STEP 5: CONSIDER MITIGATION OPTIONS

5

OVERVIEW

The fifth step in this guide will help you to identify and evaluate various mitigation options that are directly associated with, and responsive to, the losses identified during Step 4. Remember that in HAZUS-MH losses are estimated based on the cost to repair or replace damage to, or loss of, the building inventory. The fifth step, therefore, emphasizes mitigation measures that can reduce the destructive effects of earthquakes, floods, and hurricanes on this inventory. Figure 5-1 shows the tasks and outputs associated with Step 5 of this guide.

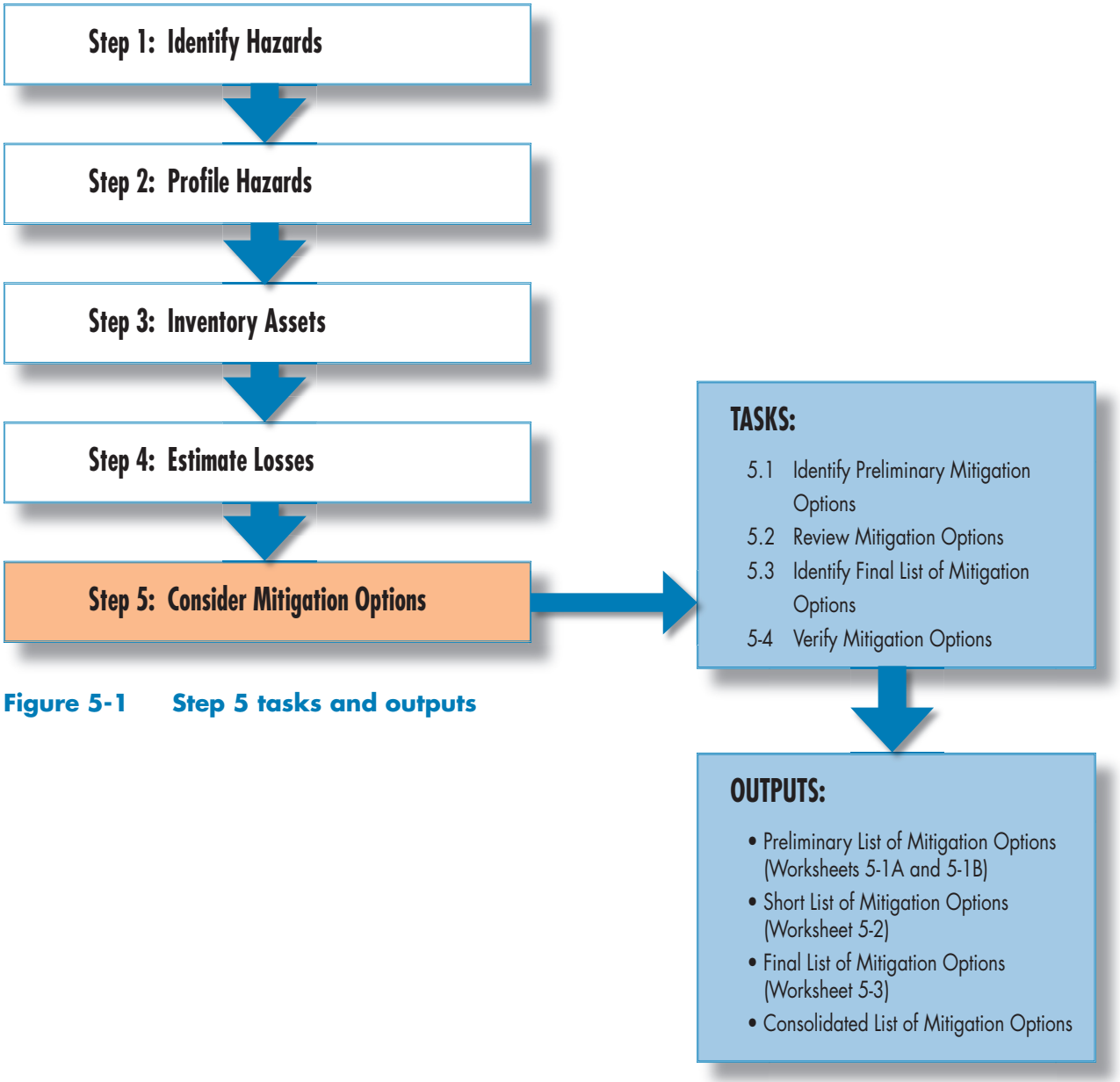

Figure 5-1 Step 5 tasks and outputs

Evaluating the effectiveness of a particular mitigation measure, whether it is regulatory or technical (protection or control), is not an exact science. It requires technical, policy, and financial expertise combined with a thorough knowledge of local perspectives and needs.

In Step 5 you will examine mitigation options from the point of view of their effectiveness, acceptability, and feasibility with respect to the prevailing conditions in your community. The proposed procedure for examining the mitigation options is not meant to replace full and thorough analysis of the technical, economic, and social merits of various mitigation measures, which may be a costly and lengthy process requiring highly specialized expert input. It is meant to help you narrow down your options and focus your attention on those measures that have the greatest chance of effective implementation.

The FEMA How-To Series for Mitigation Planning also includes guidance on mitigation measures (FEMA 386). Information is available at http://www.fema.gov/fima/planhowto.shtm.

In order to identify, select, and implement the most appropriate mitigation measures you will need to examine general mitigation goals and objectives and the merits of each potential mitigation measure. You also will need to consider local and state resources for implementation. This will prepare you to evaluate and prioritize potential mitigation options, according to the criteria that are suggested in this step. The tasks in Step 5 are designed to help you answer the following questions:

- Which mitigation measures are most appropriate for the types of risks our community faces?
- Do we have sufficient capability to implement these measures and what kind of assistance might we need?
- What impacts will the implementation of these measures have on our community?

Task 5.1 will help you to identify a broad range of preliminary mitigation options by hazard or by structure type. Task 5.2 will assist you in reviewing the appropriateness of these measures given the needs and desires of the community. Task 5.3 will help you assess the implementation of proposed mitigation options by indicating which options may be more effective for risk reduction. Task 5.4 will allow you to determine if your identified mitigation options

FEMA information about regulatory measures, rehabilitation, and protective and control structures can be found at http://www.fema.gov/fima.

are in conflict for a particular combination of hazards. It will also help you to integrate your mitigation options into your mitigation plan, taking into consideration the factors and elements considered in Tasks 5.1 through 5.3.

Identify Preliminary Mitigation Options (Task 5.1)

Mitigation measures can be viewed from many different perspectives. In this How-To Guide, the emphasis is on interventions that address the goal of mitigation with respect to buildings and infrastructure; that is, minimizing the destructive and disruptive effects of hazard events on the built environment. For this task, mitigation options for earthquakes, floods, and hurricanes are described in three broad categories:

- Regulatory measures
- Rehabilitation of existing structures
- Protective and control measures

Regulatory Measures

Regulatory measures include legal and other regulatory instruments that governments use to prevent, reduce, or prepare for the losses associated with hazard events. Examples include:

- Legislation that organizes and distributes responsibilities to protect a community from hazards
- Regulations that reduce the financial and social impact of hazards through measures such as insurance
- New or updated design and construction codes
- New or modified land use and zoning regulations
- Incentives that provide inducements for implementing mitigation measures

NOTE

In addition to the structural measures discussed in this guide, other mitigation measures are also important to local mitigation efforts. These measures include:

- Emergency preparedness measures that support emergency services to protect people and property during and after the hazard event
- Public awareness and education measures that inform and educate the general population, public officials and businesses about risks, preparedness, and mitigation measures
- Natural resource protection measures that protect the environment and preserve and restore natural systems

In most cases, regulatory measures should be considered first and before other measures because regulatory measures provide the framework for decision-making, organization, and financing of mitigation actions.

Rehabilitation of Existing Structures

As its name implies, rehabilitation deals with structural and non-structural modification of elements of existing buildings and infrastructure facilities. Although new and updated design and construction codes and new zoning laws can be effective mitigation measures to protect new construction, they usually cannot be applied retroactively. For this reason, improving the safety and structural integrity of existing buildings and infrastructure facilities is often the best way to reduce the impact of hazard events on such structures.

Buildings and infrastructure are often at risk due to their location in hazard-prone areas (such as floodplains, areas susceptible to landslides, or zones with high seismic activity). The level of damage is impacted by each structure's quality of design and construction. Poorly engineered and constructed buildings and infrastructure are usually not able to resist the forces of nature. Frequently, location and structure combine to increase the vulnerability of buildings and infrastructure facilities, especially those that were built a long time ago (e.g., before the first building codes were introduced). Mitigation measures for these structures must be targeted to the specific causes of vulnerability. For example, it would not make much sense to invest in expensive reinforcement of a structure that remains on unstable soil. Removal, relocation, or elevation of in-place structures located in highly hazardous areas is frequently the only option. Often this may mean that buildings of significant historic or cultural value have to be relocated or rebuilt, usually at great cost, on a different site.

In situations where buildings and infrastructure can benefit from structural improvements in-place, mitigation measures rely on those engineering solutions most appropriate for the substandard structures. Because the cost of these measures varies, a community must prioritize options based on the importance of the facility and its relative vulnerability. For example, essential and high potential loss facilities may generally have a priority for repair and strengthening over other buildings and infrastructure.

Protective and Control Measures

Unlike other mitigation measures that improve the resistance of buildings and infrastructure to disasters, protective and control measures focus on protecting structures by (1) deflecting the destructive forces from vulnerable structures and people or (2) erecting protective barriers. Well-known examples are dams and reservoirs, levees, discharge canals, floodwalls and sea-walls, retaining walls, safe rooms or shelters, protective vegetation belts, and similar structures.

Now that you have a general understanding of the categories of mitigation measures related to structural protection, each of these categories is reviewed for the three primary HAZUS-MH hazards – earthquakes, floods, and hurricanes.

Mitigation measures below are discussed for earthquakes, floods, and hurricanes as they relate to regulatory measures, rehabilitation of existing structures, and protective and control measures.

Task 5.1 is designed to help you identify a set of preliminary mitigation options based on HAZUS-MH loss estimates. Worksheet 5-1A provides information on HAZUS-MH inventory and building elements. It allows you to cross reference this information with that for earthquakes, floods, and hurricanes. List your preliminary mitigation options categorized by mitigation measures and hazards on Worksheet 5-1B. Example 5-1A lists a variety of mitigation measures you may want to consider for buildings and infrastructure. Example 5-1B lists a variety of mitigation options specific to earthquakes, floods, and hurricanes. Worksheet 5-2 allows you to evaluate and compare mitigation options using a number of criteria recommended by FEMA. Worksheet 5-3 helps you document your final consolidated list of options.

Mitigation Measures for Earthquakes

Earthquakes are distinguished by their unpredictability, force, sudden onset, and unparalleled destructive power. The effect of earthquake forces on the built environment can be devastating, both in terms of human casualties and economic loss. In the last few decades, however, significant advances have been made in techniques for mitigating earthquake risk.

The National Earthquake Hazard Reduction Program provides resources regarding mitigation options for this hazard: http://www.fema.gov/hazards/earthquakes/eqmit.shtm.

Regulatory Measures. Building codes are the most widely used earthquake mitigation strategy in the country. Advances in earthquake engineering in the last few decades are now incorporated in these codes and have been successfully proven in a number of earthquakes. This regulatory measure has been used effectively to raise the standard of earthquake-resistance for newly built structures and significantly reduce casualties and other losses. At the same time, zoning and land use planning regulations have been able to reduce development close to active earthquake faults.

Rehabilitation of Existing Structures. Older buildings and infrastructure pose the greatest safety threat for communities exposed to earthquake hazards.

These structures were generally constructed before regulatory mitigation measures were in place. Rehabilitation of existing structures has been implemented to increase the earthquake-resistance of this older inventory stock. Experience has shown that un-reinforced masonry buildings are especially vulnerable to earthquakes, and many jurisdictions have enacted ordinances that require them either to be retrofitted or demolished. In most cases, however, these structures are not subject to mandatory seismic codes unless substantial improvements or additions are proposed, mainly due to the high cost of these interventions. Cost-effective measures for the rehabilitation of existing buildings and infrastructure have been developed and many structures have been retrofitted, with a focus primarily on the most critical and most vulnerable buildings and facilities. Raising the earthquake resistance of these types of structures also can improve the earthquake response by ensuring that emergency equipment is immediately available after the disaster, and that these services can respond effectively to the community's needs. Many school districts in earthquake-prone regions have instituted retrofitting programs, with a primary focus on the safety of children and staff. Similarly, colleges, universities, public agencies, developers, and private owners have retrofitted facilities that are essential to the survival of their services or businesses after careful analysis of the costs and benefits of these measures.

DEFINITION

Structural elements - walls, columns, beams, and girders that support a building or structure

Non-structural elements - architectural components such as exterior cladding, parapets, glazing, cornices, and corbels, as well as interior partitions, suspended ceilings, and lighting fixtures

Structural engineers have produced a range of techniques to increase the earthquake resistance of structures. Because facility design and the materials and systems of construction differ greatly, a wide variety of strengthening techniques have been developed. The two general aspects of retrofitting that must be addressed are:

- Repair and strengthening of structural elements
- Repair and strengthening of non-structural elements and systems

Structural elements, irrespective of the construction materials used, must be protected from collapse and serious damage that might render the structure unusable or dangerous to people. Non-structural elements may also be protected through engineering retrofits. Additionally, electrical power and gas distribution systems; communication systems; water, waste and fire protection piping; and heating and cooling systems, staircases and elevators can be considered non-structural elements and must be reinforced and

protected because damage to any of these elements also may cause casualties and render the buildings unusable.

Protective and Control Measures. In regard to the earthquake hazard, this mitigation category is most frequently employed in conjunction with other mitigation measures. An example of a protective measure for buildings would be securing the slopes around buildings and critical infrastructure. Securing slopes helps to reduce the potential for landslides in the event of an earthquake and, therefore, will reduce the overall impact to a structure if an earthquake should occur. Stabilizing soils and securing hazardous sites before new construction in certain areas also would fall into this category.

Mitigation Measures for Floods (Coastal and Riverine)

The basic purpose of flood mitigation measures is to avoid or minimize exposure to flooding. This is accomplished through (1) actions that regulate new development and redevelopment and (2) engineering measures that address existing conditions. Selection of specific mitigation measures is highly dependent on the nature of the flood hazard and the types of buildings and infrastructure at risk.

The National Flood Insurance Program provides resources regarding mitigation options for this hazard:
http://www.fema.gov/fima/nfip.shtm

Regulatory Measures. For flooding, regulatory measures can be used to achieve two broad objectives: (1) to guide development to areas that are not flood-prone and (2) to ensure that new development in flood-prone areas addresses flood hazards. Many communities use regulations to guide new development to areas that are not susceptible to flooding or away from identified high hazard areas (such as the floodway, for riverine flooding). In other cases, floodplain regulations and building codes are intended to recognize flood hazards and ensure that flood loads are addressed in the planning and design of new buildings and infrastructure. Those same codes are applied to existing buildings when such buildings sustain damage and require repair and reconstruction. In these cases, the regulations impose the same degree of protection that is required for new buildings, resulting in the rehabilitation of older buildings, such as elevation-in-place and floodproofing to designed flood levels.

Rehabilitation of Existing Structures. For flooding, these measures can reduce flood damage up to pre-selected flood levels, although buildings remain susceptible to damage if more severe flooding occurs. Rehabilitation can include elevation-in-place and floodproofing for buildings. Acquisition and

demolition of flood-prone buildings is another effective mitigation measure that reduces exposed inventory in the floodplain and helps to return the floodplain to its natural function. Physically relocating intact buildings out of the floodplain to higher ground (or away from eroding shorelines), though effective, is usually reserved for special cases (such as, moving the historical lighthouse in Cape Hatteras because of beach erosion). Retrofit of infrastructure includes a wide variety of measures, depending on the type of infrastructure and the nature of the flood hazard. Examples include flood-proofed wastewater treatment plants and other public buildings, modified bridges that reduce backwater flooding, and upgraded or stabilized streambeds and banks to protect installations of sewer and water supply lines.

Protective and Control Measures. For floods, these measures are accomplished by modifying the source or path of flooding to keep floodwaters away from existing developed areas. These measures are generally referred to as "structural" flood control measures. They can focus on (1) decreasing runoff, (2) increasing discharge capacities, or (3) containing, diverting, or storing the floodwater. Construction of these protective measures depends on many factors that may limit their applicability in any given location. The most widely used measures for each of these categories are listed below:

- **Decreasing Runoff.** Dams and reservoirs that store floodwater in order to reduce downstream flood discharges
- **Increasing Discharge Capacity.** Drainage improvement measures that enlarge channels and over-bank areas, reduce obstructions (such as undersized bridges and culverts), and/or construct diversion channels that direct floodwater away from the vulnerable areas
- **Containing, Diverting, or Storing Floodwater.** Construction of floodwalls and levees as barriers to prevent inundation of protected areas from floods of a specific recurrence probability

Mitigation Measures for Hurricanes

Before mitigation measures can be implemented to protect buildings and infrastructure from hurricane and other high-wind risks, you must understand how buildings and other structures behave when exposed to wind forces. High winds can come from any direction and lateral wind forces tend to push inward on windward walls, turn structures over, and sheer them off their bases. In addition, suction forces on the walls and roof tend to pull them away from the building. At the same time, the wind pressure inside

The National Hurricane Program provides resources regarding mitigation options for this hazard:
http://www.fema.gov/hazards/hurricanes/

a structure can build up, adding to the forces that tend to pull a roof and walls outward. Therefore, to withstand hurricanes, structures must be constructed to stay down and stand up.

Another wind-related hazard is the tornado. Buildings are not typically designed to resist tornadoes. Safe rooms are sometimes added to these buildings to provide a shelter that protects humans from injury and death.

The extent to which a building is vulnerable to strong winds is a function of design and configuration, the quality of construction, the type of materials used, and the exposure of the site. In general, lightweight wood-framed structures are much more vulnerable than larger, heavier buildings. This means that single-family residential buildings are especially vulnerable.

Regulatory Measures. Planning, design, and engineering standards for new construction in high-wind zones are well developed and their application in hazard-prone areas has been effective. However, local zoning and land-use regulations have, to date, played a more limited role in regulating development to reduce exposure to high winds (except in coastal areas where the risk associated with hurricane-related storm surges and wind is very high).

Rehabilitation of Existing Structures. Rehabilitation of existing buildings concentrates on reinforcing the building and protecting its openings. The most frequently recommended mitigation measures for such cases are:

- The whole building must be tied securely to its foundations.
- Every element of the building structure and building envelope (i.e., the roof and wall covering, doors and windows) must be tied together to resist wind forces.
- Joints between various elements in a building must be strengthened to resist breaking up into separate and vulnerable elements.
- Wind must be prevented from entering the building and blowing the roof off, which is usually accomplished by strengthening the doors and providing impact-resistant glazing or window shutters.

Protective and Control Measures. For the hurricane hazard, the primary mitigation measures fall into the regulatory and rehabilitation categories discussed above.

Congratulations! You have now reviewed your loss estimation outputs and have compiled a preliminary list of mitigation options that can protect your built environment against the impacts of earthquakes, floods, and hurricanes.

Review Mitigation Options (Task 5.2)

At this point, you should have identified a preliminary list of mitigation options (Worksheet 5-1A). These options should have been grouped by hazards and under the regulatory, rehabilitation, and protective and control framework (Worksheet 5-1B). For Task 5.2, a set of criteria are provided to help you to narrow the mitigation options identified during Task 5.1. Worksheet 5-2 will help you develop a short list of your mitigation options using a set criteria that should be reviewed and modified as required by your community and institutional needs. The selected criteria that FEMA has proposed for all jurisdictions to consider consist of a common set of evaluation criteria, known as the STAPLEE evaluation criteria. This set of criteria will enable you to examine the Social, Technical, Administrative, Political, Legal, Economic, and Environmental (STAPLEE) opportunities and constraints of implementing a particular mitigation measure using a consistent framework.

- **Social criteria** are based on the idea that community consensus is a necessary precondition for successful implementation of mitigation measures (i.e., measures should be supported and accepted by the entire community). This also means that measures should not affect adversely a particular segment of the population or a particular neighborhood, or adversely impact local cultural values or resources.
- **Technical criteria** address the technical feasibility of the proposed measures, in terms of effectiveness, secondary impacts, and the technical capabilities of your community to implement and sustain these measures.
- **Administrative criteria** address the administrative capabilities required to implement each mitigation measure. For example, does your jurisdiction have the necessary organization, staff, and funding sources to implement and sustain the mitigation process?
- **Political criteria** consider the need for political support for mitigation measures. This means that all stakeholders in the political process, especially political organizations and institutions both inside and outside of the community, should support the measure.
- **Legal criteria** are used to determine the appropriate legal authority necessary to implement each mitigation measure and whether such an authority can be delegated. In addition, you will examine the mitigation measure from the standpoint of current statutes, codes, ordinances, and other regulations, as well as the possible legal ramifications of the measure's implementation.

- **Economic criteria** address the cost-effectiveness of the proposed measure and its economic impact on the community. It is only reasonable to expect that the benefits of implementation will exceed the costs incurred. Economic considerations also consider the economic impact on the community's future development.
- **Environmental criteria** have become an important consideration in examining mitigation options. Although most mitigation measures are usually beneficial for the environment, some measures may have adverse effects, which must be considered and addressed.

Now that you understand the STAPLEE criteria, you are ready to complete Worksheet 5-2, which will help you consider and compare options related to specific mitigation goals and objectives.

Congratulations! You have now developed a short list of mitigation options that can be introduced in your mitigation plan after verification (Task 5.4). This list may help you to reduce potential impacts of natural hazards on your built environment.

Identify Final List Of Mitigation Options (Task 5.3)

HAZUS-MH features can help you evaluate and compare some common mitigation measures for the earthquake, flood, and hurricane hazards. To prepare a final list of mitigation options (see Worksheet 5-3), you may want to use the tools in HAZUS-MH to rerun pre- and post-event scenarios to determine if your mitigation options are reducing the hazard risk in your community. The activities below will help you use HAZUS-MH to evaluate some of your mitigation measure options in order to refine your identified mitigation options.

Earthquakes

The HAZUS-MH earthquake model can help you test the effectiveness of some strengthening measures on the buildings and infrastructure in your study region. For example, some critical or high potential loss facilities in your area may not meet current seismic codes or may be unsafe for a variety of reasons. The HAZUS-MH Advanced Engineering Building Module (AEBM) includes specific damage and loss functions that are used to assess losses for an individual building (or a group of similar buildings) under existing conditions and after some seismic repair and strengthening measures have been implemented. The comparison of damage and loss estimates before and after mitigation measures are implemented

will provide you with a clearer picture of the effectiveness of particular mitigation measures for the buildings in question. However, this technique requires advanced use of HAZUS-MH and the services of seismic engineering specialists. For more information see the *HASUS-MH Earthquake User Manual.*

In order to estimate the effectiveness of a particular building code upgrade and strengthening measures on a whole class of buildings in the study region (e.g., the strengthening of all unreinforced masonry residential buildings in your area), you would need to change the fragility curves for that particular occupancy and building type category, and then repeat an analysis with this new data. This technique also requires the services of an experienced seismic engineer and advanced HAZUS-MH knowledge.

Floods (Coastal and Riverine)

The flood model has a built-in feature specifically designed to support mitigation planning. This "What-If" feature enables analyses that can test the proposed mitigation measures and produce new loss estimates based on the assumption that a proposed measure was implemented.

Currently, this feature allows you to analyze the several mitigation measures for riverine and coastal floods as described below. "What-If" scenarios can be used after you run a baseline flood case study analysis and obtain the associated loss estimate data.

For more information on how to use HAZUS-MH to evaluate mitigation measures, see page 4-37 of the *Flood User Manual.*

Riverine Flood Mitigation Measure Evaluation. After you estimate losses for your case study, you can estimate the effect of a new levee on flood depths by drawing the levee shape on a map and specifying its level of protection by selecting a Levee What-If Scenario under a Hazard menu.

The Riverine Flow Regulation scenario allows you to test the effects of a new reservoir by marking its location on the map and specifying its discharge value.

Coastal Flood Model Mitigation Measure Evaluation. The coastal flood model allows you to test the effects of long-term erosion; therefore, you can estimate and evaluate the additional losses that may result if mitigation measures to control that erosion are not implemented. By modifying the type of shoreline and its level of protection against erosion and waves, you can also estimate the effects of shoreline protection measures. The steps below will help you access and run the "What-If Scenario" feature of the flood model:

The "What-If" analysis options in the flood model include levee assessment, upstream storage, and simplified velocity for the riverine analysis. The "What-If" analysis options include long-term erosion and shore protection for the coastal analysis.

1. **Start the "What-If Scenario."** To begin running a What-If Scenario, select "Hazard" from the HAZUS-MH main menu. Then select "What-If Scenarios."

2. **Three riverine and two coastal options will become available.** The riverine options include: Riverine Levee, Riverine Flow Regulation, and Riverine Velocity Grid (see Figure 5-2). The coastal options include: Coastal Long-Term Erosion and Coastal Shore Protection.

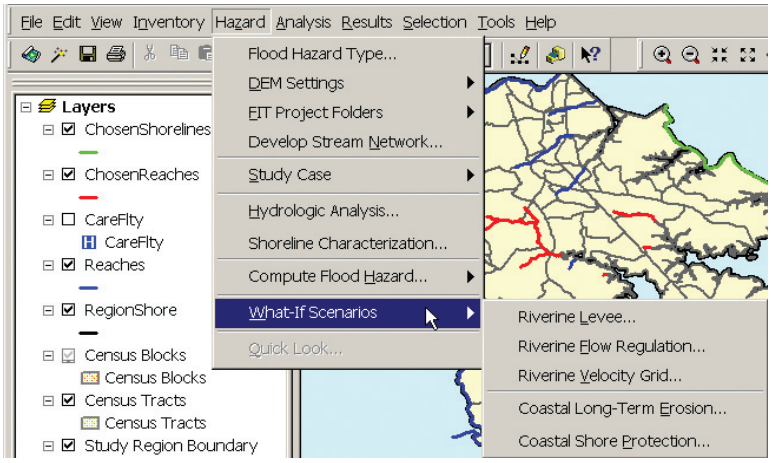

Figure 5-2 "What If" menu

3. **Set up a "What-If Scenario."** To set up the "What-If Scenario" parameters, select the option(s) you want to consider for the analysis.

   a. To include the Riverine Levee in the analysis, draw the levee shape using the "Draw" option on the levee menu (see Figure 5-3). Enter the level of protection (in years) next to "Years" and click "Save," then "OK."

   b. To include the Flow Regulation in the analysis, draw the flow regulation structure location using the "Draw" option on the flow regulation menu (see Figure 5-4). The existing return period and discharge values (in cfs) will be displayed under "Existing values." Select "Existing values" to change and enter new values for the "Return period" and "Discharge (cfs)" under "New values." Select "OK" after you have entered the new values.

   c. To include the Riverine Velocity Grid in the analysis, select the "Riverine Velocity Grid" option and a box will pop up informing you the process will take time. Click "OK" and allow the process to run to completion. This option will estimate the spatial distribution of the floodwater velocities.

   d. To include the coastal long-term erosion analysis, use the arrows on the top of the menu to select the different coastline segments of your study case (see Figure 5-5). Enter values for rate (feet/year) and duration (years) under "Erosion parameters" for each segment. Click "OK" when you have finished entering the parameters.

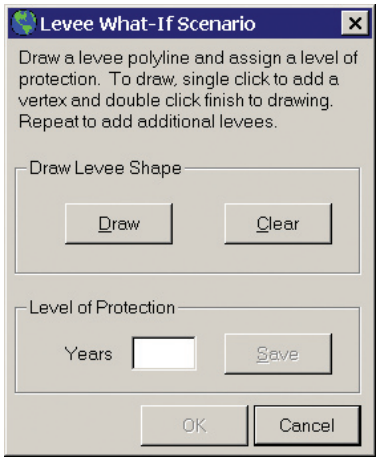

Figure 5-3 Levee options

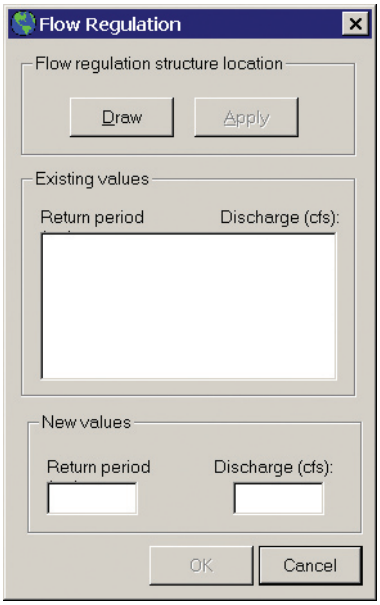

Figure 5-4 Flow regulation

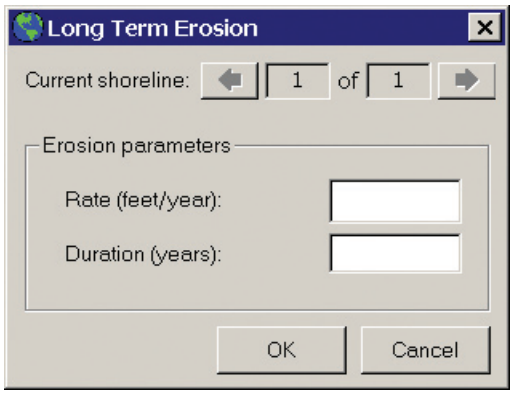

Figure 5-5 Long term erosion

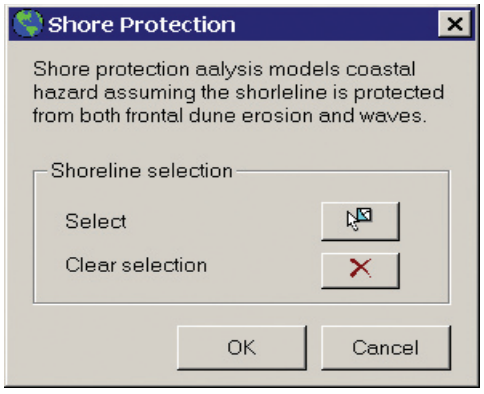

Figure 5-6 Shore protection

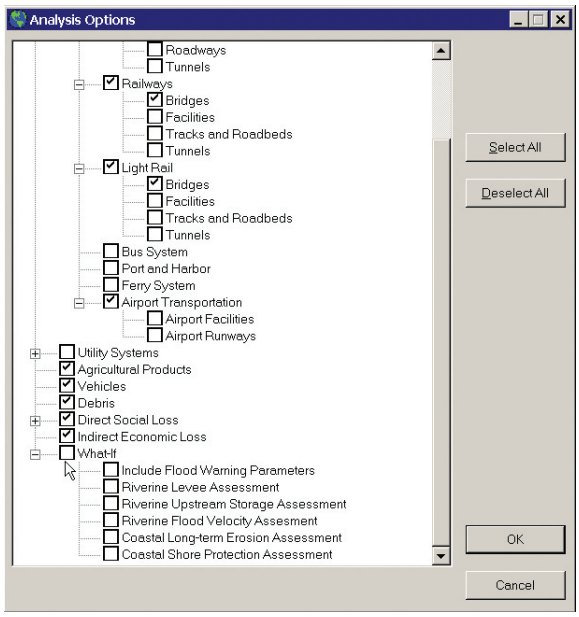

Figure 5-7 Analysis options

For more information on how to use HAZUS-MH to evaluate mitigation measures for hurricanes, see page 7-6 of the *HAZUS-MH Hurricane User Manual.*

e. To include coastal shore protection in the analysis, click the "Shoreline selection" button and select the shoreline segment on the map (see Figure 5-6). When you have finished selecting all the segments with shore protection, click "OK."

4. **Run the analysis**. To run the analysis, select "Analysis" from the HAZUS-MH main menu and then click "Run." The Analysis Options menu should now be displayed (see Figure 5-7). Click the "What-If" option and you will see the five riverine and coastal options discussed above. Select the options you want to run and then click "OK." A new analysis will be modeled using the selected "What-If" options. The results of the analysis can be viewed under the results menu option detailed in Step 4 of this How-To Guide.

Hurricanes

The hurricane model also has specific functionality to support the assessment of various mitigation measures. This function is accessed through the Wind Building Characteristics menu under General Building Stock in the Inventory. When you select the "Mitigate" option, you can assign a new wind building characteristics mapping scheme with different mitigation characteristics for single-family housing and for manufactured homes at the state, county, and Census tract levels.

The model offers four different mitigation options for single-family housing: shutters, roof straps, improved roof decking attachments, and secondary water resistance, and one option for mobile homes: tie-downs.

Using this capability of the hurricane model can help you assess quickly the potential benefits of mitigation measures (i.e., the effectiveness of residential mitigation measures or the proposed building code changes and the effects of their implementation). The steps below will help you use these features.

1. **Access the function**. To begin altering the building inventory to reflect potential mitigation measures, select "Inventory," then "General Building Stock," and "Wind Building Characteristics Distribution" (see Figure 5-8).

2. **Select mapping schemes**. To begin mitigating the building characteristics, select the mapping scheme(s) in your study region and click the "Mitigate" button on the bottom right of the Wind Building Characteristics Distribution menu (see Figure 5-9).

3. **Enter mitigation parameters**. To enter the mitigation parameters, change the values in the Mitigate Hurricane Building Characteristics Scheme Menu (see Figure 5-10). There are parameters for single-family homes and manufactured homes (represented as the percentage of homes that have undergone mitigation measures).

4. **Select options**. Options include Shutters on All Windows and Entry Doors, Roof-wall Connection Clips/Straps, Superior Roof Deck Attachment, and Secondary Water Resistance. The manufactured home option is Tie Downs. After you have entered the new values, select "OK."

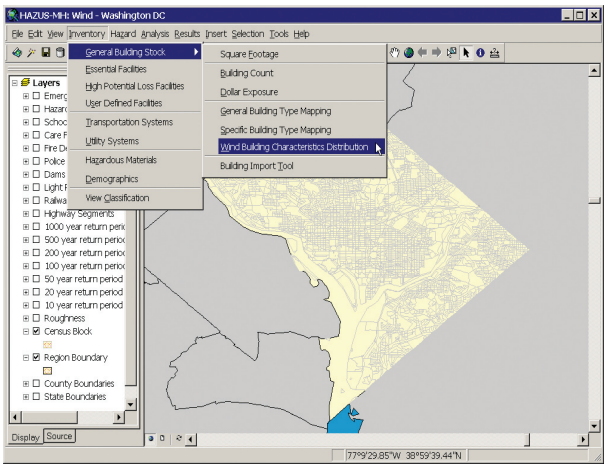

Figure 5-8
Wind building characteristics menu

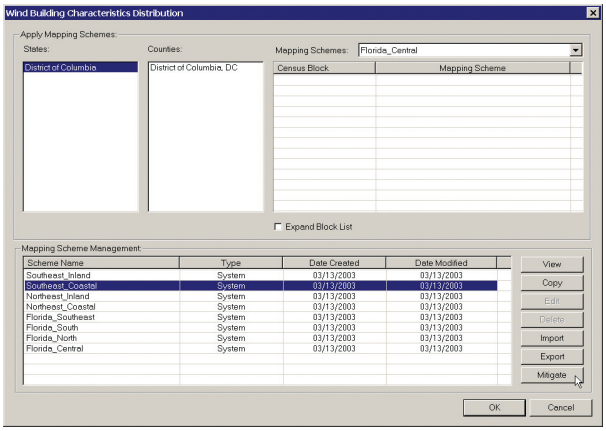

Figure 5-9
Wind building characteristics distribution menu

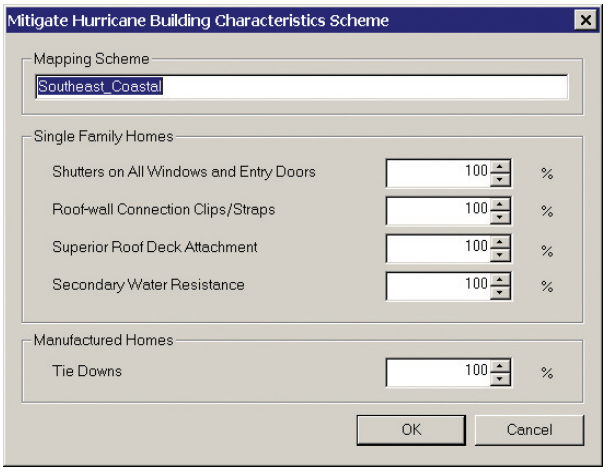

Figure 5-10 Building mitigation menu

5. **Rerun your analysis**. You may now rerun a scenario with the new mitigation measures in place.

Congratulations! You have now completed a final list of mitigation options that can be introduced in your mitigation plan after verification (Task 5.4). This list may help you to reduce the potential impacts of natural hazards on your built environment.

Verify Mitigation Options (Task 5.4)

An important challenge in designing mitigation options for all hazards in an integrated approach is that the methods used for design may reinforce one another or may conflict with one another. In the former case, the costs of multi-hazard design can be reduced, but, in the latter, they may be increased. After you prepare your final list, it would be wise to verify that these conflicts are not present in your selected mitigation options. If you identify potential conflicts, you may want to return to previous steps and review your selection of mitigation options. You can document any changes and maintain a consolidated list of options. Job Aid 5-1 in Appendix G provides a starting point for this task and will help you understand these conflicts. The material presented in this task is based on FEMA 424, *Design Guide for Improving School Safety In Earthquakes, Floods, and High Winds.*

When your final list has been reviewed, you may want to integrate selected mitigation options into your mitigation plan. Fully developing a mitigation plan goes beyond this How-To Guide; however, FEMA 386-3, *Developing the Mitigation Plan* can help you with this task. To start you in that direction, this How-To Guide provides Job Aid 5-2 in Appendix G which summarizes the general requirements of a DMA 2000 mitigation plan and where the outputs of your HAZUS-MH supported risk assessment fit.

Congratulations! You have now verified your final list of mitigation options and are ready to integrate them into your mitigation plan.

SUMMARY

Table 5-1: Consider Mitigation Options Activities and Outputs Checklist

Activity	Output	Check Completed Items
Identify preliminary mitigation options (Task 5.1)	Preliminary list of mitigation options (Worksheets 5-1A and 5-1B)	
Review mitigation options (Task 5.2)	Short list of mitigation options (Worksheet 5-2)	
Identify final list of mitigation options (Task 5.3)	Final list of mitigation options (Worksheet 5-3)	
Verify mitigation options (Task 5.4)	Consolidated list of mitigation options	

WORKSHEET 5-1A: IDENTIFY PRELIMINARY LIST OF MITIGATION OPTIONS BASED ON HAZUS-MH LOSS ESTIMATES

Worksheet 5-1A will help you record areas of major loss estimated in Step 4. First, mark areas of major loss predicted by HAZUS-MH for each hazard. Then consider specific building elements at risk. Review the areas containing check marks as a focus area for mitigation options. Refer to Examples 5-1A and 5-1B to identify potential mitigation measures. The most important mitigation measures identified during this process should be included in Worksheet 5-1B.

	Building Types							Building Occupancies							Essential Facilities						High Potential Loss Facilities and HazMat Facilities					Transportation Systems/Lifelines							Utility Systems						
HAZARDS	Concrete	Pre-cast Concrete	Reinforced Masonry	Steel	Unreinforced Masonry	Wood	Manufactured Homes	Residential	Commercial	Industrial	Agriculture	Religion	Government	Education	Medical Care Facilities	Fire Stations	Police Stations	EOCs	Schools	Shelters	Dams	Levees	Nuclear Power Facilities	Military Installations	HazMat Facilities	Highway	Railway	Light Rail	Bus Station	Ports	Ferry	Airport	Potable Water	Wastewater	Oil Systems	Natural Gas	Electric Power	Communications
EARTHQUAKE																																						
FLOOD																																						
HURRICANE																																						
BUILDING ELEMENTS																																						
Site																																						
Architectural																																						
Structural Systems																																						
Building Envelope																																						
Utility Systems																																						
Mechanical Systems																																						
Plumbing and Gas																																						
Electrical Systems																																						
Fire Alarm Systems																																						
Communication and Information Technology (IT)																																						

WORKSHEET 5-1B: PREPARE A PRELIMINARY LIST OF MITIGATION OPTIONS

Use this worksheet to list your preliminary mitigation options categorized by mitigation measures and hazards. This preliminary list is the output of Task 5.1, Worksheet 5-1A, and Examples 5-1A and 5-1B. This preliminary list of mitigation options will be further refined in Worksheet 5-2.

LIST OF PRELIMINARY MITIGATION OPTIONS	
Regulatory Measures	
Earthquake	
Flood	
Hurricane	
Rehabilitation	
Earthquake	
Flood	

WORKSHEET 5-1B: PREPARE A PRELIMINARY LIST OF MITIGATION OPTIONS (continued)

LIST OF PRELIMINARY OPTIONS	
Hurricane	
Protective and Control Structure	
Earthquake	
Flood	
Hurricane	

EXAMPLE 5-1A: MITIGATION MEASURES FOR THE BUILT ENVIRONMENT

Example 5-1A should be used in conjunction with Worksheets 5-1A and 5-1B. It provides mitigation examples and focus areas that can be used as a starting point to identify your mitigation options which will be further refined in Worksheet 5-2.

Example Focus Areas for Physical Mitigation Options – Facilities (Community-Specific, Infrastructure, and General Building Stock)	
Site	**Utility Systems**
• Access Points	• Water/Entry Points/Site
• Lighting	• Water Distribution
• Parking	• Water for Fire Suppression
• Roadway/Pedestrian/Paths	• Sanitary and Stormwater Sewer/Site
Architectural	• Sanitary and Stormwater Sewer/Building
• Access Public and Private Entrance	• Fuel Entry Point/Delivery/Storage
• Access Public-Private Space	• Manholes
• Access Public-Private Stairwells	• Above/Underground Tanks
• Access Public-Private Elevators	**Mechanical Systems**
• Egress	• Air Intakes
• Non-Bearing Walls	• Exhaust Louvers
• Non-Structural Elements	• HVAC Systems
Structural Systems	**Plumbing and Gas**
• Repairs/Rehabilitation	• Main Piping Distribution Systems
• Upgrading to New Codes and Standards	• Gas Storage Tanks
• Designing to New Performance Objectives	• Gas Reserve Supplies Location/Protection
• Ductile Structural Elements/Detailing	**Electrical Systems**
• Sheer Reinforcement	• Electrical Wiring
• Connections	• Transformers
• Lateral and Vertical Force Considerations	• Distribution Panels
• Column Spacing, Size, Shape, and Configuration	• Backup Power
• Reinforcement of Masonry	**Fire Alarm Systems**
• Flood Elevations	• Fire Alarm System
Building Envelope	• Fire Hydrant Location
• Shear Walls/Steel Frame Systems	• Smoke Evacuation System
• Reinforcement Non-Bearing Masonry Walls	
• Window Design/Frame/Anchorage/Glazing Mullions	
• Doors	
• Roof	

EXAMPLE 5-1A: MITIGATION MEASURES FOR THE BUILT ENVIRONMENT (continued)

Example Focus Areas for Physical Mitigation Options – Facilities (Community-Specific, Infrastructure, and General Building Stock)	
Bridges	**Communication and IT**
• Build to improve design standards	• Redundancy CCTV
• Retrofit existing bridges	• Telephone System/Distribution
• Use remote sensing to identify problems	• Communication System/Distribution
• Design to new performance objectives	• Radio/Wireless System
Highways	• Redundancy/Backups
• Engineering design improvements	• Mass Communication
• Retrofit existing roadways	**Gas and Oil Pipelines**
• Improve lights and signs (roads and highways)	• Improve leak detection system
• Address potential landslide concerns	• Strengthen supports and joints
• Design to new performance objectives	• Install secondary containment/features
Tunnels	• Design to new performance objectives
• Rehabilitation	**Potable Water Systems**
• Upgrade to new codes and standards	• Improve leak detection system
• Design to new performance objectives	• Strengthen supports and joints
Railways	• Design to new performance objectives
• Maintain railbeds and slopes	**Potable Water Wells**
• Upgrade connections and lines/joints	• Install protection around wellheads
• Improve warning system and problem identification systems	• Upgrade well casing
• Design to new performance objectives	**Wastewater Systems**
	• Improve shut-off and diversion systems
	• Segregate combined overflow systems
	• Design to new performance objectives
	Ports and Ferries
	• Reinforcement of site structures (sea walls)
	• Improve warning systems

EXAMPLE 5-1B: MITIGATION MEASURES FOR THE BUILT ENVIRONMENT BY HAZARD

Example 5-1B should be used in conjunction with Worksheets 5-1A and 5-1B. It provides mitigation examples organized by earthquake, flood, and hurricane and can be used as a starting point to list your mitigation options, which will be further refined in Worksheet 5-2.

EXAMPLES
EARTHQUAKE
• Conduct careful analysis of seismic risk at site or region
• Evaluate for relative seismic risk if choice of sites is available
• Involve all design consultants from the initial stages of the building design
• Ensure that seismic code is correctly applied and that design and construction to code meets the performance requirements of the owner and other stakeholders
• Use as regular a building configuration as possible
• Ensure that support and bracing of all non-structural components and systems is correctly designed and constructed
• Ensure careful quality control on the building site to ensure building is constructed in complete conformance with contract documents
• Develop risk management plan for protection of building occupants and conduct training and exercises
• Consider reprogramming building to increase occupant safety
• Perform careful evaluation of existing building using recognized techniques to determine weaknesses
• Determine acceptable risk for stakeholders
• Study alternative remedial approaches and use benefit/cost analysis to determine appropriate risk management approach
• Investigate opportunities for incremental retrofit measures to increase feasibility of implementation
FLOOD
• Use regulations to guide new development away from identified high hazard areas (such as the floodway, for riverine flooding)
• Use floodplain regulations and building codes for planning and design of new buildings and infrastructure
• Increase discharge capacity by drainage improvement measures that enlarge channels and over-bank areas, and reduce obstructions such as undersized bridges and culverts
• Use elevation-in-place and floodproofing for buildings
• Construct diversion channels that direct floodwater away from the vulnerable areas
• Contain, divert, or store floodwater by constructing floodwalls and levees as barriers to prevent inundation of protected areas from floods of a specific recurrence probability
• Alter channels, to prevent or reduce flooding
• Use acquisition and demolition of flood-prone buildings
• Use physical relocation of high value buildings (i.e., historic, schools, etc.)
• Modify building and relocate contents
• Elevate foundation walls, piers, post or columns, and piles
• Use dry floodproofing by sealing walls with waterproofing compounds, impermeable sheeting, or other covering for openings
• Use continuous wall or block foundation
• Check stability of storage tanks and pipelines through alarms and control panels; consider, buoyancy, impact load, scour of lines, and movement of connection

EXAMPLE 5-1B: MITIGATION MEASURES FOR THE BUILT ENVIRONMENT BY HAZARD (continued)

EXAMPLES
• Install utility component in-place protection
• Elevate and anchor fuel tank on platform with straps
• For utilities, elevate equipment
• Modify bridges to reduce backwater flooding
• Decrease runoff of dams and reservoirs that store floodwater to reduce downstream flood discharges
• Retrofit wastewater treatment plants and other public buildings to floodproof
• Upgrade or stabilize streambeds and banks to protect installations of sewer and water supply lines
HURRICANE
• Implement the International Building Code (IBC) that requires load resistance of the roof assembly to be evaluated by one of the test methods listed in IBC's Chapter 15
• Consider sprayed polyurethane foam and liquid applied roof systems as roof covering options
• Attach vertical flanges of coping and edge flashing as roof attachment options
• Tie the roof structure by strapping it to the walls
• Prevent wind from entering the building and blowing the roof off by strengthening the doors and providing impact-resistant glazing or window shutters
• Apply IBC requirements for glazing
• Recommend reinforced cast-in-place concrete structures, reinforced concrete roof deck, and reinforced concrete and/or reinforced and fully grouted concrete masonry unit exterior walls
• Apply engineering standards for new construction in high-wind zones (e.g., calculate loads, determine load resistance, detailed design systems, material durability, and rain penetration)
• Tie the whole building securely to its foundations
• Tie together every element of the building structure and building envelope to resist wind forces
• Strengthen joints between various building elements to resist having them break into separate and vulnerable elements
• Locate new buildings away from hurricane-prone areas and avoid abrupt changes in topography (e.g., isolated hills, ridges, and escarpments) that can cause wind speed-up

WORKSHEET 5-2: PREPARE A SHORT LIST OF MITIGATION OPTIONS

This worksheet will help you to prepare a short list of your mitigation options. Bring forward your preliminary mitigation options from Worksheet 5-1B and review them against the list of criteria. The criteria, located in the upper portion of the table, are described in Task 5.2. Use a plus "+" or a minus "-" to indicate whether your preliminary mitigation options have a positive or negative impact for each criterion. Use Worksheet 5-3 to identify your final list of options based on your assessment.

	Social		Technical			Admin.			Political			Legal			Economic				Environmental					Other	
Preliminary Mitigation Options From Worksheet 5-1B	Community Acceptance	Effects on Segments of Population	Technical Feasibility	Long-term Solutions	Secondary Impact	Staffing	Funding Allocation	Maintenance	Political Support	Local Champion	Public Support	State Authority	Existing Local Authority	Potential Legal Challenges	Benefit of Action	Cost of Action	Contributes to Economic Goals	Outside Funding Required	Effect on Land and Water	Effect on Endangered Species	Effect on HazMat and Waste Sites	Consistent w/Community Env. Goals	Consistent w/Federal Env. Law	Others	Others
EARTHQUAKE																									
Option 1																									
Option 2																									
Option 3																									
Option 4																									
FLOOD																									
Option 1																									
Option 2																									
Option 3																									
Option 4																									
HURRICANE																									
Option 1																									
Option 2																									
Option 3																									
Option 4																									

WORKSHEET 5-3: PREPARE A FINAL LIST OF MITIGATION OPTIONS USING HAZUS-MH

This worksheet will help you to document your final list of your mitigation options. The short list of options identified in Task 5.2 and Worksheet 5-1B can be further refined using HAZUS-MH tools to rerun pre- and post-event scenarios for earthquakes, floods, and hurricanes. You should also include the results of your Worksheet 5-2 evaluation. By using HAZUS-MH tools, you can determine if your mitigation options are reducing the hazard risk in your community.

Mitigation Options
EARTHQUAKE
Option 1
Option 2
Option 3
FLOOD
Option 1
Option 2
Option 3
HURRICANE
Option 1
Option 2
Option 3
COMMENTS: