforced concrete and steel that requires special equipment to break it up before it can be transported, and (2) brick, wood and other debris that can be loaded directly onto trucks with bulldozers. For each census tract, **HAZUS** determines the amount of debris of each type that is generated.

Table 10.11 Induced Physical Damage Module Outputs - Debris

Component	Description of Output	Measure
Brick, Wood & Others	a) **HAZUS** determines the expected amount of brick, wood, and other debris generated in each census tract of the study region.	a) Weight of Debris Generated
Reinforced Concrete & Steel	a) **HAZUS** determines the expected amount of reinforced concrete and steel debris generated in each census tract of the study region.	a) Weight of Debris Generated

In **HAZUS,** debris results will appear as a table, as shown in Figure 10.28, that can be printed to the screen or the printer. In addition, you will be able to map by census tract the weight of generated debris using the **Map** button, as shown in Figure 10.29.



Debris Analysis Results

Table:

	Census Tract	Brick, Wood (1,000 tons)	RC & Steel (1,000 tons)	Total Weight(1,000 tons)
1	41067032900	12.13	23.96	36.08
2	41067033200	4.44	10.16	14.60
3	41067033100	4.23	7.83	12.06
4	41067033300	7.32	10.02	17.34
5	41067032500	13.73	37.94	51.67
6	41067032101	3.21	6.25	9.47
7	41067032402	3.83	9.40	13.23
8	41067032403	3.90	6.36	10.26
9	41067032404	3.23	3.27	6.49
10	41067032601	11.39	22.66	34.05
11	41067032602	9.35	18.18	27.53
12	41051003902	4.16	7.85	12.01
13	41051003502	5.68	14.05	19.72
14	41051003501	4.76	9.39	14.15
15	41051003801	2.55	4.60	7.15
16	41051003802	3.96	7.20	11.16
17	41051003803	2.16	2.90	5.06
18	41051003901	7.12	12.97	20.08
19	41067032000	9.19	29.72	38.91
20	41005022701	21.34	50.66	72.00
21	41067031901	22.77	34.19	56.96

Close Map Print...

Figure 10.28 Output of the debris module in thousands of tons per census tract.

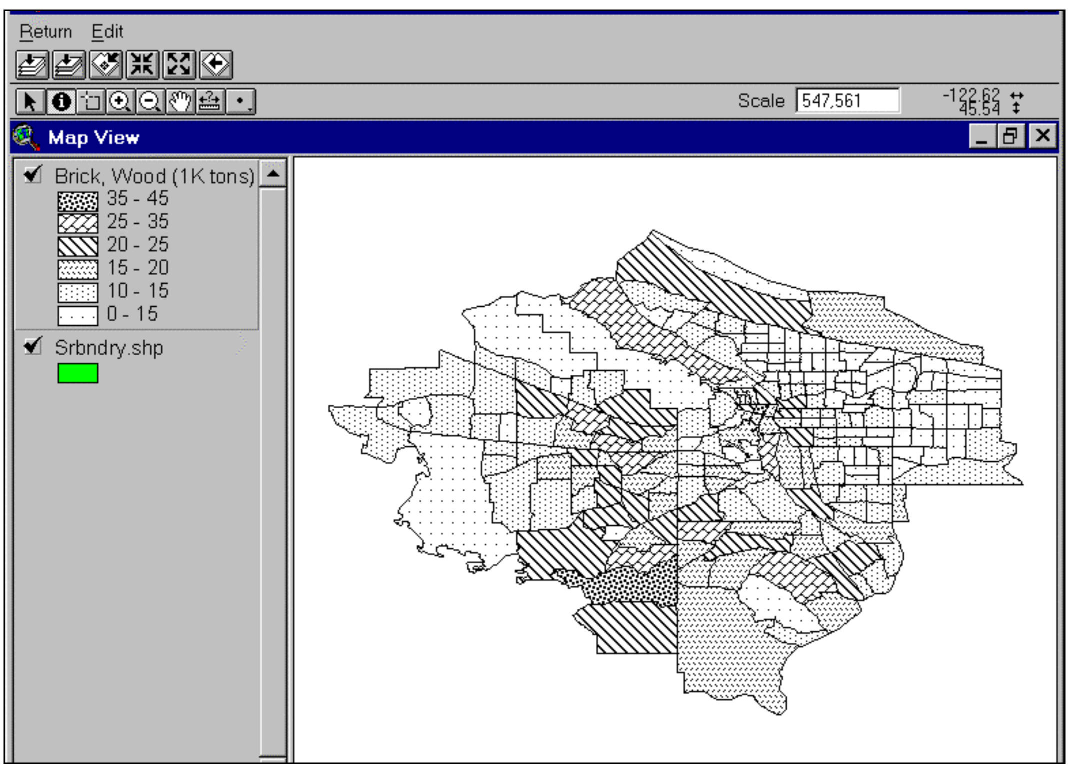


Figure 10.29 Weight of generated debris (brick, wood and other) by census tract.

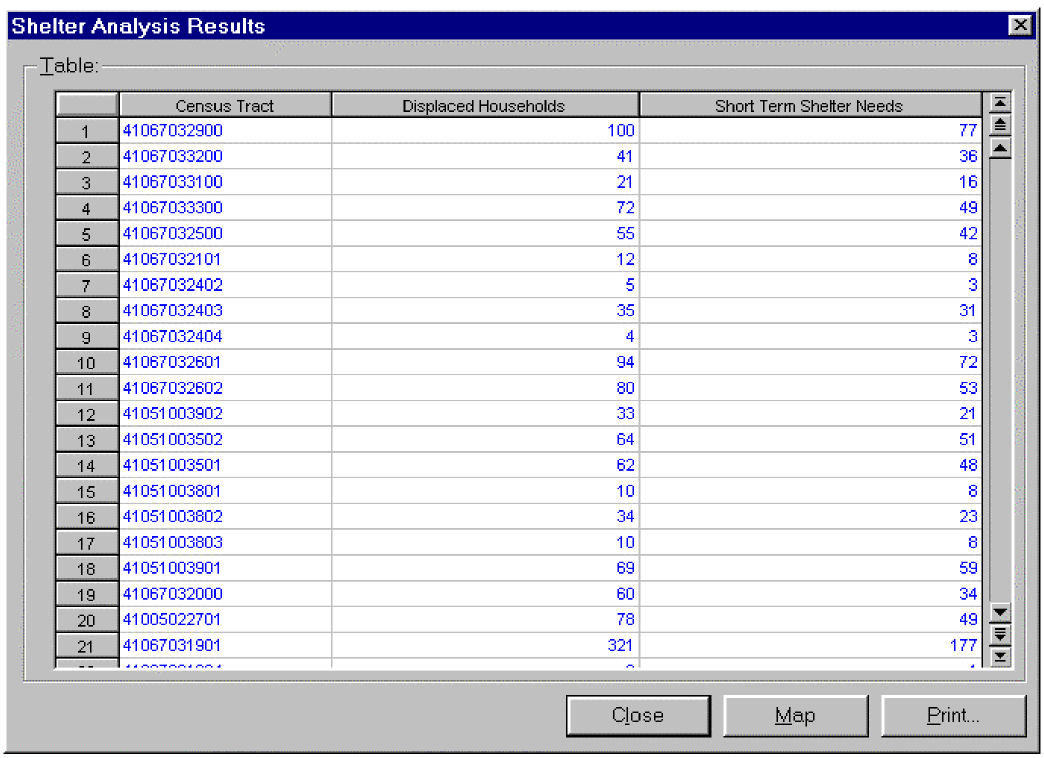
10.9 Direct Economic and Social Losses

HAZUS provides information concerning the estimated number of displaced households and persons requiring temporary shelter to enable the design of programs to temporarily shelter victims.

Table 10.11 Direct Economic and Social Losses Module Outputs - Shelter

Component	Description of Output	Measure
Displaced Households	a) **HAZUS** determines the expected number of displaced households by census tract in the study region.	a) Number of Displaced Households
Temporary Shelter	a) **HAZUS** determines the expected number of people requiring temporary shelter by census tract in the study region.	a) Number of People Requiring Temporary Shelter

The total number of displaced households for each census tract of the study region is one output of the shelter module. The number of displaced households is used to estimate the short-term shelter needs. Short-term shelter needs are reported in the number of people needing public shelter. The results, as displayed in Figure 10.30, are retrieved using the **Results|Shelter** menu. As with all results, these can be thematically mapped by highlighting a column and clicking on the **Map** button.



Shelter Analysis Results

Table:

	Census Tract	Displaced Households	Short Term Shelter Needs
1	41067032900	100	77
2	41067033200	41	36
3	41067033100	21	16
4	41067033300	72	49
5	41067032500	55	42
6	41067032101	12	8
7	41067032402	5	3
8	41067032403	35	31
9	41067032404	4	3
10	41067032601	94	72
11	41067032602	80	53
12	41051003902	33	21
13	41051003502	64	51
14	41051003501	62	48
15	41051003801	10	8
16	41051003802	34	23
17	41051003803	10	8
18	41051003901	69	59
19	41067032000	60	34
20	41005022701	78	49
21	41067031901	321	177

Close Map Print...

Figure 10.30 Output of shelter module.

The output of the casualty module is summarized in Table 10.12.

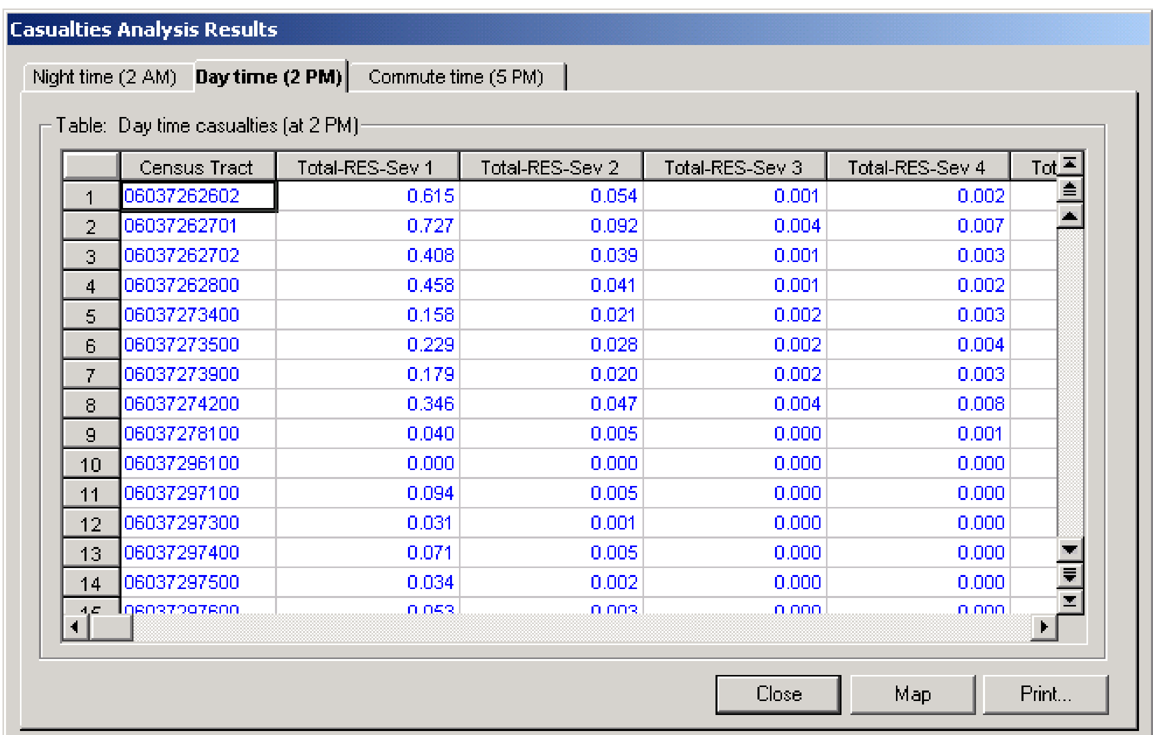
Table 10.12 Direct Economic and Social Losses Module Outputs - Casualties

Component	Description of Output	Measure
Casualties	a) **HAZUS** determines the expected number of casualties for each casualty severity (medical aid, hospital treatment, life-threatening, death) by census tract for the study region.	a) Number of casualties for each of the four severities

For each census tract, the following results (use **Results|Casualties** menu) are provided at three times of day (2 AM, 2 PM and 5 PM) by occupancy type or by building type.

- Residential casualties (severity 1, 2, 3 and 4)
- Commercial casualties (severity 1, 2, 3 and 4)
- Industrial casualties (severity 1, 2, 3 and 4)
- Education casualties (severity 1, 2, 3 and 4)
- Hotel casualties (severity 1, 2, 3 and 4)
- Commuting casualties (severity 1, 2, 3 and 4)
- Total casualties (severity 1, 2, 3 and 4)

As with the other output, highlighting the desired column and clicking on the Map button will map the results.



	Census Tract	Total-RES-Sev 1	Total-RES-Sev 2	Total-RES-Sev 3	Total-RES-Sev 4	Tot
1	06037262602	0.615	0.054	0.001	0.002	
2	06037262701	0.727	0.092	0.004	0.007	
3	06037262702	0.408	0.039	0.001	0.003	
4	06037262800	0.458	0.041	0.001	0.002	
5	06037273400	0.158	0.021	0.002	0.003	
6	06037273500	0.229	0.028	0.002	0.004	
7	06037273900	0.179	0.020	0.002	0.003	
8	06037274200	0.346	0.047	0.004	0.008	
9	06037278100	0.040	0.005	0.000	0.001	
10	06037296100	0.000	0.000	0.000	0.000	
11	06037297100	0.094	0.005	0.000	0.000	
12	06037297300	0.031	0.001	0.000	0.000	
13	06037297400	0.071	0.005	0.000	0.000	
14	06037297500	0.034	0.002	0.000	0.000	
15	06037297600	0.053	0.003	0.000	0.000	

Figure 10.31 Output of casualty module showing residential casualties at 2 PM.

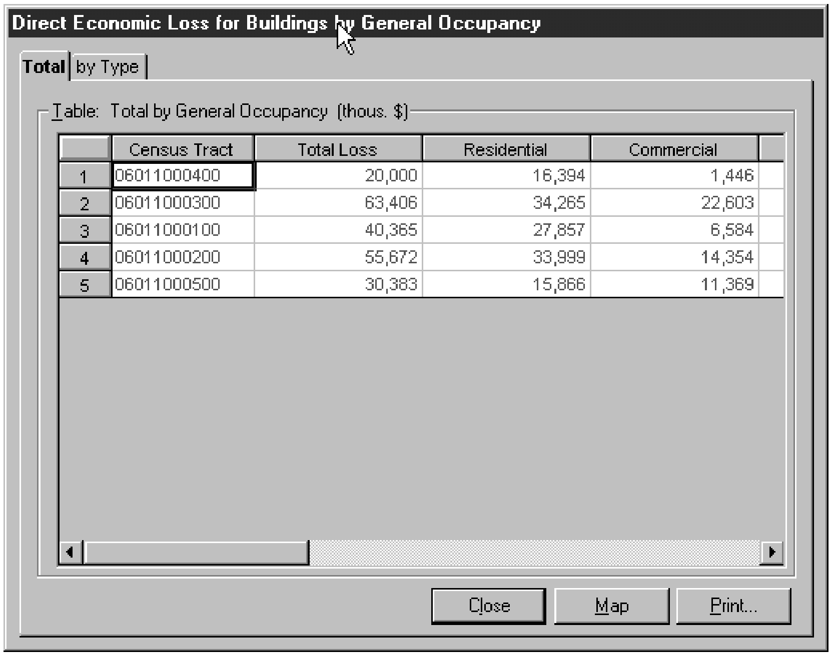
HAZUS provides economic loss information to enable users to motivate policy-makers to consider cost-benefit implication of mitigation activities. All default data for direct economic loss estimates are provided in 1994 dollars. You will need to convert 1994 dollars to those that are valid when you run your study. Losses for lifelines are reported separately from losses for buildings.

Table 10.13 Direct Economic and Social Losses Module Outputs - Direct Economic Loss - Buildings

Component	Description of Output	Measure
Repair and Replacement Costs	a) **HAZUS** determines the expected dollar loss due to the repair and replacement of the general building stock by census tract for the study region.	a) Dollar Loss
Contents Damage	a) **HAZUS** determines the expected dollar loss due to contents damage by census tract for the study region.	a) Dollar Loss
Business Inventory Damage	a) **HAZUS** determines the expected dollar loss due to business inventory damage by census tract for the study region.	a) Dollar Loss
Relocation Costs	a) **HAZUS** determines the expected dollar loss due to business relocation by census tract for the study region.	a) Dollar Loss
Capital-related Income Loss	a) **HAZUS** determines the expected business income loss by census tract for the study region.	a) Dollar Loss
Wage Loss	a) **HAZUS** determines the expected wage loss by census tract for the study region.	a) Dollar Loss
Rental Loss	a) **HAZUS** determines the expected dollar loss due to the repair and replacement of buildings by census tract for the study region.	a) Dollar Loss

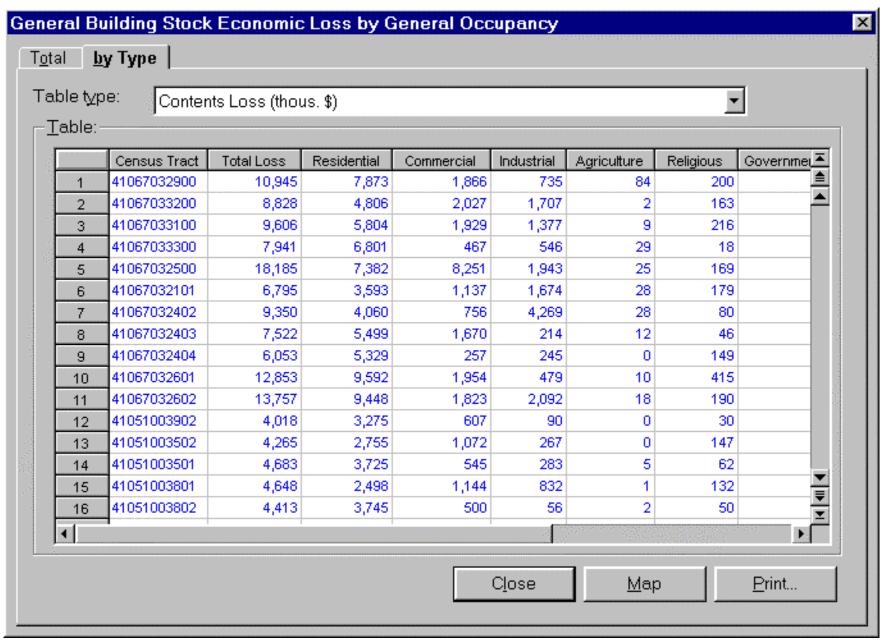
Building loss estimates can be viewed by clicking on the **Results|Buildings Economic Loss** menu. Building losses are summarized in terms of the seven General Occupancy classes (Residential, Commercial, Industrial, Agriculture, Religious, Government and Education), or in terms of the 28 Specific Occupancy Classes. As can be seen in Figure 10.32, the total direct economic losses for each census tract are reported. The total losses include structural and non-structural repair, contents loss, relocation costs, proprietor's income loss and rental loss.

Losses also can be reported by type. The types reported are structural and non-structural repair, total building costs (the sum of structural and non-structural), contents loss, relocation costs, proprietor's income loss and rental loss. These losses are reported by census tract for each of the seven general occupancy classes as shown in Figure 10.33.



	Census Tract	Total Loss	Residential	Commercial
1	06011000400	20,000	16,394	1,446
2	06011000300	63,406	34,265	22,603
3	06011000100	40,365	27,857	6,584
4	06011000200	55,672	33,999	14,354
5	06011000500	30,383	15,866	11,369

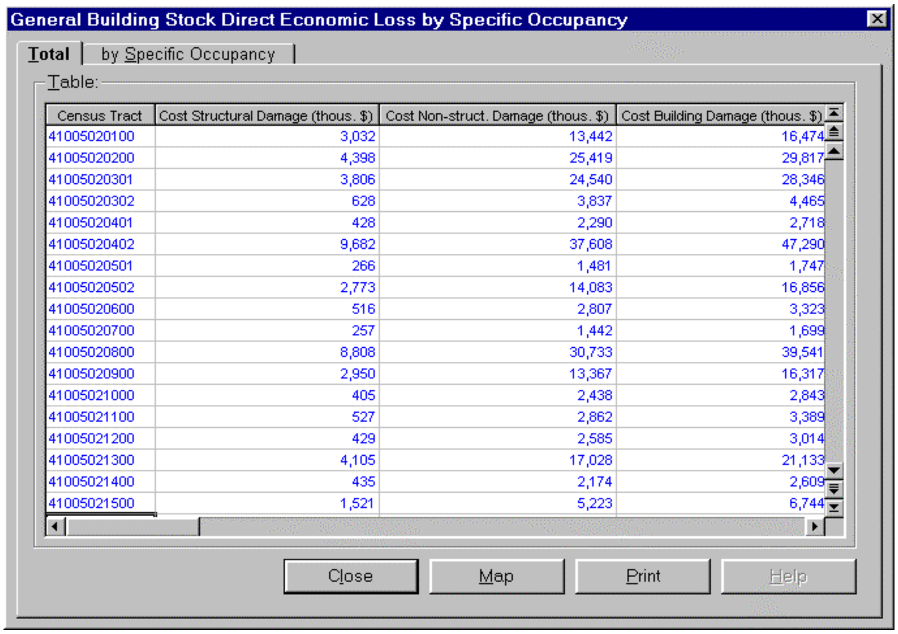
Figure 10.32 Total building losses reported by general occupancy class



	Census Tract	Total Loss	Residential	Commercial	Industrial	Agriculture	Religious	Governme
1	41067032900	10,945	7,873	1,866	735	84	200	
2	41067033200	8,828	4,806	2,027	1,707	2	163	
3	41067033100	9,606	5,804	1,929	1,377	9	216	
4	41067033300	7,941	6,801	467	546	29	18	
5	41067032500	18,185	7,382	8,251	1,943	25	169	
6	41067032101	6,795	3,593	1,137	1,674	28	179	
7	41067032402	9,350	4,060	756	4,269	28	80	
8	41067032403	7,522	5,499	1,670	214	12	46	
9	41067032404	6,053	5,329	257	245	0	149	
10	41067032601	12,853	9,592	1,954	479	10	415	
11	41067032602	13,757	9,448	1,823	2,092	18	190	
12	41051003902	4,018	3,275	607	90	0	30	
13	41051003502	4,265	2,755	1,072	267	0	147	
14	41051003501	4,683	3,725	545	283	5	62	
15	41051003801	4,648	2,498	1,144	832	1	132	
16	41051003802	4,413	3,745	500	56	2	50	

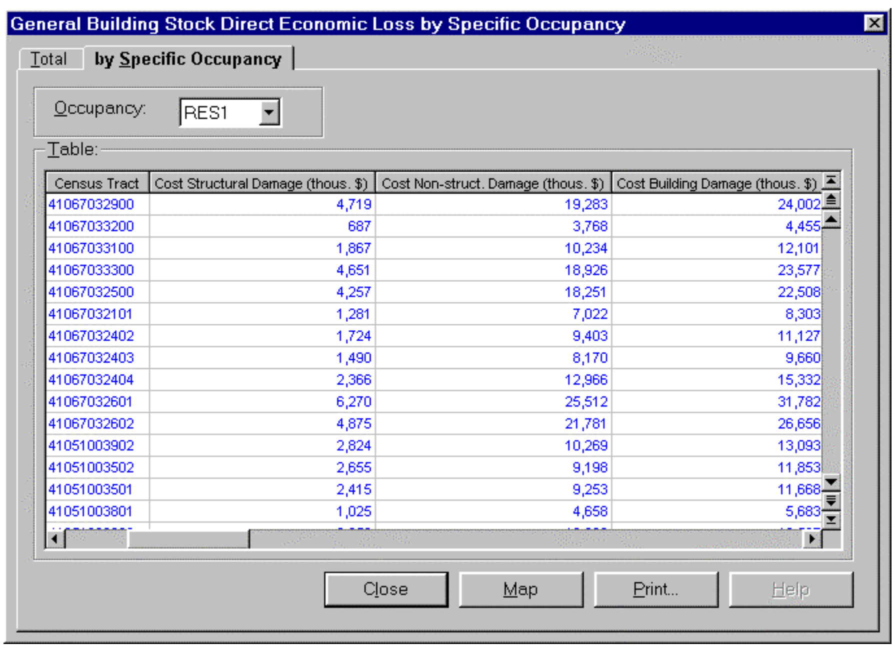
Figure 10.33 Types of building losses reported by general occupancy class

The total loss of each type for all economic sectors can be viewed using the window shown in Figure 10.34. This window differs from that shown in Figure 10.33 in that, for example, the total cost of structural damage as reported in Figure 10.34 is the sum of the contents damage for all of the seven general occupancies shown in Figure 10.33.



Census Tract	Cost Structural Damage (thous. $)	Cost Non-struct. Damage (thous. $)	Cost Building Damage (thous. $)
41005020100	3,032	13,442	16,474
41005020200	4,398	25,419	29,817
41005020301	3,806	24,540	28,346
41005020302	628	3,837	4,465
41005020401	428	2,290	2,718
41005020402	9,682	37,608	47,290
41005020501	266	1,481	1,747
41005020502	2,773	14,083	16,856
41005020600	516	2,807	3,323
41005020700	257	1,442	1,699
41005020800	8,808	30,733	39,541
41005020900	2,950	13,367	16,317
41005021000	405	2,438	2,843
41005021100	527	2,862	3,389
41005021200	429	2,585	3,014
41005021300	4,105	17,028	21,133
41005021400	435	2,174	2,609
41005021500	1,521	5,223	6,744

Figure 10.34 Types of building losses reported by census tract.



Census Tract	Cost Structural Damage (thous. $)	Cost Non-struct. Damage (thous. $)	Cost Building Damage (thous. $)
41067032900	4,719	19,283	24,002
41067033200	687	3,768	4,455
41067033100	1,867	10,234	12,101
41067033300	4,651	18,926	23,577
41067032500	4,257	18,251	22,508
41067032101	1,281	7,022	8,303
41067032402	1,724	9,403	11,127
41067032403	1,490	8,170	9,660
41067032404	2,366	12,966	15,332
41067032601	6,270	25,512	31,782
41067032602	4,875	21,781	26,656
41051003902	2,824	10,269	13,093
41051003502	2,655	9,198	11,853
41051003501	2,415	9,253	11,668
41051003801	1,025	4,658	5,683

Figure 10.35 Types of building losses reported by specific occupancy

Finally, losses can be reported for each of the 28 specific occupancy classes for each census tract as shown in Figure 10.35.

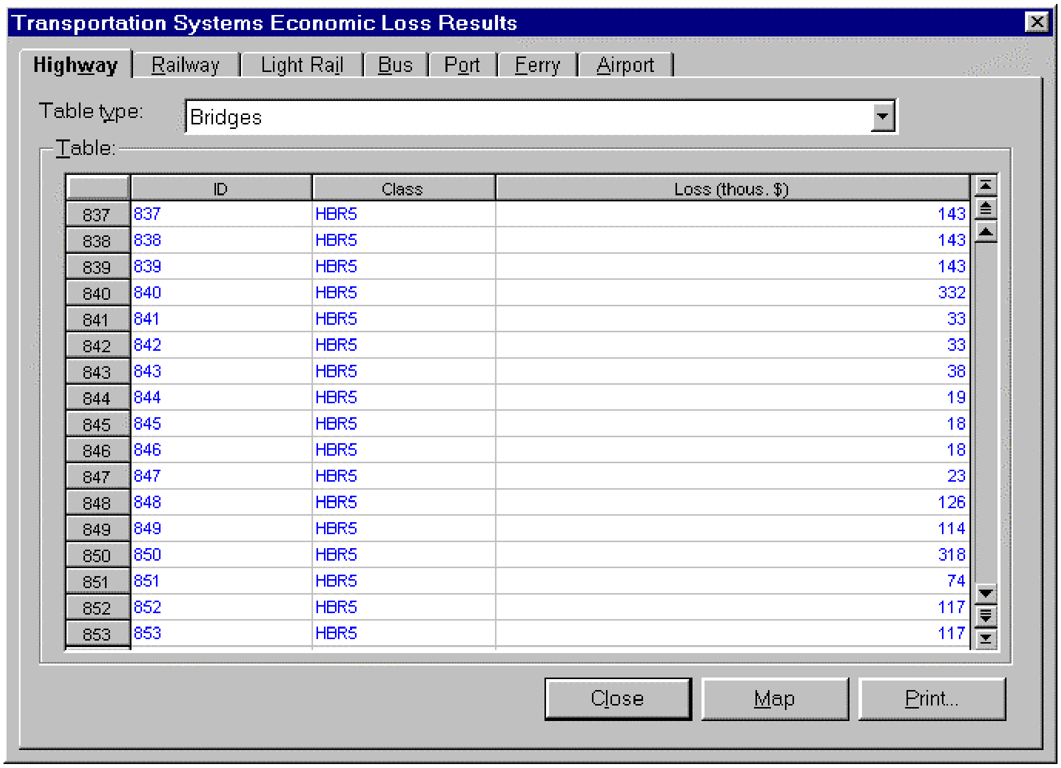
The loss estimates for lifeline systems are summarized in Table 10.14. These are accessed through the **Results|Lifelines Economic Loss** menu.

Table 10.14 Direct economic and social losses module outputs - direct economic loss - lifelines

Component	Description of Output	Measure

Repair and Replacement Costs	a) The methodology determines the expected dollar loss due to the repair and replacement of lifelines components.	a) Dollar Loss

Figure 10.36 shows an example of a results window for transportation systems. Losses are reported for each component of the system, for example, in this window, losses are reported for each highway bridge. You can create similar reports for each type of component and each type of lifeline by clicking on the tabs at the top of Figure 10.36 and using the list box next to the label "Table Type". The results in Figures 10.32 through 10.36 can be mapped by clicking on the **Map** button.



	ID	Class	Loss (thous. $)
837	837	HBR5	143
838	838	HBR5	143
839	839	HBR5	143
840	840	HBR5	332
841	841	HBR5	33
842	842	HBR5	33
843	843	HBR5	38
844	844	HBR5	19
845	845	HBR5	18
846	846	HBR5	18
847	847	HBR5	23
848	848	HBR5	126
849	849	HBR5	114
850	850	HBR5	318
851	851	HBR5	74
852	852	HBR5	117
853	853	HBR5	117

Figure 10.36 Direct economic losses to lifeline components

10.10 Indirect Economic Impacts

HAZUS provides information concerning the indirect economic effects of the scenario event to enable financial institutions and government planners to anticipate losses and develop programs to compensate for them. The indirect economic impact information also enables users to motivate policy-makers to consider cost-benefit implications of mitigation activities.

Table 10.15 Indirect economic impacts module outputs

Component	Description of Output	Measure
Economic Output	a) Indirect output loss as a percentage of original output	Percentage
Employment	a) Indirect employment loss as a percentage of original employment	Percentage
Income	a) Indirect income loss as a percentage of original income	Percentage

10.11 Summary Reports

The options to view summaries of the outputs of each of the **HAZUS** modules are: Inventory, Building Damage, Lifeline Damage, Induced Damage and Losses as shown in the Figure 10.37. You can pick the summary report from any of the windows below and click on the **View** button to generate the report. Sample summary reports of building damage by general occupancy and building stock exposure by building type are shown in Figures 10.38 and 10.39. Additional information in these reports can be viewed by scrolling to the right. Clicking on the print button can print reports.

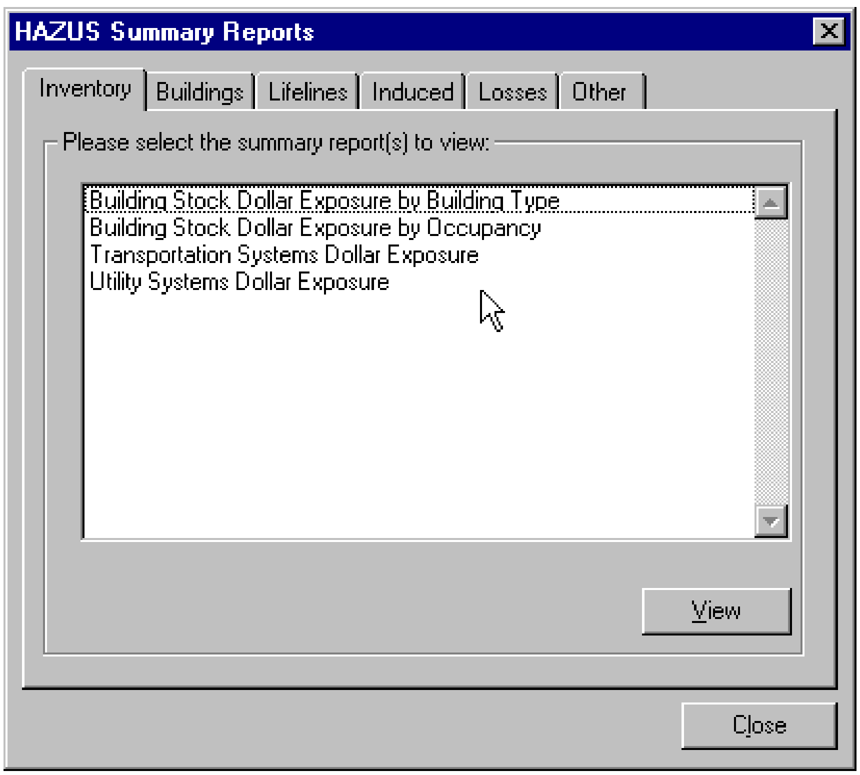
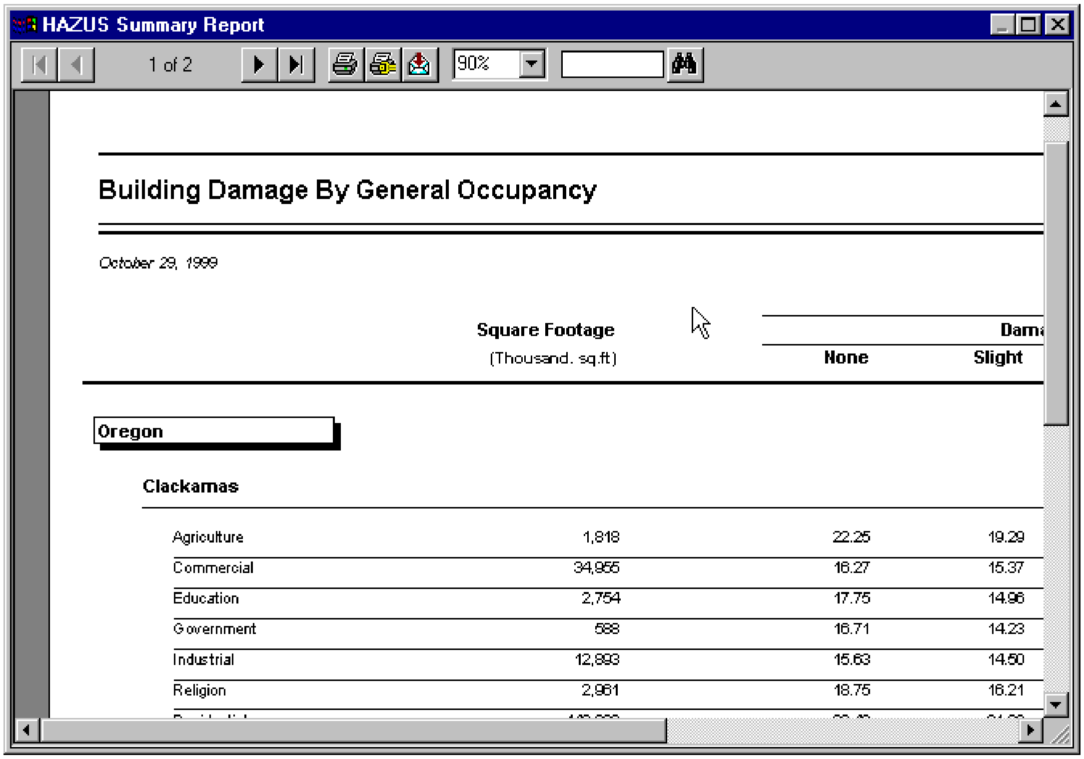


Figure 10.37 Summary report selection window for inventory summary report.



HAZUS Summary Report

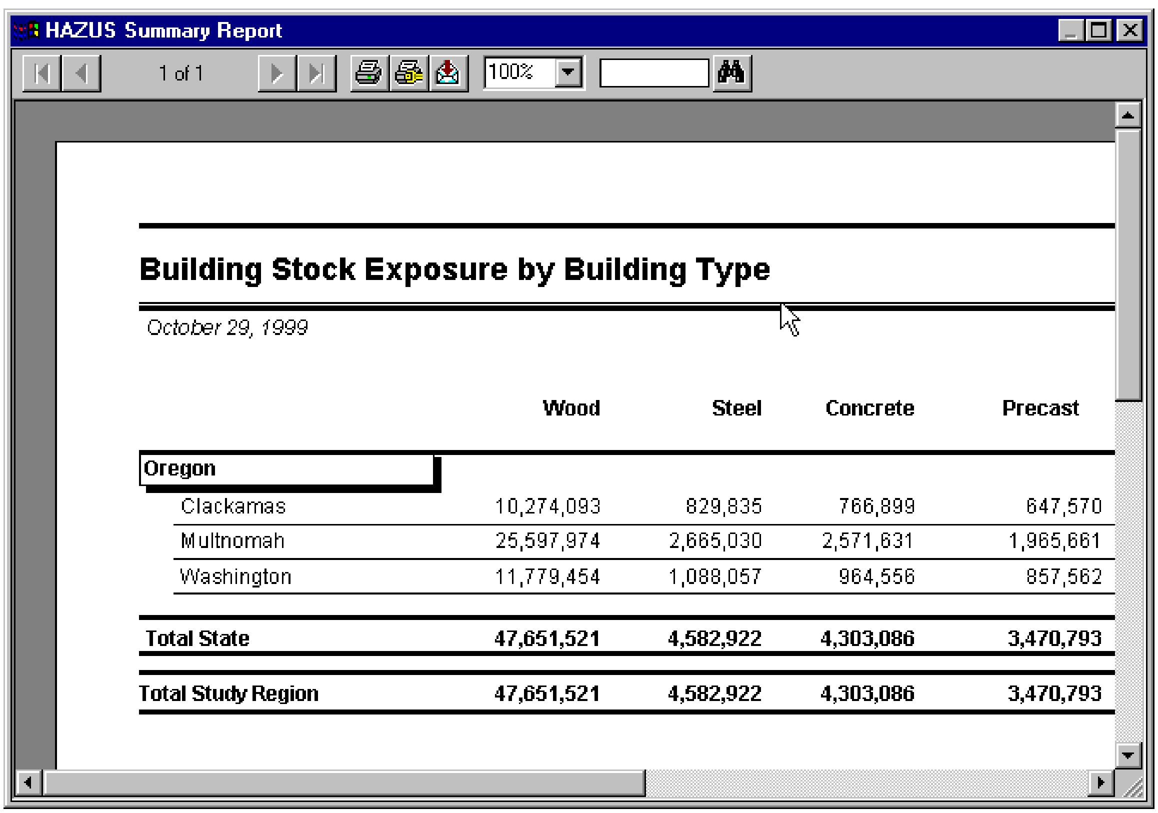
1 of 2 90%

Building Damage By General Occupancy

October 29, 1999

	Square Footage (Thousand. sq.ft)	Dama... None	Slight
Oregon			
Clackamas			
Agriculture	1,818	22.25	19.29
Commercial	34,955	16.27	15.37
Education	2,754	17.75	14.96
Government	588	16.71	14.23
Industrial	12,893	15.63	14.50
Religion	2,961	18.75	16.21

Figure 10.38 Sample summary report of building damage by general occupancy.



HAZUS Summary Report

1 of 1 100%

Building Stock Exposure by Building Type

October 29, 1999

	Wood	Steel	Concrete	Precast
Oregon				
Clackamas	10,274,093	829,835	766,899	647,570
Multnomah	25,597,974	2,665,030	2,571,631	1,965,661
Washington	11,779,454	1,088,057	964,556	857,562
Total State	**47,651,521**	**4,582,922**	**4,303,086**	**3,470,793**
Total Study Region	**47,651,521**	**4,582,922**	**4,303,086**	**3,470,793**

Figure 10.39 Sample summary report of building stock exposure by building type.

The 20 page **Global Summary Report** is a comprehensive standardized summary report that provides inventory, hazard and analysis results related to the scenario event. Selecting the **Other** tab as shown in Figure 10.40 will access the window that contains the **Global Summary Report**.

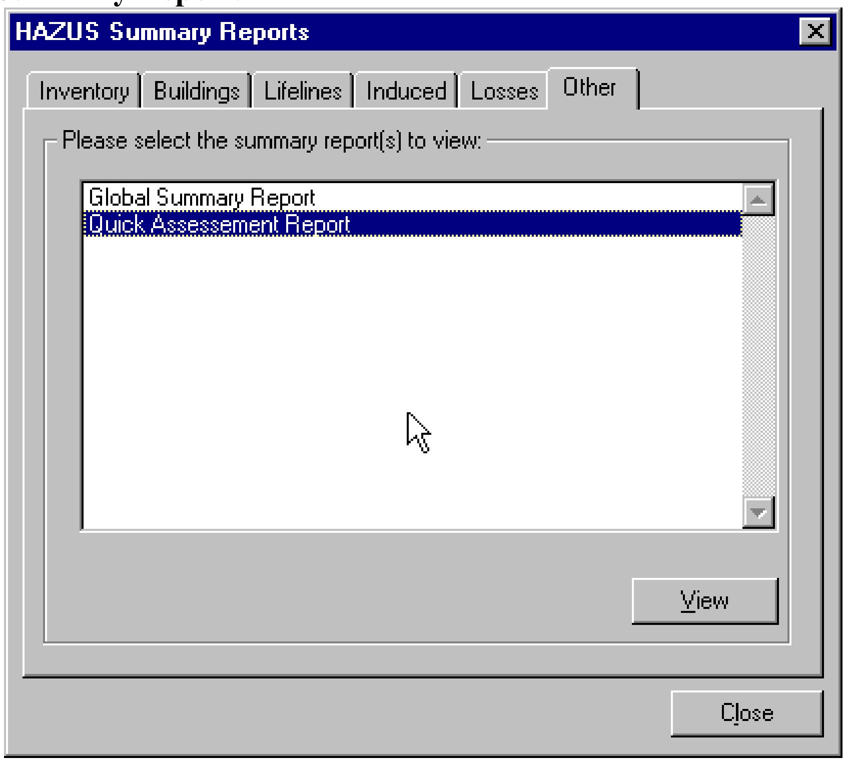


Figure 10.40 The Global Summary report option

The Global Summary Report is organized as follows:

1. **General Description of the Region**
2. **Building and Lifeline Inventory**
   - **2.A Building Inventory**
   - **2.B Critical Facility Inventory**
   - **2.C Transportation and Utility Lifeline Inventory**
3. **Earthquake Scenario Parameters**
4. **Direct Earthquake Damage**
   - **4.A Buildings Damage**
   - **4.B Critical Facilities Damage**
   - **4.C Transportation and Utility Lifeline Damage**
5. **Induced Earthquake Damage**
   - **5.A Fire Following Earthquake**
   - **5.B Debris Generation**
6. **Social Impact**
   - **6.A Shelter Requirements**
   - **6.B Casualties**
7. **Economic Loss**
   - **7.A Building Losses**
   - **7.B Transportation and Utility Lifeline Losses**
   - **7.C Long-term Indirect Economic Impacts**

10.12 Ground-Truthing the Results

The analysis results obtained from **HAZUS** are the best estimates given the current state-of-the-art earthquake engineering algorithms, but when a real earthquake event occurs, the damage observed on the ground ***is*** the absolute.

Through the ground-truthing feature, **HAZUS** allows the user to feed it the real observed data so that analysis results can get refined. For example, **HAZUS** uses the damage to say the medical care facilities to calculate their functionality, but if the damage values can be updated with real observed data, then **HAZUS** can use those new values to refine the functionality analysis for said medical care facilities.

To use the ground-truthing feature, follow the steps below:

1. Run an analysis including all of the modules
2. By default, ground-truthing is off. To find out the current setting, select the **Analysis** menu option as showing in Figure 10.41. The ground-truthing option will either show as **Ground Truthing Off** or **Ground Truthing On.** Also, when ground truthing is off, all of the results tables are non-editable (they show up in blue.)
   The ground truthing menu option is a toggle, so if the option is off, selecting it will toggle the ground truthing to *on*.

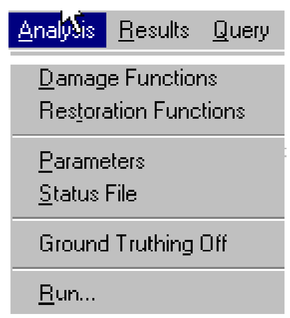


Figure 10.41. The Ground Truthing option

3. Select the results table which you need to edit/ground truth
4. Right-click the table to invoke the data management pop-up menu. When ground truthing is on, the option **Edit results** becomes enabled and can be selected as shown in Figure below.

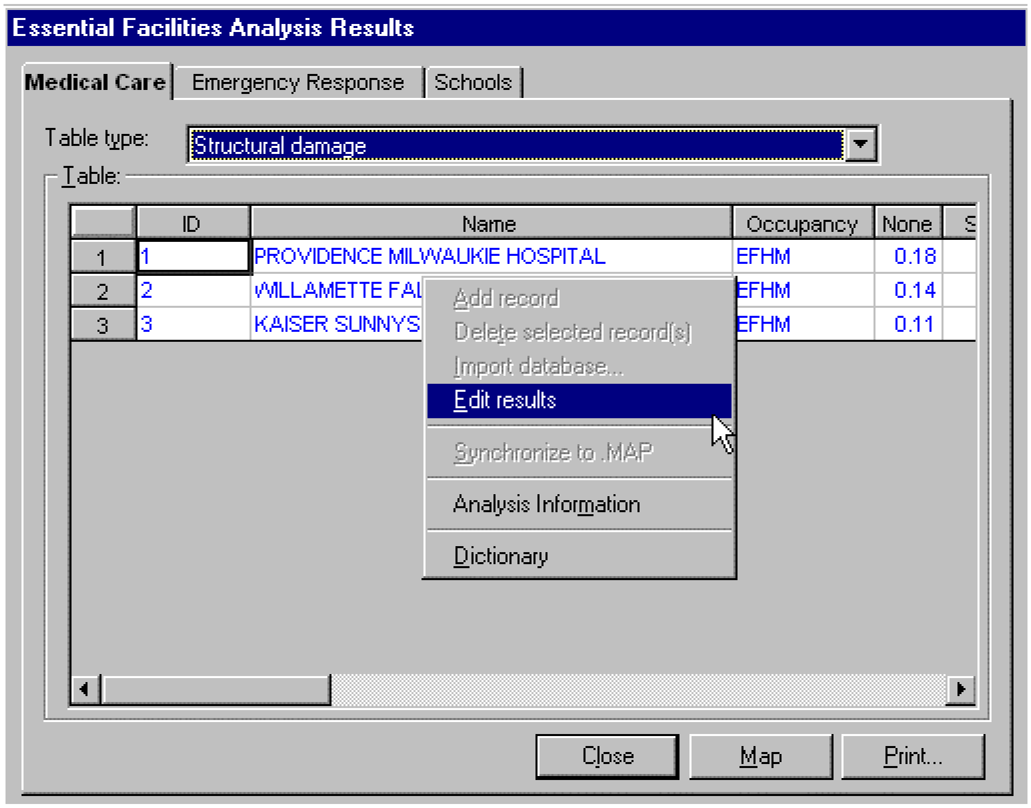


Figure 10.42 Ground Truthing option

5. Click on **Edit results** then all the result cells become editable (showing in black). Edit the appropriate values as needed. When done, click **Close** and say **yes** to the **Data table changed. Save to file?**

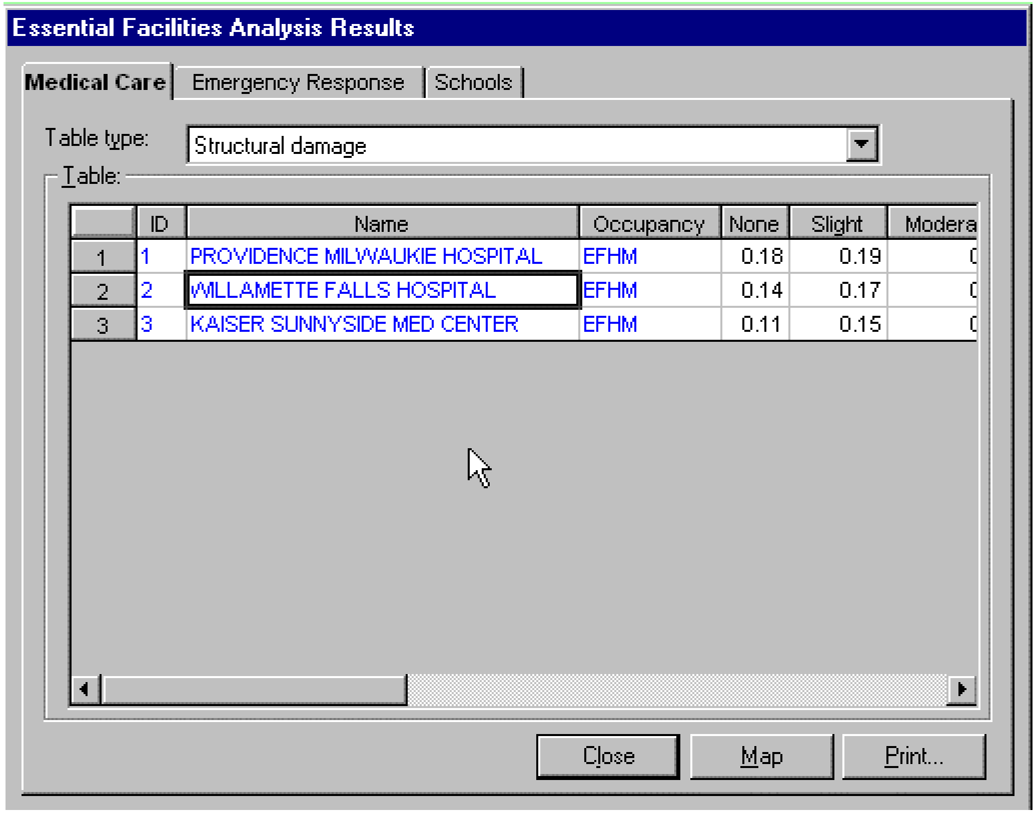


Figure 10.44 Results table in edit mode

6. Re-run the analysis on the dependant modules (or if in doubt, run all modules). **HAZUS** will use the entered values when needed. In the example above, if the value for “Slight” is updated for the hospital ID 2, then this value and only this value will be used. All the other values will be calculated by **HAZUS** as before.

Steps 3 through 6 can be repeated as many times as needed. ***The ground truthing mode stays in effect until it is turned off explicitly.*** This allows the refinement of the results as more observed data is fed into the **HAZUS**.

Note:

When the ground truthing option is turned off, all of the entered values are *discarded*.

Chapter 11. Extension of HAZUS to Other Natural Hazards

11.1 Vulnerability to Natural Hazards

There are a variety of natural hazards that can cause significant damage to both the built and natural environments. The impact of these types of events, which include earthquakes, floods, hurricanes, tropical storms, tornadoes, volcanoes, tsunamis, landslides, and droughts, can be devastating and in extreme cases, such as the volcano in Pompeii, can destroy an entire population. In addition to damage to buildings and building contents, natural hazards can destroy crops, forests, and farmland, can undermine the infrastructure that is vital to the function and well being of the community, can cause significant monetary losses, casualties and disease and can have a destabilizing effect on the local or regional economy. When we talk about the vulnerability of a region to a natural hazard, we are talking about how susceptible the region is to damage, losses, and casualties.

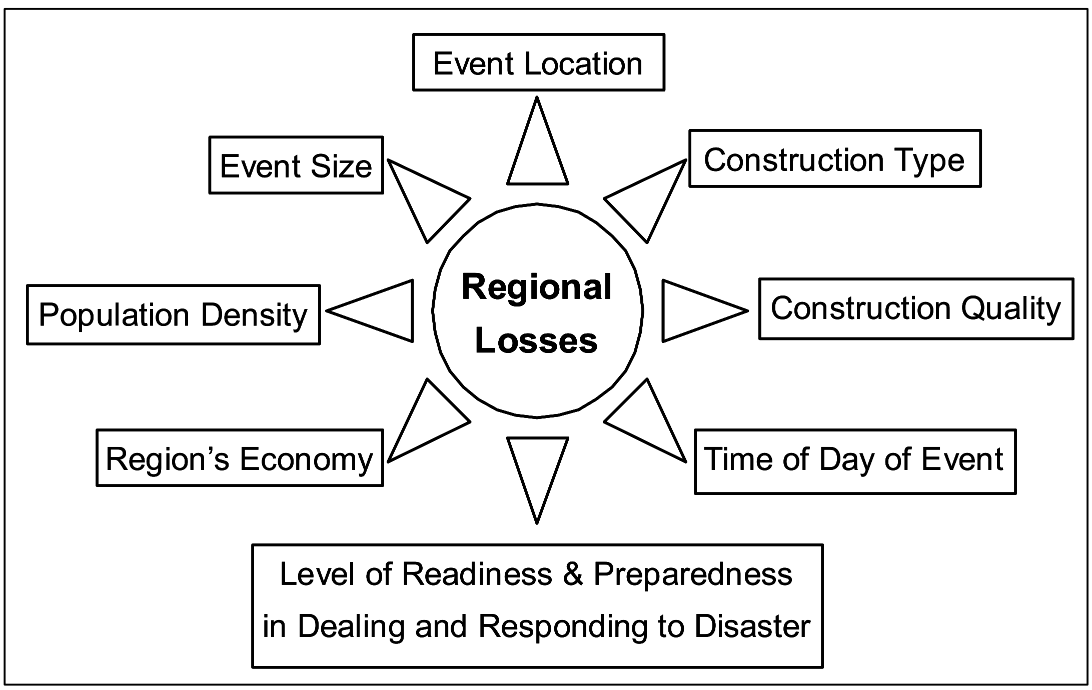


Figure 11.1 Factors that contribute to the regional vulnerability

Damage and losses depend not only on the type of natural hazard but also to a great extent upon the density of the population; the type, spatial distribution, and quality of construction; and the socio-economic makeup of the region (Figure 11.1). If an earthquake occurs in an unpopulated region, there will be little to no effect on regional infrastructure and little likelihood of loss of life. However, if the same earthquake were to occur near a large city then one could expect significant damage and monetary as well as social losses. As the world has become progressively more urbanized and people have moved to and settled in densely populated metropolitan areas, earthquakes occurring near these urban areas can result in very high losses. The Northridge earthquake and Hurricane Andrew illustrate the impact of natural disasters in high-density environments. Poorer regions with inexpensive non-engineered construction are more vulnerable and can expect heavier damage than regions that have large numbers of new buildings that are designed and constructed to modern codes. If the local economy is highly dependent on one or two types of business or industry, and these are destroyed, high unemployment can occur, resulting in a very slow recovery. To better understand vulnerability to natural hazards, it is necessary to discuss the types of damage that occur in these events.

11.2 Damage From Hurricane, Tornado and Flood

Many of the issues that are important in the assessment of damage and losses due to earthquakes are applicable to hurricanes, tornadoes and floods. Certain types of buildings and lifeline facilities are more vulnerable than others. Vulnerability can depend to some extent on the location of the facility but damage also has a random character about it. Damage can occur to structural elements, non-structural elements or to the contents of a facility. Damage to a facility can also result in secondary consequences such as fires and hazardous materials releases. All three of these hazards can affect a large region and can inflict long-term economic hardship on a community. These natural hazards, like earthquakes, can also cause injuries and deaths. The inventory that would be needed to perform a regional loss estimate for one of these hazards is much the same as that required to perform a loss estimate for earthquakes. An understanding of the types of damage that occur in hurricanes, tornadoes and floods will serve to illustrate this point.

11.2.1 Hurricanes

Hurricanes are severe storms (with sustained wind speeds over 120 km/hr) that begin over tropical seas. Hurricanes pick up strength over the ocean where they are fueled by evaporation of water and tend to lose their strength as they move inland. In the United States, the Gulf and Atlantic coasts are the areas that are affected by hurricanes. In addition to high winds, hurricanes can cause inundation as a result of storm surge (a rise in the level of the sea). While earthquakes can cause injury and death to livestock and can cause damage to crops and other vegetation, particularly if there are landslides, floods or fires, the losses are likely to be small in comparison to losses to the built environment. Losses can also occur to vehicles, farm equipment, trains, and boats as the result of hurricane event.

Wind is one of the main damaging characteristics of hurricanes. Wind speeds as high as 320 km/hr have been recorded (Alexander, 1993). Wind severity can depend on the location of a structure with respect to the density of other buildings, since winds tend to be more severe in open terrain. Structures can collapse as a result of very high wind pressures; however, a large percentage of the losses occur as a result of water damage. In Hurricanes Andrew and Iniki, 85% and 59%, respectively, of the houses suffered significant water damage to their interiors (Crandell et al., 1993). Once the roof or a portion of the roof has been destroyed, or windows and doors have been broken, the contents of a structure are very vulnerable to water damage. Damage occurs not only as a consequence of direct exposure to high winds, but also because of wind blown debris (or missiles) that impacts structures. In areas very close to the coast, inundation can exacerbate damage that results from the wind.

Small residential structures are vulnerable to roof damage. Gable roofs are more susceptible than hip roofs, and certain types of roof covering (e.g. composition shingle) are more vulnerable than others (e.g. gravel). A common problem is that roofs do not have positive connections to counteract the uplift forces that result from the winds, thus roof members can become detached from the walls.

Similar to their behavior in earthquakes, high-rise structures can experience a great deal of non-structural damage from loss of exterior cladding and windows. Broken glass can occur due to missiles or due to interstory drift. In Hurricane Alicia, 80% of glass breakage was due to missile impact (Alexander, 1993). Exterior cladding and parapets often are inadequately supported or inadequately attached to the structural system to withstand the forces of the wind.

Hurricanes can cause extensive damage to lifelines. Electric power supply systems sustain some of the most extensive damage after hurricanes. The damage to the system can be so great that it takes days to bring minimal service on-line. After Iniki there was complete service interruption on the island of Kauai (Zadeh et al., 1993). Loss of electric power can affect the operation of other lifeline systems such as water and wastewater treatment facilities, gas transmission lines and communications lines and facilities. After Hurricane Hugo little damage occurred to power plants and sub-stations but transmission lines and transmission line support structures were badly damaged. Transmission lines with metal support structures performed well in comparison to those with wood poles. Electric power distribution systems were also badly damaged, with the majority of damage being attributed to falling trees downing distribution lines (Cook, 1991).

Roads and bridges are mainly affected by the accumulation of debris on the surface. Similar problems occur with airport runways. Roadway signs and signals can be blown down which affects the delivery of emergency relief. Near the coast, bridges or roads may be damaged by inundation.

Communications transmission towers and dishes are vulnerable to the high wind loads that occur in a hurricane. Damage to telecommunications networks is expected to be similar to electric power distribution systems. If phone lines are above ground, falling trees may damage lines. In Hurricane Andrew, almost 100% of the drop lines, the line from the distribution lines to the service connection, were destroyed (Zadeh et al., 1993). It should be noted that in Hurricane Hugo, the post storm performance of the telephone system was relatively good, since most of the lines were underground (Cook, 1993). While long distance service may be undamaged, it can be unusable because of damage to local phone lines.

Underground water and gas pipes are not significantly affected by hurricanes except by occasional uprooted trees, so the main performance reduction to water systems is due to loss of power. This affects the operation of pumps and equipment in treatment plants. Loss of electrical power also affects the operation of wastewater treatment plants.

In conclusion, the inventory collected to estimate losses from hurricanes is similar to that needed to estimate losses from earthquakes. Additional characteristics may be needed such as type of roof (hip or gable), locations and value of farm land, density of development, and the locations of structures relative to the extent of storm surge. These are summarized in Table 11.1.

11.2.2 Tornadoes

Tornadoes, rapidly rotating columns of air, are found in the central, southeast and northeast United States. Wind speeds can be in excess of 400 km/hr. Tornadoes can form over dry land or can be generated as a result of hurricanes. Tornadoes can be essentially dry accompanied by dust and debris or they can be accompanied by rain or hail. They can occur individually or in families. Tornadoes may lift off the ground and touch down in some random pattern as they travel. They tend to cause the most damage where they touch down, and damage tends to occur in patches.

Damage from tornadoes, similar to hurricanes, occurs as a result of high wind pressures or by airborne objects. The types of damage are also similar. The inventory required to estimate losses from tornadoes, as summarized in Table 11.1 is similar to that for hurricanes.

11.2.3 Floods

Flood damage can occur as a consequence of riverine flooding or coastal flooding. Riverine flooding occurs when streams and rivers overflow because of excessive rainfall or snowmelt. Coastal flooding can result from large storms such as hurricanes that cause large waves or storm surge. The damage from coastal flooding can be more severe than that from riverine flooding because of the added force of waves. Other factors that affect the severity of damage are depth of flooding, the velocity of the floodwaters, duration of flooding and the presence of debris in the water. The location and elevation of the property with respect to the source of flooding determines the depth of flooding that can be expected. One of the major factors in assessing potential losses from inundation is the location of properties with respect to flood zones.

A large portion of the losses in floods occurs to building contents. Losses in floods are higher in properties with basements since basements often contain expensive items such as water heaters, heating and air conditioning units and many have been finished for use as extra living spaces. In some cases if there is a warning of flooding, moving valuable contents to upper floors can reduce losses. Losses to properties can be greatly reduced if buildings are raised on stilts or berms or if floodwalls or levees protect the property from flooding. Thus it is important to understand if “flood resistant” measures have been taken.

As with hurricanes and tornadoes, losses to vehicles, farm equipment, trains and boats can be significant. While flood damage can be minimized if areas prone to flooding are not developed, floods can cause severe damage to vegetation and agricultural land. Therefore land use is an important characteristic in assessing potential losses.

Inventory collected for assessing losses from floods is similar to that required for assessing losses from earthquakes. Additional attributes that you will need to collect are the locations of flood zones, elevation of the facility and evidence of flood resistant measures.

11.3 Key Factors in Estimating Losses from Natural Hazards

As has been discussed in the previous sections, the inventory required for estimating losses from different natural hazards has common elements. For all of the hazards discussed (earthquakes, floods, hurricanes and tornadoes) you must first determine the size and location of the event with respect to the region you are studying. The impacts will be more severe if the event is large and close to an urban area, if the dominant types of construction are vulnerable, and if the region is not well prepared. Impacts are also related to the type of economy in the region and the ability of certain sectors of the economy to rebound from production and inventory losses. Table 11.1 compares inventory for estimating losses from earthquakes, hurricanes, tornadoes and floods.

Table 11.1 Key Factors for Estimating Regional Losses From Natural Hazards

	Earthquake	Hurricane	Tornado	Flood
Hazard Considerations				
• Size of event	✓	✓	✓	✓
• Location of event	✓	✓	✓	✓
• Type of soil	✓			
• Topography	✓	✓	✓	✓
• Type of terrain (open or built-up)		✓	✓	
• Flood potential	✓	✓	✓	✓
• Tsunami potential	✓			
Buildings				
• Type of structural system	✓	✓	✓	✓
• Location of structure	✓	✓	✓	✓
• Height of structure	✓			✓
• Square footage of structure	✓	✓	✓	✓
• Age of structure	✓	✓	✓	✓
• Occupancy or use of the structure	✓	✓	✓	✓
• Building code design standards	✓	✓	✓	✓
• Potential for hazardous material release	✓	✓	✓	✓
• Cost per square foot for replacement	✓	✓	✓	✓
• Type of roof (e.g. hip or gabled)		✓	✓	
• Roof covering (tile, shingle, gravel or		✓	✓	
composition)				✓
• Existence of a basement				
Transportation Lifeline Systems				
• Types of components (e.g. bridges, tunnels,	✓	✓	✓	✓
cranes)	✓	✓	✓	✓
• Locations of components	✓	✓	✓	✓
• Amount of component (e.g. miles of	✓	✓	✓	✓
roadway)	✓	✓	✓	✓
• Age of components	✓	✓	✓	✓
• Characteristics of components (e.g. concrete or asphalt road)				
• Cost of replacement				

Table 11.1 (cont.) Key Factors for Estimating Losses From Natural Hazards

	Earthquake	Hurricane	Tornado	Flood
Utility Lifeline Systems				
• Types of components (e.g. pipes,	✓	✓	✓	✓
substations, treatment plants)	✓	✓	✓	✓
• Locations of components	✓	✓	✓	✓
• Amount of component (e.g. miles of pipe)	✓	✓	✓	✓
• Characteristic of specific components (e.g.		✓	✓	
cast iron or clay pipe)	✓	✓	✓	✓
• Above or below ground transmission lines	✓	✓	✓	✓
• Age of components				
• Cost of replacement				
Other Inventory				
• Agricultural products and livestock		✓	✓	✓
• Vehicles, rolling stock and boats		✓	✓	✓
Socio-Economic Factors				
• Population density	✓	✓	✓	✓
• Income, age and ethnicity of population	✓	✓	✓	✓
• Numbers of homeowners and renters	✓	✓	✓	✓
• Type of economy	✓	✓	✓	✓
• Employment in different economic sectors	✓	✓	✓	✓
• Business inventory	✓	✓	✓	✓

11.4 Accessing Supplemental Hazard Maps

A number of supplemental hazard maps are shipped with the **HAZUS** software. When you aggregate a region, you will be asked if you want to include the supplemental hazard data in the aggregation. If you indicate yes, the data will be downloaded from the CD and copied to your hard drive at that time.

If, on the other hand, you decide to download the supplemental hazard maps at a later time, use the following procedure. Go to the **File** menu and click on **Aggregate Multi-Hazard Data**. You will be asked to insert a CD in the drive (see Figure 11.2). Click the **OK** button. If you have the wrong CD you will be prompted to try again. Note: depending on the size of your region, it could take from 15 minutes to over an hour to download and aggregate the supplemental data.

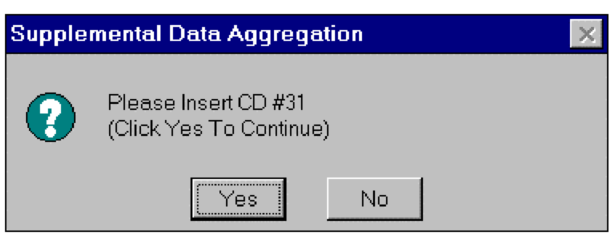


Figure 11.2 Prompt to insert CD when downloading supplemental hazard maps.

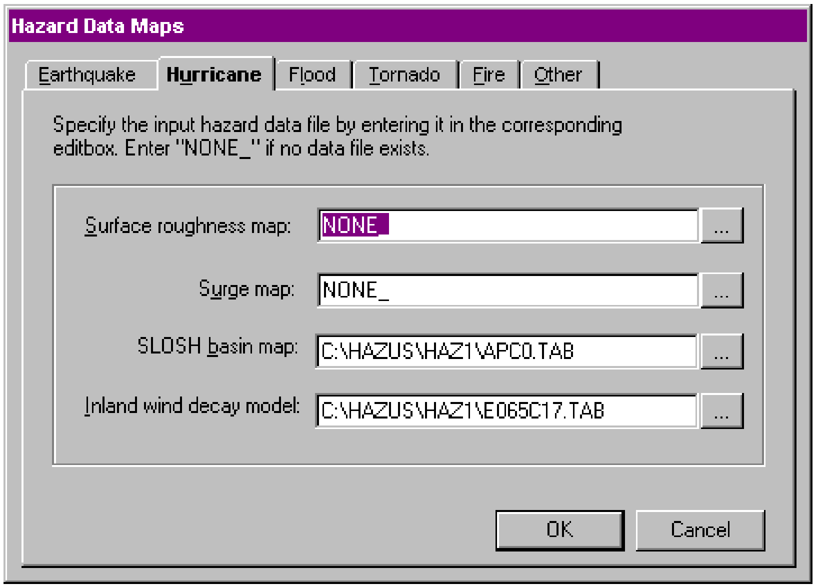


Figure 11.3 Hazard Data Maps window.

To view the maps, click on the **Hazard|Data Maps** menu and the window in Figure 11.3 will appear. Using the tabs at the top of the window, specify the maps you are interested in. In some cases, such as with SLOSH basins or inland wind decay models, multiple maps will be available for your use. To view which maps are available, click on the **…** button at the right of the list box and a window listing all of the maps, such as the one shown in Figure 11.4, will appear. Select the map you want to view and click **OK**. To view the maps, use the **Map** menu.

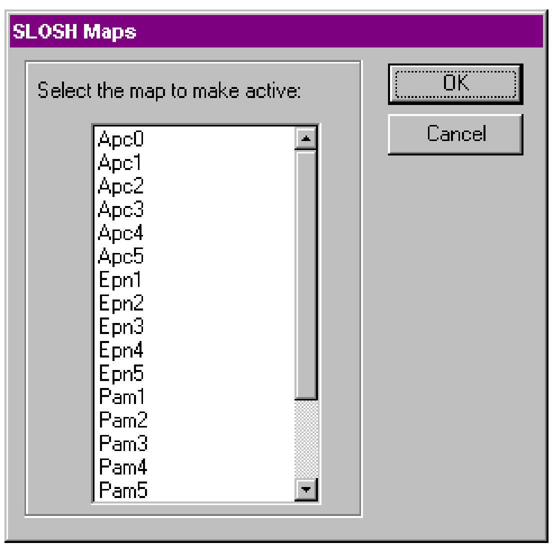


Figure 11.4 Window listing available SLOSH maps.

11.5 Hurricane Data Maps

SLOSH Basin maps (Sea, Lake, and Overland Surges from Hurricanes) outline the land areas expected to be inundated by hurricane surges. These maps are named according to the SLOSH Basin ID and hurricane category they represent. For example, FMY3 represents the surge from a Category 3 hurricane on the Fort Meyers, Florida basin. The surge (in feet) specifies the elevation of water above the National Geodetic Vertical Datum (NGVD) and **not** the depth of flooding. The surge value compared to the actual ground elevation **will** provide the depth of flooding. The National Oceanic and Atmospheric Administration (NOAA) Technical Report NWS 48 of April 1992 describes the development of these maps. Table 11.2 lists the Basin ID, the Basin Name and the states it affects. These files are located on the Supplemental CD-ROM in the \SURGE directory.

Table 11.2 SLOSH Basin Coverage
(Polar Coordinate System except where noted)

Basin ID	Basin Name	States Covered
APC	Apalachee Bay (Apalachiacola), FL	FL
BOS	Boston Bay, MA	MA, ME, NH
BPT	Sabine Lake, LA/TX	LA, TX
BRO	Brownsville, TX	TX
CDR	Cedar Key, FL	FL
CHE	Charleston Harbor, SC (Elliptical)	GA, SC
CHP	Chesapeake Bay, DE	DC, DE, MD, NC, NJ, PA, VA
COF	Cape Canaveral, FL	FL
CRP	Corpus Cristi, TX	TX
EBP	Sabine Lake, LA/TX (Elliptical)	LA, TX
EHT	Pamlico Sound, NC (Elliptical)	NC, VA
EPN	Pensacola, FL (Elliptical)	AL, FL
ETP	Tampa Bay, FL (Elliptical)	FL
EYW	Florida Keys, FL	FL
FMY	Fort Meyers, FL	FL
GLE	Galveston Bay, TX (Elliptical)	LA, TX
HNL	Island of Oahu (Honolulu), HI	HI
ILM	Wilmington, NC	NC, SC
LFT	Vermillion Bay, LA	LA
MIA	Biscane Bay (Miami), FL	FL
MSY	New Orleans, LA	LA, MS
NYC	Long Island Sound, NY	CT, MA, NY, NJ, RI
PAM	Panama City, FL	FL
PBI	Palm Beach, FL	FL
PNS	Pensacola, FL	AL, FL, MS
PSX	Matagorda Bay, TX	TX
SJU	Puerto Rico	PR
SSI	Brunswick, GA	FL, GA, SC

The National Hurricane Center's Inland Wind Decay Model displays the Maximum Envelope Of Winds (MEOWs). These MEOW maps are separated into three regions; the Gulf of Mexico, the Northern Atlantic coast and the Southern Atlantic coast. The files are named **ABBBcDD.*** where,

A	is the region specification: **E** for Southern Atlantic Coast **G** for Gulf Coast **V** for Northern Atlantic Coast
BBB	is maximum one minute sustained wind speed, in knots, of the hurricane. There are four possible values: 65, 85, 105, and 125
c	is a placeholder
DD	Is the forward speed of the hurricane, in knots. There are six possible values: 8, 12, 17, 22, 30, and 40.

The Wind_Spd value is the expected sustained surface wind speed (mph) at a location assuming the storm travels the minimum distance between the coastline and that location. The \HURR directory of the Supplemental Data CD-ROM contains this data.

11.6 Flood Data Maps

The Flood Insurance Rate Map (FIRM) is based on National Flood Insurance Program (NFIP) Q3 Flood Data. It shows the outline of the flood plains at a county level. Table 11.3 contains the zone classification descriptions. These files are found on the Supplemental CD-ROM in the \FIRM directory and are specified as FLQxxxxx.* where xxxxx is the county FIPS code.

Table 11.3 Q3 Zone Classifications

Classification	Description
A	Areas inundated by 1% annual chance flooding where Base Flood Elevations (BFE) have not been determined.
AE	Areas inundated by 1% annual chance flooding where BFEs have been determined.
A0	Areas inundated by 1% annual chance flooding (typically sheet flow on sloping terrain) where average depths have been determined to range from 1 to 3 feet.
AH	Areas inundated by 1% annual chance flooding (typically ponding) where average depths have been determined to range from 1 to 3 feet.
A99	Areas inundated by 1% annual chance flooding for which no BFEs have been determined. This area is to be protected from the 1% annual chance flood by a Federal flood protection system under construction.
AR	Areas inundated by flooding for which BFEs and Average depths have been determined. This is an area that was previously and will again be protected by a Federal flood protection system and whose restoration is Federally funded and underway.
V	Areas inundated by 1% annual chance flooding with velocity hazard (wave action) where BFEs have not been determined.
VE	Areas inundated by 1% annual chance flooding with velocity hazard (wave action) where BFEs have been determined.
X500	Areas inundated by 0.2% annual chance flooding; areas inundated by 1% annual chance flooding with average depths of less than 1 foot or with drainage areas less than 1 square mile; areas protected by levees from 1% annual chance flooding.

Similar to the FIRM maps, the Floodway map outlines those areas required for the discharge of the base flood. The classification descriptions can be found in Table 11.4. These tables are found in the same directory as the FIRM maps and are specified as FLFxxxxx.* where xxxxx is the county FIPS code.

Table 11.4 Floodway Classifications

Classification	Description
FW	Areas that includes the channel of a river or other watercourse and the adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation by more than a designated height (typically Zone AE).
FE	Areas within a community usually bordering a stream that has more restrictive floodplain development criteria imposed by governing body (town, city, etc.) than required for participation in NFIP.
SEA	Areas within a community usually bordering a stream that has more restrictive floodplain development criteria imposed by the state than required for participation in NFIP.

Coastal Barrier Resources System Areas (COBRA), are those regions where flood insurance is not available for structures newly built or substantially improved after the Coastal Barrier date. COBRA maps are provided for display purposes only and are available only for certain coastal regions. These areas are specified by the COBRA_IN code in the COBRA field. These files a located with the other flood data and are specified as FLCxxxxx.* where xxxxx is the county FIPS code.

11.7 Elevation Data Maps

The Elevation Contour maps are based on the USGS Digital Elevation Model (DEM) data (see the **Fire** tab in Figure 11.3). The maps are contoured at 10 meter intervals and are available by county. The DEM data is based on a 1^{o} x 1^{o} quadrangle using a 3 arc-second grid. The maps are located in the \DEM directory of the Supplemental Data CD-ROM specified as DEMxxxxx.* where xxxxx is the county FIPS code. More information concerning the methods of developing the Digital Elevation Model can be found in the USGS Data Users Guide 5.

11.8 Land Use/Land Cover Data Maps

Land-Use/Land-Cover (LULC) maps are based on USGS data (see **Other** tab in Figure 11.3). They represent the characteristics of the land, indicating whether it is built-up land or tundra and forest. The original USGS classifications have been grouped into 11 categories in the NEWCODE field as shown in Table 11.5. The original data was retained in the LUCODE field. The LULC files are found on the Supplemental Data CD-ROM in the \LULC directory named as LUCxxxxx.* where xxxxx is the county FIPS code. Information concerning the development of the LULC data can be found USGS Data Users Guide 4.

Table 11.5 Land-Use/Land-Cover Classifications for the NEWCODE field.

Code	Description
11	Residential
12	Commercial Services
13	Industrial
14	Transportation, Communication
19	Mixed Urban Use
29	Agricultural
39	Rangeland
49	Forest Land
59	Water
69	Wetland
99	Barren Land/Tundra

11.9 FEMA Shelter Data

Maps locating facilities within the state that are classified as FEMA shelters are located on the Supplemental Data CD-ROM in the \SHELTERS directory. These maps contain data concerning the building ownership, structure type, and other characteristics of the structure.

11.10 Street/Roadway Data Maps

These maps contain the surface street information at a county level. They are found in the \STREET directory of the Supplemental Data CD-ROM directory named as STRxxxxx.* where xxxxx is the county FIPS code. They list street names and road classifications where available.

Chapter 12. QASEM and Ground Truthing the Results

QASEM the Quick Assessment Event Monitoring tool, allows **HAZUS** to automatically run real-time scenarios on computers equipped with a **REDI-CUBE** system.

Given a correctly installed **REDI-CUBE** system, when an earthquake occurs, **QASEM** automatically launches **HAZUS,** creates a study region of the appropriate size, defines a scenario with the parameters (location, magnitude) of the earthquake which has just occurred, and runs the analysis. All steps do not require any intervention from the user.

To use **QASEM** correctly, the following requirements should be met:

1. The **REDI-CUBE** system should be installed and working correctly as per the instructions that came with the system.
2. **QASEM** should be installed. Since the **HAZUS** setup program *does not* install **QASEM** by default, the **QASEM** option has to be selected specifically.
3. **QASEM** should be running at all time. By default, the **HAZUS** setup program adds the **QASEM** shortcut to the user's startup folder so that **QASEM** is launched automatically every time Windows is launched.

12.1 Launching QASEM

By default, **QASEM** runs every time Windows is launched. If **QASEM** is not running, launch it by selecting **Start|FEMA Risk Assessment System|QASEM** (this assumes that the default group "FEMA Risk Assessment System" was used during the setup.)

12.2 QASEM Options

Like **HAZUS**, **QASEM** includes pre-set options for most of its parameters; however, these options must be edited to reflect the correct user's choices.

12.2.1 The Pager File

There is no default to this option. When started, **QASEM** will always display the message shown in Figure 12.1. To correct the error, click the **Specify…**button for **REDICUBE pager data file**, and select the pager file used by your **REDI-CUBE** system.[6]

Figure 12.1 Error message about

[6] QASEM has been tested with version 2.5 of the pager file format.

12.2.2 Monitoring Type

Whenever an earthquake event occurs in California that can be picked up by the **REDI-CUBE** system, the signal is sent to the pager and will be picked up by **QASEM**. The monitoring type option allows filtering of the events based on the location.

Select the **All events** option if you want **HAZUS** to be launched for all the events that can be picked up by **REDI-CUBE**. Select **Only those within the boundary** option to pick up only the earthquake events that occur inside a given boundary. Specify the boundary map by clicking the **Specifiy…**button.

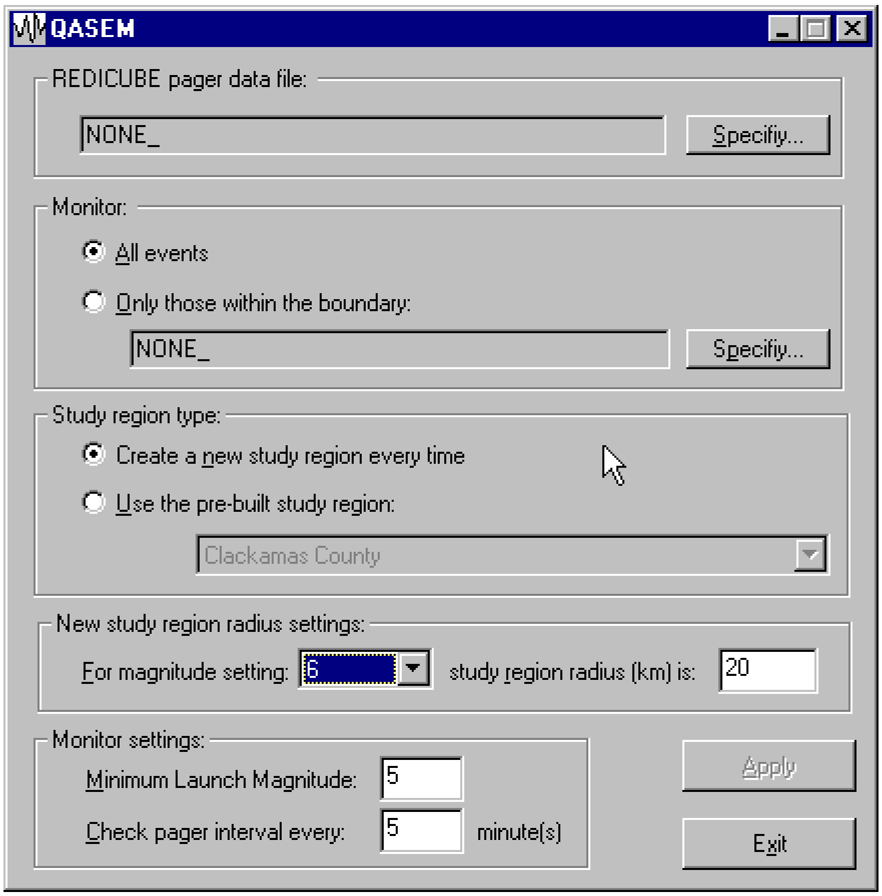


Figure 12.2 QASEM Options

12.2.3 Study Region Type

This option controls what type of study region will be used. The option **Create a new study region every time** will have **HAZUS** create a new region for each new earthquake event. The region boundaries are controlled by the **New study region radius settings** as follows:

- The epicenter of the earthquake event will be used as the centroid of the study region
- **HAZUS** will include all of the census tracts that lie within the radius of that epicenter. The radius of the circle is the value specified under **New study region radius settings**
- The option **Use the pre-built study region** makes **HAZUS** use the specified study region (which was pre-built). This option comes in handy in the case the user cares only about his region, which he/she has already created and enhanced. To define the pre-built region to use, simply select from the combo-box (**QASEM** will list automatically all the regions which are pre-built.)

12.2.4 Study Region Radius

This option is used when the **Create a new study region every time** option was selected (as explained in the above section.) Since the extent of the region affected by an earthquake is a function of the magnitude of the event (large events affect larger regions), **QASEM** allows settings different values for different magnitudes and will interpolate correctly the radius for any event size.

12.2.5 Monitor Settings

This option controls at what point **QASEM** is triggered. The **Minimum launch magnitude** filters the events based on their size, i.e. all events that are less than the value specified will be ignored. The **Check page interval every** x minutes controls how often **QASEM** probes the **REDI-CUBE** system. To have **QASEM** *react* to an event real-time, set the interval to a low value like 1 or 2 minutes. The downside is that this will burden the machine[7].

12.3 QASEM Results

When an earthquake event that meets the criteria specified in the all the options described above, **QASEM** launches **HAZUS.**

HAZUS then creates a new study region (or use a pre-built one) depending on the study region type option set, defines a scenario with the parameters of the event, runs the analysis using a pre-defined set of options, and then shuts down[8].

The results for a QASEM analysis are summarized into a QAS (Quick Assessment Summary Report) that can be accessed in HAZUS through the option **Results|Summary Reports|Other|Quick Assessment Report** as shown in Figure 12.3.

[7] In a typical environment, a machine should be dedicated exclusively to **REDI-CUBE** and **QASEM** and therefore the interval should be set to the minimum (1 minute) for real-time monitoring.

[8] HAZUS always shuts down at the end so that any after-shock events can be picked up and analyzed too.

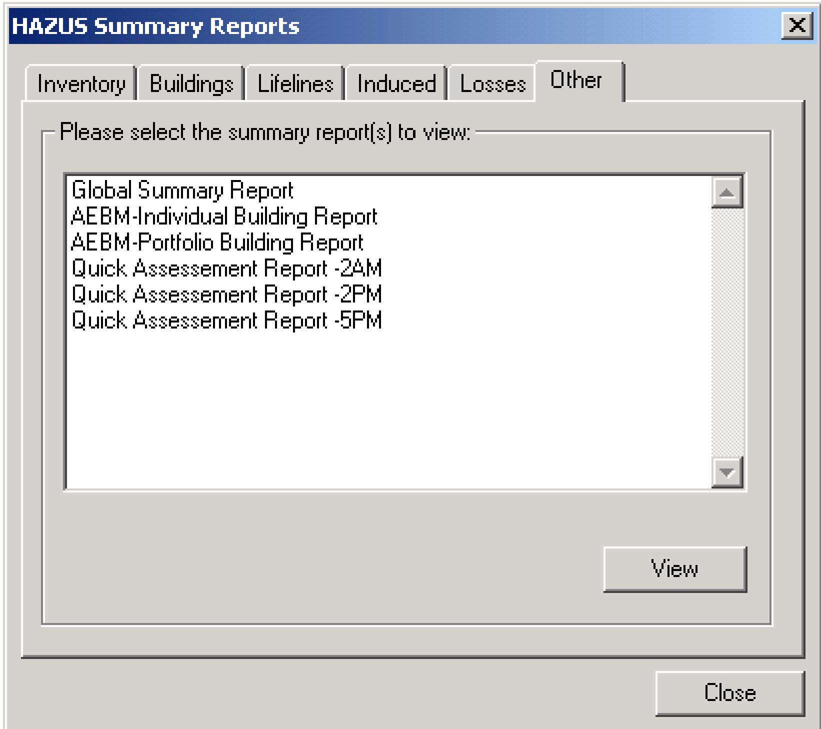


Figure 12.3 Accessing the QAS Report

References

Note to users: Many of these references are difficult to find. However, most of them can be obtained from the libraries maintained at the National Center for Earthquake Engineering Research at Buffalo, the Earthquake Engineering Research Center at the University of California, Berkeley, the National Hazards Research and Applications Center of the University of Colorado and the Natural Hazards Research Program of the American Institue of Architectrual Research, AIA/ACSA in Washington D.C.. Publications by Applied Technology Council, Association of Bay Area Governments, the Federal Emergency Management Agency, US Geological Survey, US Census Bureau and other government agencies can be obtained directly from these organizations.

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