Multiple Hazard Mitigation

Report of a Workshop on Mitigation Strategies for Communities Prone to Multiple Natural Hazards

July 6-8, 1983
Snowmass, Colorado

Advisory Board on the Built Environment
Commission on Engineering and Technical Systems
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FOREWORD

This report describes a workshop on multiple hazard mitigation that was conducted by the Advisory Board on the Built Environment (ABBE) for the Federal Emergency Management Agency (FEMA). The workshop's purpose was to shed light on current capabilities and needs relevant to the development of hazard mitigation strategies for communities prone to several different kinds of natural hazards.

The workshop procedure and content were developed by a seven-member Committee on Natural Hazard Vulnerability and Hazard Mitigation. Members of that committee served in key roles at the workshop (as workshop chairman and as chairmen of working groups). No attempt was made to reach agreement on specific findings or recommendations, and this report--which was prepared by the planning committee and edited by the ABBE staff--is intended simply to reflect the more significant ideas and suggestions that were voiced during the workshop.

The success of the workshop was due in large part to the interest and support of John D. Seyffert and Larry Zensinger of FEMA, who recognized the potential value of such an activity and provided guidance and information, and to the workshop attendees, whose enthusiastic participation created two intense days of thoughtful and stimulating discussion.

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PREFACE

In the course of the discussions at the workshop and the preparation of this report, it became apparent that there were occasional uncertainties and misinterpretations concerning some of the concepts and terms relevant to consideration of mitigation strategies for communities prone to multiple natural hazards. In particular, there are four dichotomies that appear to be worth noting. These involve (1) the distinction between a single hazard and a multiple hazard approach to the management of natural hazards; (2) the distinction between emergency management, which addresses the immediate and urgent aspects of a disaster, and mitigation, which focuses on long-term planning, engineering, and economics; (3) the distinction between those emergency management and mitigation measures for which statutory and regulatory authority exists and those measures that are actually funded and undertaken; and (4) the distinction between mitigation measures that are undertaken in the absence of a disaster as part of a community's long-term planning and those measures that are undertaken after a disaster strikes in order to lessen the adverse impact of a recurrence of a similar disaster.

The lines of demarcation between these concepts are not always clear--sometimes because of ambiguities in the way terms such as "mitigation" are used in laws and regulations, and sometimes because of differing perceptions on the part of individuals who do not have a clear view of the whole picture. Some confusion and inconsistency in the discussion of these concepts can undoubtedly be discerned in this report. However, a concerted effort has been made to differentiate the important issues clearly. To support this effort the following terminology has been adopted:

Natural hazards are natural events that have adverse impacts on human society. A potentially damaging, or hazardous, natural event is an occurrence such as a flood, landslide, or earthquake having the potential to cause harm to people and damage to property. Such an event is considered a hazard only when it occurs, at a level of intensity or severity capable of causing damage, in a location where people, structures, and natural resources of value to society are exposed. The risk of such an event is its probability of occurrence in a particular location. The level of intensity or severity that is capable of causing damage depends upon the vulnerability of the exposed community; vulnerability is generally a function of the way in which structures are designed, built, and protected, and the vulnerability of a structure or community to a particular natural event is a measure of the damage likely to be sustained should the event occur. The degree to which a community is prone to a particular natural hazard depends on risk, exposure, and vulnerability. When a natural hazard occurrence significantly exceeds the community's capacity to cope with it, or causes a large number of deaths and injuries or significant economic loss, it is called a disaster.

Hazard management includes the full range of organized actions undertaken by public and private organizations in anticipation of and in response to hazards. Hazard management has two primary (but not completely distinct) components: emergency management, typified by the police, fire, rescue, and welfare work carried on during a disaster; the advance planning and training that are necessary if emergency operations are to be carried out successfully; and the postdisaster recovery period in which damage is repaired; and mitigation, which focuses on planning, engineering design, economic measures, education, and information dissemination, all carried out for the purpose of reducing the long-term losses associated with a particular hazard or set of hazards in a particular location.

Society may, through its efforts, be able to alter the frequency with which hazardous natural events occur. Human activities may deliberately or inadvertently increase or decrease the severity of hazardous events, alter the size of the areas impacted, influence the exposure of people and property, and modify the vulnerability of exposed populations and structures. These activities, when carried out intentionally for the purpose of decreasing a hazard's adverse impact, are considered mitigation. Society's efforts to mitigate the effects of natural hazards have included the construction of dams, sea walls, and dikes; the elevation of buildings above expected flood levels; the construction of buildings in a manner designed to increase their ability to withstand the forces of wind, water, and land movement; the adoption of measures to exclude susceptible structures and activities from hazard-prone areas; and the pursuit of education and public information programs concerned with planning for and coping with natural hazards. There have also been programs designed to assist those who have sustained damage from natural hazards in rebuilding in a manner that makes them less vulnerable to damage in future disasters.

Whatever degree of mitigation is practiced, if the hazard occurs certain measures must be taken in response to it. These measures include warnings, evacuations, fire fighting, rescue work, emergency medical care, emergency communications and transportation, provision of emergency supplies of food, water, clothing, and shelter, and measures to preserve public health and safety. These emergency response activities are most effective if there has been an emergency preparedness program including planning, purchase of emergency equipment, and training of emergency personnel. Once the emergency is over, damage must be repaired and the community must be restored to a normally functioning state in a series of financial and construction recovery activities that can include disaster relief, low-cost loans, and insurance. This sequence of preparedness, response, and recovery constitutes the process of emergency management.

Mitigation and emergency management are not mutually exclusive. Mitigation measures can be incorporated, together with emergency preparedness, in community preparedness programs, and mitigation measures are often incorporated in the recovery process.

The leadership in hazard management is usually exercised by governmental agencies at the local, state, and federal levels, with important participatory roles for business and civic organizations and quasi-public relief and welfare agencies. The steps that constitute hazard management usually require legislative authorization and provision of funds at one or more governmental levels. Even where the basic legislation is in place, it does not necessarily follow that funds will actually be provided, personnel hired, and programs undertaken. Ideally, hazard management ought to begin before a hazard occurs; however, as a practical political matter the impetus for such activities is often missing until a disaster strikes. Even then the hazard management activities undertaken may not cover the full range of potential hazards or even the ones that geophysical and economic reasoning dictates are most important. Instead, hazard management often focuses on the kinds of hazards publicly perceived as having the highest priority, or those for which funds appear to be most readily available.

Only natural hazards are addressed in this report. Technological hazards such as chemical fires, oil spills, and nuclear accidents are very different in nature and were not addressed at the workshop, even though the same organizations that are involved in natural hazard management may be involved in the emergency management and mitigation of technological hazards.

A single hazard or hazard-by-hazard approach is one that addresses only one kind of potentially damaging natural event (e.g., floods) at a time. While the juxtaposition of several such single hazard programs may be termed multiple hazard management, in this report the term multiple hazard management generally means an integrated or coordinated approach addressing the full range of serious hazards to which a community is prone. Multiple hazard mitigation is the component of multiple hazard management that is concerned with reducing the long-term adverse impacts of the full range of natural hazards within a particular community, state, or region or for the nation as a whole.

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INTRODUCTION

On July 6-8, 1983, 26 experts in community planning, geophysics, engineering, economics, and emergency management assembled in Snowmass, Colorado, to participate in a workshop on multiple hazard mitigation.[1] The workshop focused on present capabilities relevant to the development of mitigation strategies for communities that are subject to a variety of natural hazards such as those associated with riverine and coastal floods, earthquakes, landslides, windstorms, and other potentially damaging natural events.

Although human safety, emotional security, and material well-being are all threatened by natural hazards, the workshop focused almost entirely on economic losses. Occupation of hazardous areas usually produces both benefits and costs to society. As used at the workshop and in this report, the term "loss" refers to the sum of those benefits and costs, i.e., to net economic losses.

BACKGROUND

The degree to which a community is vulnerable to economic loss from natural hazards depends upon such factors as the nature, extent, and spatial configuration of its developed areas, the design and construction of its roads and buildings, its ability to take protective action when a disaster warning is issued, and its capacity for marshaling human and economic resources for rebuilding and recovery after a disaster strikes. It would appear sensible for such a community to adopt a rational strategy for keeping its economic losses from natural hazards to a minimum. This strategy might encompass a variety of measures designed to lessen the long-term adverse impact of a natural disaster, such as:

- protective engineering works (e.g., levees, debris basins)

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[1]The workshop participants are listed on pages v-vi.

o defensive design of structures (e.g., floodproofing), achieved though appropriate building codes

o land use management (e.g., exclusion--accomplished either through regulation or economic incentives--of certain kinds of structures from hazard-prone areas, or imposition of special engineering design requirements on structures in those areas)

o temporary protective actions (e.g., erection of sandbag levees or evacuation of threatened areas) in response to warnings

o provision of emergency services such as police, fire, rescue, ambulance, public health, and emergency food and shelter during a disaster

o disaster relief, loans, insurance, and other financial assistance to individuals and communities for recovery and rehabilitation

o programs of public education and disaster planning encompassing all of the above

The development of such a strategy requires the community to engage in a decision process involving risk analysis, vulnerability analysis, estimation of expected economic loss, identification of measures for reducing expected economic loss, and selection and implementation of a hazard mitigation strategy. Specifically, the community must

o know the probability of occurrence of each potentially damaging natural event at all locations within the community (risk analysis);

o estimate the amount of damage likely to be sustained by roads, bridges, buildings, etc., at all locations within the community, for each hazardous event that might occur (vulnerability analysis);

o estimate the economic losses likely to be sustained by the community in the event the hazard occurs, and, by taking into account the probability of occurrence, estimate the community's expected annual economic loss from each hazard and from all hazards;

o identify measures for reducing the overall expected economic loss to the community from natural hazards, and be able to estimate the cost and the effectiveness of those measures; and

o possess institutional mechanisms for selecting, designing, and implementing a cost-effective, multiple hazard mitigation strategy.

There may be a number of reasons why a community cannot follow such a course. The community may not have sufficient knowledge about the probability of occurrence of the hazardous events, or about their potential damaging impact, to estimate risk and vulnerability with confidence. It may not have sufficient knowledge of the economics to confidently estimate the expected economic loss associated with natural hazards and the likely costs of mitigation. It may have a greater degree of understanding of the risks, losses, and mitigation costs for some hazards than for others. And finally, given the practical realities of intergovernmental cooperation and federal funding--where programs and resources are generally directed, often by statute, toward specific hazards--it may be more effective in practice for the community to develop plans on a hazard-by-hazard basis than to follow the seemingly more rational path of multiple hazard mitigation.

THE WORKSHOP PROCESS

The goal of the workshop was to assess the degree to which it is feasible today to develop a multihazard mitigation strategy for a community that is prone to a multiplicity of natural hazards. This was accomplished by focusing on a series of questions relating to the process outlined above. These questions provided a frame of reference for assessing the adequacy of our present knowledge, techniques, and institutional mechanisms for this purpose. The questions related to the information, knowledge, and techniques that are available today to serve as a basis for developing a hazard mitigation strategy. They focused on the following:

- risk analysis
- vulnerability analysis
- estimation of expected economic losses
- identification of measures for reducing potential economic losses
- selection and implementation of a mitigation strategy
- the value of new information, new knowledge, and new techniques

Using these questions as a starting point, the workshop participants were asked to

- revise the questions or add other questions to the list, where appropriate;
- answer the questions, where possible; and
- identify information needed to answer the remaining questions, and how that information might be obtained, indicating areas in which further research, data collection, etc., are necessary.

All new questions, answers, and definitions of needs were tested by assessing their relevance to three specific "test communities" that are prone to a multiplicity of natural hazards and that have known geographical, demographic, sociopolitical, and economic characters. The test communities were the St. Louis area (where the primary hazards of concern are floods, tornadoes, and earthquakes), the San Francisco Bay area (earthquakes, landslides, and floods), and Hawaii (tsunamis, volcanoes, and hurricanes).

QUESTIONS ADDRESSED AT THE WORKSHOP

The following questions were addressed at the workshop:

Risk Analysis: The goal of risk analysis may be conceived as the preparation of maps indicating the probability of occurrence of all potentially damaging natural events, at various levels of intensity or severity, at all locations within the community. The maps would also indicate joint or conditional probabilities, e.g., the probability of a flood and landslide occurring simultaneously would reflect the capacity of a flood to trigger a landslide.

o For each kind of potentially damaging event, what information is needed to construct such a series of maps?

o To what extent is that information available or obtainable today, at what cost, and at what level of quality or confidence? What would it take to make information available that is not available today?

o Where the desired information is not available, or is very costly or technically difficult to obtain, is there surrogate information that could be used (e.g., can data on landslides be used to estimate the probability of mudflows, or can data derived from county maintenance records or electric utilities be used to estimate the frequency of severe windstorms)?

o What additional information is required to treat "compound hazards," i.e., circumstances in which one hazardous event triggers another, as when an earthquake triggers a landslide?

o Are there commonalities among hazards that relate to risk analysis?

o Can an overall assessment be developed of the degree to which the community is at risk from natural hazards? Can such an assessment be expressed as a "risk index" for the community? With what confidence? Could such an index be used to rank communities in order of risk?

Vulnerability Analysis: The goal of vulnerability analysis or potential damage estimation can be conceived as preparation of a map of the community showing, for each potentially damaging natural event at each level of intensity or severity, the damage that would occur at every location within the community if that event should occur. "Damage" can conceivably include not only physical damage to buildings, roads, power lines, crops, and natural resources, but also nonphysical damage to the economic, social, and political infrastructure of the community.

o Which elements of the community (e.g., buildings, bridges, highways, communication systems, public services, financial infrastructure) should be considered, and which aspects of these elements are most important?

o What measures of damage should be used?

o What information--including information about the nature of the hazardous events as well as information about the nature of the damage-prone elements of the community--is necessary to assess potential damage?

o To what extent is that information available or obtainable, at what cost, and at what level of quality or confidence? What would it take to make information available that is not available today?

o Where the desired information is not available, or is very costly or technically difficult to obtain, is there surrogate information that could be used (e.g., could information derived from tax assessment data, or information about building height and year of construction, together with a knowledge of the building code history, be used in assessing the likely damage to each building)?

o Can an integrated assessment of the overall vulnerability of the community to the full range of potentially damaging natural events be developed? Can such an assessment be represented by a "vulnerability index" for the community? With what confidence? Could such an index be used to rank communities in order of vulnerability?

Estimation of Expected Economic Losses: This involves (1) translating damage into economic terms, (2) for each hazard, combining the measure of risk with the measure of vulnerability to give the expected economic loss due to that hazard at each location within the community, and (3) combining the different hazards to give a map of total expected economic loss from all natural hazards. (Note: there are several different orders in which these steps can be accomplished, e.g., the translation of damage into economic terms can be the first step, the last step, or somewhere in the middle.)

o What information is needed to translate damage estimates into quantitative measures of economic loss?

o To what extent is that information available or obtainable, at what cost, and at what level of quality or confidence? What would it take to make information available that is not available today?

o Where the desired information is not available, is there surrogate information that could be used?

o How can the resulting estimate of expected economic loss to the community be used in a manner that is realistic in terms of the quality of the economic data? Can it be used to estimate total expected economic loss to the nation? Can it be used to rank communities in order of expected economic loss?

Identification of Measures for Reducing Expected Economic Loss: The long-term economic loss experienced by a community due to a particular class of hazard can be reduced by (1) reducing the probability of the hazardous event (e.g., reducing the probability of landslides by stabilizing slopes), (2) reducing the vulnerability of the community (e.g., by earthquake-proof design and construction of buildings, by erection of protective levees, or by wise management of land use), or (3) enhancing the community's capacity to respond to a disaster and recover from its losses (e.g., by adoption of insurance programs or other measures to make both technical and financial resources available for recovery).

o What measures are available for reducing both short-term and long-term economic losses from each hazard that threatens the community?

o What information, knowledge, techniques, and other resources (e.g., raw materials, skilled personnel) are required to design and implement these measures?

o How can the likely effectiveness of these measures be determined, and with what degree of confidence? Can effectiveness be expressed in economic terms, i.e., in terms of a reduction in expected economic loss? What information would be required to do this? How much confidence could we have in the answers?

o What would it take to assess the cost of designing and implementing these measures? Are the necessary information, knowledge, techniques, and resources available? If not, what would it take to make them available? What confidence could we have in the answers? Would they support a cost-benefit analysis?

o Can loss-reduction measures be designed that are effective and economical for a variety of hazards, or to be effective (or economical), must they address a particular hazard? (For example, evacuation may be an effective measure for a variety of hazards, but flood insurance is effective only for floods.)

Selection and Implementation of a Mitigation Strategy: The design and implementation of a hazard mitigation strategy requires (1) technical capability (i.e., knowledge, data, and techniques), (2) resources (i.e., funds, equipment, and skilled personnel, which may be available in varying degrees to different public and private organizations), and (3) the cooperative efforts of a number of governmental and private institutions at the local, state, federal, and even international levels. The institutional and political challenge may be greater than the technical and economic challenge. From a practical viewpoint,

o What decision processes are necessary to design and implement a multihazard mitigation strategy? What skills are required? What institutions must be involved? What institutional mechanisms are required? Are they available? How effective are they? Who might serve as the chief administrators of a multihazard mitigation strategy: planners, politicians, geophysicists, or engineers?

o What funds and other resources are required? Who can provide them? What would it take to make this happen?

o Given the present organization of government at the local, state, and federal levels, and the limits on the availability of governmental funds that often result from specific laws with narrow purposes, what obstacles hinder a community in developing a multihazard mitigation strategy? Can these obstacles be overcome? How?

o Under what circumstances might it be more feasible for a community to address mitigation on a hazard-by-hazard basis? Under what circumstances would multihazard mitigation be feasible?

The Value of New Information, New Knowledge, and New Techniques: Where the information, knowledge, techniques, or institutional mechanisms available today are inadequate, new knowledge, new information, and new techniques can often be developed, but at a cost: the cost of research, engineering development, data collection, etc. Unless there are significant nonmonetary benefits, it is not effective to spend more to acquire new information than the reduction in economic loss that can be expected to result from the new information. In each of the areas addressed by earlier questions,

o What is the (economic) value of better information, new knowledge, more effective techniques, etc.?

o What are the costs and time requirements of acquiring better information, new knowledge, etc.?

o What confidence can we have in the answers to these questions?

FOCUS OF THE WORKSHOP

The major emphasis of the workshop was on the long-term economic impact on the community--the costs associated with rebuilding not only houses and bridges, but also the economic and social fabric of the community. Once the immediate crisis is over--when the floodwaters have receded and the building rubble has been searched for victims--longer-term reconstruction and recovery needs usually raise many fundamental economic issues. A key question at the workshop was whether our economic understanding of natural hazards and their impact is sufficient to provide a rational economic basis for policy and strategy decisions about mitigation, preparedness, and recovery.

The focus of this workshop was on communities prone to a number of different natural hazards. Clearly, the principles enunciated at the workshop will apply equally well to the simpler case of a community that is at risk from only one kind of natural disaster.

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THE MULTIPLE HAZARD APPROACH TO MITIGATION

In the United States today, natural hazard mitigation is typically undertaken on a hazard-by-hazard basis. There are flood control programs, earthquake damage reduction programs, landslide stabilization programs, and others. While these programs have many common features, they also possess unique elements. Multiple hazard mitigation can be viewed as a logical and necessary mechanism for overcoming the limitations of existing single hazard mitigation programs. Its appeal rests on the belief that the overall adverse economic impact of natural hazards--for a particular locality, a geographic region, and the nation as a whole--may be more effectively minimized by governmental actions that address the full range of hazards, in a coordinated or integrated way, than by the present piecemeal approach. Yet the conceptual basis for multiple hazard mitigation is complex, the technical problems that it raises are formidable, and its successful adoption as national policy will require broad vision, sensitive application, and firm commitment from the Federal Emergency Management Agency (FEMA) and cooperating agencies at all levels of government.

NATURAL HAZARD MANAGEMENT

Natural hazard management refers to the full spectrum of organized actions that are undertaken by public and private organizations and individuals in anticipation of and in response to natural hazards. Today's natural hazard management programs encompass a wide variety of measures. Many of these measures are designed to help victims survive and recover from disasters; others are directed toward reducing, avoiding, or preventing losses. Natural hazard management may be divided into two major components: emergency management and mitigation.

Emergency management is primarily concerned with the short-term, immediate response to, and recovery from, an emergency situation, and with preparation for that response. When a potentially damaging natural event such as a landslide, flood, or earthquake occurs, a chain of relevant actions comes into play. These actions, which constitute the response to the event, include warnings, evacuations, rescue operations, fire fighting, emergency medical care, emergency food and shelter programs, and measures to preserve public health and safety and to protect abandoned property. For this response to be effective, certain actions must be undertaken before the event occurs. These preparedness activities include development of disaster plans, identification of evacuation routes, design and installation of warning systems, purchase of emergency equipment, and training of emergency personnel. Once the emergency is past, steps must be taken to restore the community to a normally functioning state. These recovery activities include repairing damaged roads, buildings, pipelines, and other structures and reconstructing the community's physical, social, and economic infrastructure.

Emergency management, if well executed, can do much to minimize the loss and suffering associated with a particular disaster. However, unless it is guided by the goals of preventing or reducing long-term hazard losses, it is unlikely to reduce the adverse impact of future disasters significantly. This is where mitigation becomes important.

In a general sense, any action that eases the burden of hazards can be described as mitigation, but the term as used in this workshop (and by many in the natural hazard management community) has a special meaning. Mitigation is concerned with actions that reduce the potential long-term adverse consequences of disasters, either by reducing the likelihood of occurrence of potentially damaging events or by reducing the vulnerability of the community.

Mitigation includes such measures as land use management, zoning practices, and economic programs (i.e., tax and insurance incentives) designed to keep vulnerable structures and activities out of the most hazard-prone areas; building codes designed to minimize the likelihood of structural damage; construction of protective engineering works such as levees and debris catch basins; and development and testing of emergency preparedness plans. These actions are generally the responsibility of community planners, public works directors, emergency management coordinators, and emergency response professionals.

Mitigation also includes postdisaster actions such as rebuilding damaged roads and structures in a more hazard-resistant way or in a less vulnerable location. These actions depend on the availability of funds in the form of relief, insurance, assistance, and loans, and on the available of engineering techniques for building hazard-resistant structures. They are the responsibility of individual property owners, private and governmental financial institutions, engineering firms, and the construction industry.

While all of these mitigation actions can be classed as either predisaster or postdisaster, and can be carried out in conjunction with preparedness and recovery, they incorporate a concern for improving the long-term situation that goes beyond the usual objectives of preparedness and recovery programs.[1]

NATURAL HAZARD MITIGATION AT THE FEDERAL LEVEL

Mitigation is a relatively new and underdeveloped component of the federal effort in natural hazard management. Mitigation is included among FEMA's responsibilities, but thus far that agency's main concern has been emergency management.

FEMA's authority for involvement in mitigation activities covering a broad spectrum of natural hazards is well established. For example, Section 206 of the Disaster Relief Act of 1970 (P.L. 91-106) authorizes federal assistance for the development of comprehensive state predisaster plans that include provisions for long-range recovery and for the development of reconstruction assistance plans for seriously damaged or destroyed public and private facilities (24 CFR 2200, Subpart C, Disaster Planning). Section 406 of the Disaster

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[1]Two analogies may make this distinction clear. In the area of highway safety, preparedness involves the installation of warning signs and emergency roadside telephones; the establishment of a network of fire stations, rescue squads, ambulances, and tow trucks; and the training of police, fire, hospital, and auto salvage personnel. Response involves the summoning of emergency personnel and equipment to the scene of an accident, diversion of traffic, rescue of trapped victims, and transportation of victims to hospitals. Recovery involves the removal of damaged vehicles and the repair of damage to the road surface, crash barriers, etc., and the successful medical treatment of the injured. Mitigation, on the other hand, can include redesign of highways and vehicles to make accidents less likely, adoption and enforcement of laws against dangerous driving, more effective driver training, insurance programs to protect accident victims from serious economic loss, and so forth.

In the area of health care, preparedness is analogous to vaccination against a disease, response is analogous to the treatment provided when a person gets sick, recovery is analogous to physical therapy during convalescence, and mitigation is analogous to epidemiological and public health measures undertaken to reduce incidence of the disease and reduce the seriousness of its effects if it should occur.

Relief Act of 1974 (P.L. 93-288) sets forth provisions for the preparation of postdisaster hazard mitigation plans that include safe land use and construction practices for hazards in disaster impacted areas (44 CFR 205, Subpart M, Hazard Mitigation Regulations). Under these provisions, states and local governments in declared disaster areas may ask FEMA for technical assistance in identifying and evaluating natural hazards in order to recommend appropriate mitigation actions.

FEMA has accepted some hazard mitigation plans prepared by states after floods and other disasters. These plans have generally been geographically limited and confined to the specific hazards that initiated the disasters. These hazard mitigation plans have only recently been subject to systematic review and evaluation within FEMA, and their usefulness has not yet been assessed. However, FEMA is now beginning to encourage states to broaden the scope of their hazard mitigation plans to include larger areas and to encompass all of the hazards from which they are at risk.

FEMA also possesses authority for specific mitigation programs concerned with floods, hurricanes, earthquakes, dam failures, and other hazards. For example, in the Earthquake Hazards Reduction Program (Earthquake Hazards Reduction Act of 1977, P.L. 96-124), FEMA has coordinated activities of the U.S. Geological Survey, the National Bureau of Standards, and the National Science Foundation in efforts to bring together earthquake prediction research, development of earthquake-resistant construction standards, dissemination of model codes and information for land use and building decisions, and public education initiatives.

FEMA's most extensively developed mitigation activities have been associated with flood hazards. The agency inherited responsibilities for the Unified National Program for Floodplain Management from the Water Resources Council (U.S. Water Resources Council, 1976). It now holds administrative authority over a wide variety of mechanisms for flood mitigation. These include regulations, executive orders, and interagency agreements (National Science Foundation, 1980). For example, Title II of the Flood Disaster Protection Act of 1973 (P.L. 93-234) encourages community participation in the National Flood Insurance Program (NFIP) as a means of mitigating flood losses. Other legislative actions support floodplain regulation, floodproofing, floodplain acquisition, and relocation as alternative mitigation measures. As an outgrowth of an interagency agreement, FEMA organizes and leads multidisciplinary and multiagency hazard mitigation teams that are responsible for making hazard mitigation recommendations in the wake of presidentially declared flood disasters (Federal Emergency Management Agency, 1981). Although no comprehensive evaluation of the effectiveness of these teams has yet been completed, preliminary evidence suggests that reductions in future hazard losses may have been brought about in some communities (e.g., Mobile, Alabama, and Fort Wayne, Indiana) as a result of their efforts.

FEMA recognizes both the importance of mitigation and the fact that mitigation is most effective when undertaken in advance of a disaster. However, most of the agency's mitigation activities have been undertaken during the recovery and reconstruction of disaster-impacted communities. Little is known about the effectiveness of these postdisaster mitigation measures in reducing the long-term adverse impact of natural hazards, and even less is known about the effectiveness of disaster preparedness plans and other predisaster mitigation measures in achieving this goal.

MULTIPLE HAZARD MITIGATION

Multiple Hazard Mitigation (MHM) is a step beyond conventional, hazard-by-hazard mitigation. It represents an attempt to reduce long-term natural hazard losses by addressing, in a coordinated fashion, the problems, issues, and processes of mitigation that are common to more than one type of natural hazard, or that transcend interrelated groups of hazards.

There are a number of reasons why a community may find it advantageous to undertake multiple hazard mitigation, and why, in the present setting, it may encounter difficulties in doing so. An appreciation of the difficulties can be helpful in understanding in just which circumstances MHM may be worthwhile.

The Challenge of Managing Multiple Hazards

In some communities only a single hazard (e.g., riverine flooding) may be of importance. However, many communities are susceptible to more than one kind of natural hazard. While a hazard-by-hazard approach is often workable, there are a number of circumstances in which a community--or a regional, state, or federal agency--may find it necessary or desirable to consider several hazards jointly. For example:

- There may be a causal relationship between two or more hazards; e.g., an earthquake may trigger a series of landslides.
- Two or more hazards, although not directly related to each other, may tend to occur at the same time in different locations within a community, perhaps by virtue of having a common cause (e.g., rain may induce mudflows along the hillslopes and flooding in the river valleys).
- The same location may be prone to two or more hazards which, although they do not occur simultaneously, must both be taken into account in such measures as zoning (e.g., hillslopes near a fault may be subject to both earthquakes and landslides from different causes; coastal areas may be subject to flooding from both hurricanes and tsunamis).

o The same mitigation or response action may be applicable to different hazards and may or may not be identical for each hazard (e.g., an evacuation plan may be appropriate for a number of different hazards, although the routes may have to be modified--to avoid low elevations during floods and to avoid hillsides during landslides, for example; building code requirements may address floods, earthquakes, landslides, and tornadoes, but the ideal requirement for structural walls may be different for each hazard).

o A government agency may, because of the regional or temporal extent of its authority, be responsible for a number of different hazards that may occur at the same or different times and places (e.g., a state agency may be responsible for all natural hazards within the state, encompassing the possibility of floods and landslides occurring in different parts of the state at the same time or in the same part of the state at different times).

The Concept of Multiple Hazard Mitigation

To the extent that commonalities among hazards are the focus of concern, MHM is essentially an incremental process that considers, in turn, separate sets of hazard-specific measures, and works out a balanced general strategy for the entire spectrum of significant natural hazards. This process involves taking advantage of overlaps and resolving inconsistencies or contradictions among different mitigation programs. (For example, building code provisions designed to reduce tornado damage may prove beneficial in hurricane-prone areas as well. On the other hand, a building that is elevated to avoid floods may be at added risk from earthquakes.) From this perspective the cumulative effect of MHM is greater than the sum of single hazard mitigation strategies because elimination of program duplication, along with other economies of scale, makes it possible to address more problems in greater depth and to avoid counterproductive actions. Thus, public officials responsible for making recovery and redevelopment decisions should take into consideration all significant hazards that affect an area, not just those involved in the most recent disaster. This should be of particular concern to members of interagency hazard mitigation teams, state officials charged with the preparation and implementation of Section 406 hazard mitigation plans, local emergency management officers, and others associated with redevelopment.

Interaction problems that transcend separate hazards require a shift of perspective from incrementalism to the broader systems framework of MHM. Increasingly, scientists and public officials are recognizing the existence of interactive hazards that may occur simultaneously, in sequence, or in a common area, and produce synergistic, cumulative impacts that are different from those of their separately acting component hazards. Such impacts often exceed the capabilities of hazard-specific management programs. For example, scientists suspect that recent, widely separated meterological disasters in California, Utah, and Hawaii, along the Colorado River, and elsewhere, are all related to the oceanic El Nino phenomenon. Earthquakes can trigger a variety of secondary hazards; barrier islands are habitually at risk from an interrelated set of problems that includes floods, storms, erosion, and sea-level fluctuations; semiarid canyons and alluvial fans are affected by interconnected brush fires, landslides, mudflows, and flash floods. Most hazard systems transcend governmental boundaries, and programs for their mitigation require the involvement of hazard professionals and public bodies other than those that engage in conventional emergency management. Successful MHM requires inputs from earth and atmospheric scientists; engineers and natural resource management professionals in agencies such as the Geological Survey, Corps of Engineers, and National Oceanic and Atmospheric Administration; and specialists associated with river basin commissions, soil conservation districts, urban drainage or flood control authorities, planning boards, public utilities and other bodies with regional responsibilities for hazard mitigation.

Five serious difficulties stand in the way of multiple hazard mitigation: (1) Many existing programs are based on legislation that addresses a specific hazard—e.g., earthquakes, or floods. This may result in funds being made available to a qualified community for flood mitigation but not for landslide mitigation, even though landslides may represent a greater threat in the particular community. (2) In many communities, the planners, fire chiefs, emergency management officials, developers, and builders do not routinely plan and work together, nor do they devote their joint efforts to hazard mitigation. (3) The present scientific, engineering, economic, and sociological understanding of hazards and hazard management is limited. Moreover, there is insufficient integration between the scientific community and the public officials responsible for emergency management and hazard mitigation. (4) There is insufficient experiential knowledge about, and a lack of concrete examples of, successfully implemented hazard mitigation measures. (5) There is no agreement on whether problems that arise from interactions among several hazards are best treated via a comprehensive, integrated approach that makes similar or uniform provisions for all hazards that affect a community, or whether they might be better addressed by an alternative strategy that is keyed to the mitigation of a single, locally dominant hazard with special provisions for interacting secondary hazards.

The appeal of MHM derives from the assumption that natural hazard costs can be reduced significantly by addressing, in an integrated fashion, those problems, issues, and processes that are common to more than one type of natural hazard, or that transcend interrelated groups of hazards. Some communities are affected by several, more or less equally serious, natural hazards while others are affected by only one serious hazard. It is likely that most communities lie somewhere between these two extremes. For this reason MHM complements, but does not replace, existing hazard-specific approaches. The latter will continue to be applied where appropriate (e.g., in communities that are at risk from only one significant natural hazard).

Advantages of MHM

MHM offers four main advantages to hazard managers: (1) It directs attention to the full range of natural hazards that require mitigation, not only to those for which hazard-specific, or segmental, agency programs exist. (2) It allows for consideration of transcendent problems that arise from the interaction of separate hazards. (3) It provides for increased efficiency in the use of financial, personnel, and other hazard management resources by eliminating duplication and encouraging concentration on key problems. (4) It can increase the effectiveness of hazard mitigation by involving the entire spectrum of organizations and activities that are affected by, and party to, hazard mitigation. Thus MHM can provide the basis for more comprehensive, efficient, and publically responsive natural hazard management programs.

Implications of MHM

The adoption of an MHM strategy has implications for public awareness of hazards and for the funding, organization, and operation of hazard management. For example, information about net exposure to all threatening hazards can provide a more equitable basis for allocating federal disaster planning and assistance funds to states and localities. This approach is of direct relevance to hazard program managers, agency administrators, and others concerned with the distribution and use of budgetary resources.

A multiple hazard mitigation initiative can also stimulate or reinforce the use of more efficient, integrated procedures for emergency management (i.e., preparedness, response, and recovery). Local emergency management agencies can be encouraged to forgo reliance on separate, hazard-by-hazard procedures for preparedness and response in favor of systematic programs organized around functions that are common to most natural disasters (e.g. warning, communications, sheltering, evacuation). This is the primary goal of FEMA's Integrated Emergency Management System (IEMS). MHM also affects hazard management in places that are particularly susceptible to several types of hazards. These include "edge areas" like coastlines, break-of-slope zones, and floodplains. In such locations, MHM includes identifying, planning, developing, and regulating the safe use of sites and communities that are exposed to hazards, as well as long-term redevelopment of disaster-impacted sites to reduce aggregate future hazards. Public agencies, private developers, and citizens groups concerned with urban and industrial development, land use planning and regulation, environmental management, and the operation of public utilities and other infrastructure systems are thus an important audience for MHM.

Given the piecemeal nature of existing public responsibilities for natural hazard management, any successful mitigation strategy requires the learning of new hazard planning and management skills and the creation of cooperative agreements or other coordination mechanisms designed to ensure the optimal involvement of all relevant agencies and interest groups. Such steps have only begun in the context of single hazard mitigation programs (e.g., the interagency postdisaster flood hazard mitigation teams). MHM will necessitate greatly expanded efforts in this regard.

PROGRESS IN THE EVOLUTION OF MULTIPLE HAZARD PERSPECTIVES

For federal agencies in general and FEMA in particular, the concept of MHM is still evolving. Within FEMA widespread interest in its practical applications has been generated by recent experiences with multiple hazard problems in Utah and in Times Beach, Missouri. In Utah FEMA is sponsoring a six-phase, state-level, multihazard study. This study began as an investigation of collective mitigation measures for earthquakes, landslides, and dam failures in communities along the Wasatch Front, but acquired a broader dimension as a result of the 1983 spring meltwater flooding, mudflows, and high water table problems. In Times Beach it was discovered that aspects of technological hazard management programs and natural hazard management programs could be beneficially combined to assist the buyout and relocation of residents of a community afflicted by the joint impact of flooding and chemical contamination.

Integration of Emergency Management Functions

Although MHM may be a new organizing concept for federal hazard mitigation activities, states and localities have been developing and applying multiple hazard perspectives to emergency management functions for many years. For example, FEMA's recent adoption of IEMS was preceded by almost a decade of similar attempts to improve emergency management pioneered by associations of state legislators and state governors, by individual states, and by other groups (National Governors Association, 1979; Federal Emergency Management Agency, 1983). Most states have now adopted policies for the coordination of emergency management resources in different agencies. Many local civil defense organizations have also begun to develop comprehensive, coordinated systems and procedures for emergency management. These include standardized communication equipment and warning systems. Anecdotal evidence from emergency managers indicates that there is considerable carryover of experience from the development of one single hazard preparedness and response plan to another, and from one disaster to another. This encourages the use of common analytical methods, management procedures, and evaluation criteria for emergency management.

Risk and Vulnerability Mapping

Hazard identification, mapping programs, and vulnerability assessments constitute a second aspect of hazard management that emphasizes multiple hazard perspectives; moreover, these activities are more directly concerned with mitigation than with emergency management. Various groups at different levels of government in the United States and elsewhere report progress in these fields. The scope and format of a national risk profile matrix have been outlined by scientists associated with the International Council of Scientific Unions (Whyte and Burton, 1980). British Columbia's Provincial Emergency Program has developed a table for rating the multiple hazard disaster potential of communities (Foster, 1980). The California Urban Geology Master Plan (California Division of Mines and Geology, 1973) has produced a statewide microzonation map of 10 geological hazards. This portrays composite risks for 7.5 minute U.S. Geological Survey quadrangles and is supported by information on potential per capita economic losses in the areas at risk. Similar maps have been developed elsewhere (Foster, 1980).

The U.S. Geological Survey has pioneered a multiple-hazard-sensitive land capability mapping procedure for earthquake, flood, and landslide-prone areas in San Francisco Bay (Laird et al., 1979) and has produced composite geological hazard maps for volcanic risk areas in Hawaii and the Pacific Northwest (Crandell and Mullineaux, 1974). However, most such procedures are not standardized on a national basis.

The Tampa Bay Regional Planning Commission has developed methods for synthesizing information about the separate damage components of hurricanes (i.e., rainfall, wind, storm surge). Such combinations of hazard subprocesses provide analogs for the assessment of multiple hazards in other communities.

Foster has devised a natural disaster impact index that integrates deaths and injuries, economic losses, and other consequences for a variety of causes, and might be adapted to provide a yardstick for comparing net community hazardousness (Foster, 1980). The United Nations Disaster Relief Organization has published a composite risk and vulnerability analysis methodology that is based on computer simulation techniques for approximating the overlap and interaction of storm, flood, and earthquake severity patterns with spatial arrays of population and properties at risk (United Nations, 1979). This methodology has been tested in a study of metropolitan Manila (United Nations, 1977).

In a comprehensive review of the natural hazard data field, Tubbesing (1979) has documented vulnerability mapping and data inventory initiatives and needs in federal, state, and local agencies and in the private sector. The workshop on which that study was based recommended measures to improve hazard identification, delineation, and risk assessment systems, and proposed the design of national vulnerability and risk models for use by FEMA and other agencies.

Perhaps the most ambitious nationwide risk and vulnerability analysis of natural hazards has been completed by Petak and Atkisson (1982). This analysis uses county-level data and estimates to assess composite potential losses to buildings and other structures stemming from 10 natural hazards during the period from 1980 to 2000. The economic consequences of applying existing (single hazard) mitigation strategies are calculated at the national level and for sample local areas under hypothetical disaster scenarios. No attempt is made to assess the feasibility and consequences of MHM strategies that cut across existing programs.

Coordination of Management Activities

Broad coordination of multihazard management activities, going well beyond hazard analysis and emergency response, is being encouraged by groups such as the Association of State Floodplain Managers. The philosophy of the Association's Multi-Hazards Committee is clearly set out in a recent report (Association of State Floodplain Managers, 1983): "The goal of the Committee is to increase the ability of states and locals to intergrate policies and procedures dealing with all hazards. Floods, dam safety, and earthquakes share many common elements of preparedness/mitigation, warning, response, and recovery. At the local level most of the same people deal with these different hazards. If the state and federal governments don't integrate the activities for different hazards the locals must do it in spite of us." This committee has encouraged the American Society of Appraisers to include systematic assessments of vulnerability of all hazards on appraisal forms.

IMPLEMENTATION OF MHM

Although MHM depends more on the integration and extension of existing practices than on the development of radical new alternatives, its successful adoption will require changes in the way we think about, and deal with, natural hazards. This may necessitate the use of well-designed information, education, and training programs, carefully targeted to user groups in different levels of government, business and civic organizations, and the affected public.

If FEMA chooses to pursue multiple hazard mitigation as a national policy, a number of specific steps will be required to put the new policy into practice at the regional, state, and local levels. It will be necessary to

- o define and describe the MHM process;
- o issue regulations and guidance documents; and
- o inform, instruct, and train officials and personnel at the national, regional, state, and local levels.

A number of organizations of different types will be involved. In addition to governmental entities at the national, regional, state, county, and city levels, private developers, and financial institutions, there will be universities and community colleges; research institutions and consulting firms; professional societies; professional associations such as the National Emergency Managers Association (state emergency service directors), U.S. Civil Defense Council (city and county civil defense directors), American Planning Association (urban planners), and International City Management Association (local administrators); and nonprofit information dissemination organizations such as the Natural Hazards Research and Information Center at the University of Colorado, the Disaster Research Center at Ohio State University, and the Earthquake Engineering Research Institute. Many of these organizations are involved in aspects of hazard management today. Their roles and their understanding will have to change if their activities are to be extended to truly include multiple hazard mitigation.

For example, many organizations whose responsibilities encompass areas relevant to natural hazard mitigation exist primarily for purposes entirely or largely unrelated to natural hazards. Land use planning measures, zoning regulations, and building codes are adopted for purposes of economics, safety, aesthetics, and community amenities. Police, fire, rescue and ambulance services, and hospitals exist to meet everyday needs relating to crime, traffic, accidents, and illness. Lending institutions and public assistance programs are designed primarily for nondisaster economic activities. Public works departments have primary responsibilities that are concerned with water resources, transportation, and other everyday needs.

Therefore, in order to be effective in minimizing the long-term adverse impacts of natural hazards, it is necessary to encourage such diverse groups as planners, public works departments, hospitals, police and fire departments, and lending institutions to devote attention and resources to natural hazard problems that until now have had relatively low priority among their full range of responsibilities and that may appear to require a disproportionately large portion of their budgets.

While this can often be accomplished for the immediate and urgent purposes of disaster response and recovery, it is more difficult to engage the necessary range of organizations in the longer-term effort required for mitigation. The task is even harder when there is no one at the local level with the authority and resources to spearhead such an effort.

In many communities, emergency management is the formal responsibility of a director of civil defense or emergency services who interacts with the planning, engineering, police, and fire services, and with local business and civic leaders, to develop and carry out a program of emergency preparedness, response, and recovery. The emergency director's responsibilities usually encompass far more than natural hazards--they can include industrial and transportation accidents, oil and chemical spills, building collapses, terrorist acts, and so forth. The emergency services director should continually be aware of the hazards of highest priority to the community and should ideally be in a position to ensure that the community has a satisfactory capability for dealing with these hazards. However, many communities do not have a responsible official whose primary concern is emergency services or, if they do, have not allotted sufficient resources, personnel, or authority to that office. Where community interest is high, and where funds and personnel are made available, the job is still a difficult and demanding one, requiring technical expertise in a number of areas to an extent that is beyond the reach of many small communities. Consequently, many communities must turn to regional, state, and federal agencies for technical and financial assistance.

Given all these realities, most local emergency management officials have all they can do to keep up with the basic demands of preparedness, response, and recovery. Many emergency management directors appreciate the value of incorporating multihazard concepts into their programs. However, they generally do not have the resources to undertake a broad, multiple hazard approach to long-term mitigation, nor is there often local interest and political support for such an effort. Consequently mitigation, where it is undertaken, tends to be addressed on a hazard-by-hazard basis.

Local hazard mitigation responsibilities are rarely identified or defined separately from emergency management. It is generally accepted that planners, public works directors, and other offícals share the responsibility for mitigation and that these individuals should attempt to guide the activities of builders, investors, real estate developers, and others concerned with the development and use of hazardous areas. However, there is generally no well-defined system for incorporating hazard mitigation per se into the basic functions of local government.

In such a setting, introduction of a new, untried concept, such as MHM, is always difficult. Some comments about technology transfer, formulated in a different context, are relevant here:

1. If an idea is entirely new, it may be rejected because of unfamiliarity with its concepts.

2. There are practical problems with new ideas in that the technology is less apt to be well developed. Thus, there are greater risks in adopting it.

3. It generally takes considerable time and money to go from a demonstration to a form suitable for large-scale application.

4. If an idea has been previously considered and rejected, some prejudice may remain, even though new information would seem to make it worth considering.

5. Between innovators and appliers there often exists a difference in temperament and point of view which makes the transfer of an idea difficult.

6. All of the above problems apply within organizations. They become even more difficult, however, when transfer takes place across organizational boundaries, or if there is a geographical separation.

7. When the transfer takes place between federal agencies, the appropriate congressional committees and administrative bureaus must be brought into the exchange.[2]

The successful adoption of multiple hazard mitigation strategies at the local and regional level will require that public officials be convinced that the strategies presented to them are politically and economically acceptable to the community, that they rest on a sound foundation of scientific and technological studies, and that implementation guidance and assistance will be available. Local officials are likely to be less concerned with the precise form that MHM takes in their community than with the adoption of strategies that lead to effective mitigation programs for the natural hazards that they perceive as significant. Their receptivity to MHM will depend on the extent to which its consideration of common or shared aspects of different hazards can be shown to lead to mitigation that is more effective, more economically efficient, and more valued by the community, than are mitigation measures developed on a hazard-by-hazard basis.

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HIGHLIGHTS OF THE WORKSHOP

The workshop participants were asked to assess the current feasibility of developing multiple hazard mitigation (MHM) strategies for communities that are prone to multiple natural hazards. Ideally such strategies emphasize commonalities and interrelationships among hazards rather than addressing specific hazards on a piecemeal basis.

The three areas on which the working groups focused were selected on the basis of their exposure to a wide range of natural hazards: Hawaii (tsunamis, hurricanes, volcanoes); San Francisco (earthquakes, landslides, floods); and St. Louis (floods, earthquakes, tornadoes)[1]. Workshop participants found relatively few fully developed examples of MHM in these communities. Evidence of progress in the development of multiple hazard perspectives was uncovered in a wide range of geographic locations and at a variety of governmental levels.
This progress was primarily in the preparation of multiple hazard maps, analyses, and vulnerability assessments and in the integration of local emergency management functions pertaining to the immediate predisaster and postdisaster periods.

With the exception of immediate emergency management functions, multiple hazard perspectives have rarely been applied to mitigation. This is particularly so for the long-term predisaster planning, development, and regulation activities, and the postdisaster recovery programs that are major instruments of hazard mitigation. Even with regard to immediate emergency management, the majority of efforts to develop multiple hazard perspectives have considered hazards incrementally. We are only now beginning to witness attempts to adopt inherently interactive hazard system management approaches to natural hazards.

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[1]Summaries of the working group discussions are found in Appendixes IV, V, and VI. This chapter should be read in conjunction with those summaries.

CONTRIBUTIONS TO THE FORMULATION OF MHM STRATEGIES

Several contributions to the formulation of tools for multiple hazard mitigation emerged from the working group discussions. A procedure was developed for identifing and ranking mitigation activities in terms of their potential applicability to more than one hazard at a time. This suggested that hazard mapping offered the largest potential rewards when carried out for several (or all) local hazards at the same time. Mitigation measures that lent themselves to the widest cross-hazard application tended to be activities that occurred either in advance of hazard events, or during long-term disaster recovery. This finding was widely supported by workshop participants and suggests that the best prospects for applying MHM initiatives may lie in the areas of long term predisaster planning and preparedness and postdisaster recovery, rather than in the areas of hazard warnings and immediate emergency response.

Also explored was a related procedure designed to rank hazards by the extent to which their analysis and mitigation generated spillover benefits for understanding and mitigating other hazards. With methodological refinement, it may be possible to specify which mitigation actions, applied to which hazards, are most likely to bring about a general increase in the level of protection against a multiplicity of hazards. Thus, in a particular location it might be best to first map potential tsunami inundation zones in an area susceptible to earthquakes, subsidence, wave attack and storm surge, because tsunami risk areas may encompass most of the other hazard zones and because information about tsunami impacts may serve the widest range of purposes. Alternatively, a process for detailed geological review of site plans might be a preferred mitigation measure for an area at risk to earthquakes, landslides, and floods.

Workshop participants felt that the adoption of multiyear funding of conventional hazard-specific mitigation programs would be both economically and administratively advantageous. They also felt that technical and managerial benefits could be gained by adopting MHM strategies at various levels of government. However, the economic efficiency of multiple hazard mitigation is largely unknown. It is, therefore, premature to base public resource allocation decisions on the presumed efficiency of MHM pending the development of an improved national data base that includes information on losses, hazard probabilities, and expenditures for current and modified mitigation programs. Such a data base must be capable of supplying the information necessary for measuring the economic aspects of mitigation strategies considered across a range of hazards and government agencies, and for calculating the distribution of costs and benefits between the public and private sectors and among various governmental levels.

There was divergence of opinion about which levels of government are most appropriate for the development and application of MHM strategies. A majority of the workshop participants argued that MHM is most appropriate for nonlocal (i.e. regional, state, federal, and international) agencies. This was seen to be a function of the wider range of hazards that are typically encountered in larger territorial jurisdictions and of the fact that such agencies generally possess more extensive technical and financial resources than do their local counterparts. That viewpoint was countered by a minority argument which suggests that higher levels of government are mainly involved in only a few local disasters. (For example, during 1982 there was only one presidentially declared disaster in Illinois, whereas the state Emergency Services and Disaster Agency responded to 2,617 disasters.) The majority of lesser hazards are routinely managed by local community agencies without recourse to outside aid. Both arguments have merit, and it is likely that the appropriate level of government for MHM will depend on which hazard loss threshold is used as a reference level for the initiation of mitigation measures.

Several workshop participants identified important limits to the applicability of MHM. Some argued that MHM cannot be expected to succeed without a much stronger commitment to mitigation principles and practice than is currently manifest within FEMA and other agencies. Others pointed out that many communities are at risk from only one significant natural hazard and do not need to employ multiple hazard perspectives. The debate between those who perceive MHM as uniform, across-the-board integration of mitigation functions for all local hazards, and those who perceive MHM as integration of secondary hazard mitigation measures within the context of primary hazard mitigation programs remained unresolved and needs further detailed exploration.

It was also recognized that there are dangers in overextending the principle of commonalities among hazards. The specialized scientific and technical basis of natural hazard management, along with the distinctive nature of the associated public issues, tends to separate natural hazards from technological hazards, strategic warfare, and other types of emergencies and--with a few closely circumscribed exceptions such as disaster communications--to limit the use of the MHM approach to natural hazards. An MHM program that blurs important distinctions between natural and technological hazards may be counterproductive.

This should not be interpreted to mean that public officials and disaster specialists can ignore interactions among natural, technological, and other hazards, or that members of one field have little to learn from those in other fields. Clearly, natural hazards can cause failures of technological systems. Landslides and earthquakes can damage railways, roads, and pipelines. Hurricanes and submarine mudflows have collapsed offshore oil and gas platforms. Tornadoes and earthquakes may threaten nuclear power stations, and floods can imperil toxic waste sites. The reverse is rarely true; technological hazards are unlikely to trigger natural disasters.

Natural hazards can also provide useful analogs of technological disaster processes (e.g., volcanic ash dispersal patterns illustrate the potential distribution of nuclear fallout). Technological hazards sometimes provide appropriate tests of emergency response systems, but the fact that they (1) stem directly from human causes, (2) generally occur at known locations, and (3) pose new experiences for society, set them apart from natural hazards. This suggests that attempts to understand and resolve technological hazards are likely to employ completely different casts of specialists and to require different mitigation strategies from those for natural hazards. Such a finding counsels against the extension of MHM principles to technological hazards at this time.

SUGGESTIONS FOR THE SUCCESSFUL ADOPTION OF MUTIPLE HAZARD MITIGATION

The following suggestions emerged from the workshop:

1. A generally higher priority should be accorded to mitigation as an element of natural hazard management. Increased funding for mitigation and multiyear budgets for natural hazard mitigation would be positive steps in this direction.

2. A comprehensive, multiple natural hazard mitigation initiative should be undertaken at the federal level to focus and coordinate the contributions of all agencies with mitigation-related roles and responsibilities. The initiative should include, but not be limited to, agencies now represented on interagency postdisaster flood hazard mitigation teams. As part of their activities, parties to the initiative should define, identify, and encourage constituencies for multiple natural hazard mitigation at state and local levels. This should guide the targeting of MHM strategies to appropriate user groups.

   In the course of this work FEMA should identify those locations and communities affected by more than one significant natural hazard, and should examine the comparative advantages of (a) MHM programs that involve integrating the complete range of mitigation actions for all local hazards and (b) MHM programs that build mitigation actions for secondary local hazards into mitigation programs for preeminent or primary local hazards.

3. Consideration should be given to issuance of a presidential executive order that requires the use of site-specific, multiple natural hazard mitigation measures for federally financed and owned property.

4. Initial development and use of multiple natural hazard mitigation strategies should be confined to the federal level with later application to states and selected local communities. Community involvement should be on a voluntary basis, supported by incentives for local adoption and preceded by demonstration projects, personnel training, technical assistance programs, public education campaigns, and public participation schemes.

5. Major emphasis should be placed on predisaster, mitigation-related, land use and facilities planning and development actions, and on postdisaster recovery measures that involve significant, mitigation-related changes in land use and community development.

6. Communities should be encouraged to formulate multiple natural hazard mitigation strategies on a "hazard system" basis as well as on an "incremental" basis. This requires (a) increased research and wider

dissemination of scientific information about interactive, synergistic dimensions of multiple hazards; (b) examination of the conditions that would encourage (or discourage) public practitioners to undertake multiple hazard mitigation; and (c) the development of mitigation innovations, including new or expanded procedures for intergovernmental cooperation.

7. A community-level demonstration study should be carried out to assess the value of an improved data base for natural hazard losses and expenditures and to use the resulting information to improve the economic efficiency of multiple natural hazard mitigation decisions.

8. FEMA should (a) require the preparation of, and evaluate the use of, state disaster plans that encompass all natural hazards; (b) adopt uniform state and local funding provisions that reflect the risk and vulnerability of individual communities; and (c) seek to extend the use of interagency postdisaster hazard mitigation teams to all types of natural disasters.

9. The experience of other nations (e.g., Japan) that have developed multiple natural hazard mitigation programs or measures should be investigated to evaluate their success and to identify potential applications in the United States.

Appendix I

BIOGRAPHICAL SKETCHES OF COMMITTEE MEMBERS AND WORKSHOP PARTICIPANTS

*Earl Jay Baker is associate professor of geography at Florida State University. He specializes in individual and community response to natural hazards and in natural hazard vulnerability.

*Don C. Banks is chief of the Engineering Geology and Rock Mechanics Section of the U.S. Army Corps of Engineers Waterways Experiment Station. He specializes in slope stability problems. He is a registered engineer in Mississippi.

*Glen V. Berg is professor of civil engineering at the University of Michigan. He specializes in structural vulnerability to earthquake damage.**

Richard L. Bernknopf is chief of the Plans and Programs Staff in the Office of the Director, U.S. Geological Survey. His responsibilities include formulating the agency's program and budget plans and directing economic analysis. His experience in economics has been in estimating the value of information for geologic hazards and for energy and mineral resources, estimating fair-market value for coal and for offshore oil and gas, and conducting benefit-cost analyses in these fields.

Arthur N. L. Chiu is professor of civil engineering at the University of Hawaii at Manoa. His fields of specialization are structural engineering, structural dynamics, and wind effects on structures. He served as leader of the National Research Council postdisaster team that inspected damage in Hawaii caused by Hurricane Iwa. He is currently involved in a cooperative research project with Taiwan on typhoon characteristics.

Harold C. Cochrane is associate professor of economics at Colorado State University. His expertise is in industrial economics, natural resources economics, economic consequences and inflationary impacts of disasters, and distributional effects of disasters. He has served on National Research Council panels concerned with research needs in earthquake engineering.

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*Committee member

**Dr. Berg was a member of the planning committee but was unable to attend the workshop.

Doak C. Cox is director of the Environmental Center at the University of Hawaii at Manoa. He has extensive experience with tsunamis and tsunami hazard mitigation, and in recent years has been increasingly involved in natural hazard mitigation generally.

Leo M. Eisel is a consulting engineer and is vice-president of Wright Water Engineers. He has extensive experience in water resource management. He has served as director of the Illinois Division of Water Resources, director of the Illinois Environmental Protection Agency, and director of the U.S. Water Resources Council.

David A. Griffith is principal planner in the disaster preparedness program, Tampa Bay Regional Planning Council. His background is in urban and regional planning, and he has specialized in hurricane evacuation and vulnerability analysis.

William Haddon, Jr., M.D., is president of the Insurance Institute for Highway Safety. He is an executive who has specialized in developing and directing programs at the interface of the medical and biological sciences, engineering, and public policy. He has extensive, senior background at both the state and federal levels of government, as well as in public service work supported by the private sector. Prior to his present position, he set up and headed, in the administration of President Johnson, the agencies that became the present National Highway Traffic Safety Administration. He has written extensively on strategies for reducing damage from environmental hazards.

Michael J. Helpa is chief of the Emergency Management Branch in the Office of the Chief of Engineers, U.S. Army Corps of Engineers. He is a civil engineer with experience in construction, navigation and maintenance, and emergency operations. He is a registered professional engineer in Pennsylvania and a member of the Corps of Engineers' Committee on Channel Stabilization.

Joseph C. Kellogg is the founder and president of the Kellogg Corporation and an innovator of ideas designed to improve the construction process. His expertise is in troubleshooting and problem solving on complex construction and mining projects of a multidisciplinary nature. He has served on numerous committees of the American Society of Civil Engineers and the Associated General Contractors of America.

Harry Kim is administrator of the Hawaii County Civil Defense Agency. He had earlier served as director of the Hawaii County Law Enforcement Assistance Agency, and prior to that he taught at the high school and community college level in Hawaii. He has served on an ad hoc UNESCO working group on volcanic emergencies and participated in writing a UNESCO manuscript on volcanic risk and emergency management.

Howard Kunreuther is professor in the Department of Decision Sciences at the University of Pennsylvania's Wharton School. He is an economist interested in decision making with respect to low-probability events and the role that insurance can play as a tool for hazard mitigation.

John A. Kusler is a lawyer with a Ph.D. in water and land use planning. He has served as a policy analyst and writer concerned with natural hazards for federal, state, and local agencies, and has been particularly involved in regulatory approaches to reducing flood losses.

John P. Lockwood is a scientist at the U.S. Geological Survey's Hawaiian Volcano Observatory. He has both theoretical and practical knowledge of Hawaiian volcanism and has had first-hand experience with volcanic hazard mitigation problems related to the active Hawaiian volcanoes, Kilauea and Mauna Loa. He has participated in volcano monitoring and lava-diversion studies and has worked directly with county and state civil defense officials.

George G. Mader is vice-president of William Spangle and Associates, Inc. He is a city planner with experience at local, county, and regional levels in California, and has been involved with planning for earthquake and landslide hazards.

Jerome W. Milliman is director of the Bureau of Economic and Business Research at the University of Florida. He is an economist specializing in urban and environmental economics and particularly in the theory and measurement of benefits and costs associated with natural hazards and their mitigation.

*James K. Mitchell is professor of geography and director of the Graduate Program in Geography at Rutgers University. He has specialized in human responses to natural and man-made hazards, coastal zone management, and natural resources policy. He has served as chairman of the U.S. Scientific Committee on the Outer Continental Shelf. He is a member of the National Research Council's Committee on Natural Disasters, and participated in an earlier NRC study of methods for mapping potential mudslide hazards in southern California.

Christian P. Mortgat is senior earthquake engineer with the Tera Corporation. His specialty is probabilistic earthquake engineering ranging from structural analysis for buildings and earth dams to the development of seismic hazard maps. He has developed a Bayesian risk-analysis methodology and has studied earthquake response spectrum shapes and their attenuation. He has directed or participated in major seismic risk-analysis projects throughout the United States and abroad (Costa Rica, Nicaragua, Alaska, Algeria).

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*Committee member

Robert A. Olson is president of V.S.P. Associates, a consulting firm. He is a former executive director the California Seismic Safety Commission, and had earlier served with the Bay Area Metropolitan Transportation Commission and the U.S. Office of Emergency Preparedness. He is a political scientist with expertise in policy analysis, earthquake hazards, and legislative relations.

*R. Blaine Roberts is professor of economics at the University of South Carolina, specializing in microeconmic theory and decisions under uncertainty. His current research centers on individual responses to imperfect information concerning changes in risk of natural hazards and on ways to measure the costs and benefits of various hazard mitigation strategies.

*Claire B. Rubin is principal investigator with the Disaster Recovery Project in the Program of Policy Studies in Science and Technology at George Washington University. She is also a consultant in emergency management. She has been heavily involved in research, development of prototype training programs, and information exchange in the field of natural hazards. She has served as director of the Natural Disaster Research Center of the Academy for State and Local Government and as director of the Contract Research Center of the International City Management Association.

*L. Scott Tucker is executive director of the Denver Urban Drainage and Flood Control District. His concerns center on planning floodplain management and construction and maintenance of major urban drainageways.

Evan Vlachos is professor of sociology and director of the Environmental Resources Center at Colorado State University. His specialties are the sociology of natural resources, impact assessment, and social forecasting. His current research involves risk perception and methods for assessing cummulative, long-range effects of public projects on the environment.

James P. White is director of the St. Louis County Office of Civil Preparedness. His background is political science and urban planning. He has been involved in several emergency response and recovery operations in presidentially declared disasters.

Larry Zensinger is with the Mitigation Assistance Division of the Federal Emergency Management Agency.

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*Committee member

Appendix II

WORKSHOP AGENDA

Wednesday, July 6

1:00 PM - 4:00 PM	Registration and Check-in, Crestwood lobby.
4:00 PM - 5:30 PM	Welcome Reception Independence Room, Crestwood. Cash Bar. Introduction of participants. Discussion of FEMA's purpose in funding the workshop by Larry Zensinger. Explanation of the goals, procedures, and products of the workshop by Ken Mitchell. (For participants only.)
5:30 PM - 7:00 PM	Dinner at the Snowmass Club. (For participants only; no charge.) Transportation will be provided.
7:30 PM - 9:30 PM	Session 1. Independence Room (Plenary Session) The speaker will be Dr. William Haddon, Jr. Dr. Haddon's talk will be followed by some comments by Jon Kusler and a general discussion.

Thursday, July 7

8:00 AM - 9:00 AM	Session 2. Independence Room (Plenary Session) Panel discussion based in large part on the written material prepared by participants prior to the workshop and the previous evening's talk, and will be followed by general discussion. The panel will be chaired by Don Banks; panelists will be David Griffith, Howard Kunreuther, Claire Rubin, and James White.
9:00 AM - 12:00 Noon	Session 3. (Working Groups) The three working groups will meet separately. Room numbers will be announced at the Plenary Session.
12:00 Noon - 3:00 PM	Lunch Outing and Recreation Time. A barbecue lunch for workshop participants and their families and guests at the Krabloonik Restaurant, in a spectacular mountain setting at the site of the Krabloonik Kennels. (There will be a charge, and advance reservations are necessary, for

	family members and guests.) Transportation will be provided; meet in Crestwood lobby at noon.
3:00 PM - 6:00 PM	Session 4. (Working Groups) The three working groups will meet separately.
6:00 PM - 7:00 PM	Session 5. Independence Room (Plenary Session) Progress reports from working groups and general discussion.
7:00 PM -	Dinner and Discussion Time. Unstructured time set aside for respite, recreation, and thought. Participants are encouraged to join others in small groups for dinner. A variety of restaurants and cultural activities are available within walking distance. Free shuttle service is available. Restaurant menus are on display in the Crestwood lobby. (Dinner costs are participants' responsibility.)

Friday, July 8

8:00 AM - 8:15 AM	Session 6. Independence Room (Plenary Session) Review of previous day's progress.
8:15 AM - 11:15 AM	Session 7. (Working Groups) The three working groups will meet separately.
11:15 AM - 12:15 PM	Session 8. Independence Room (Plenary Session) Progress reports from working groups and general discussion.
12:15 PM - 3:00 PM	Luncheon and Contemplation time. Unstructured time set aside for discussion, relaxation, and exploration of Snowmass. Participants are encouraged to join others in small groups for lunch; a variety of restaurants are available in the Snowmass Village Mall, or meals may be prepared in the condominium kitchens. (Lunch costs are participants' responsibility.)
3:00 PM - 6:00 PM	Session 9. (Working Groups) The three working groups will meet separately.
6:00 PM - 6:30 PM	Light Buffet Supper. Workshop participants will meet in the Independence Room for a light buffet supper. (For participants only; no charge.)

6:30 PM - 8:30 PM	Session 10. Independence Room (Plenary Session) Final reports from the working groups, general discussion, summary comments by Jon Kusler, and a final overview by Ken Mitchell. (Note: Be prepared for the possibility that this session may extend beyond its indicated ending time. The light supper prior to the start of the session should ensure that the discussion need not be cut off prematurely by virtue of hunger!)
8:30 PM or whenever Session 10 ends	ADJOURN

Appendix III

THE WORKING GROUPS

St. Louis Area (tornadoes, floods, earthquakes)

Arthur N. L. Chiu (Civil engineering: wind)
Leo M. Eisel (Hydrology, water resource engineering)
William Haddon, Jr. (Loss reduction strategies)
Howard Kunreuther (Economics, decision sciences)
Jerome W. Milliman (Economics)
Christian P. Mortgat (Civil engineering: seismic)
R. Blaine Roberts, Discussion leader (Economics)
James P. White (Local emergency management, St. Louis area)

San Francisco Bay Area (earthquakes, landslides, floods)

Don C. Banks (Rock mechanics)
Richard L. Bernknopf (Economics)
Harold C. Cochrane (Economics)
Joseph C. Kellogg (Construction problem solving)
George G. Mader (Planning)
Robert A. Olson (Governmental management of seismic hazards)
L. Scott Tucker, Discussion leader (Flood control management)

Hawaii Area (tsunamis, volcanoes, hurricanes)

Earl Jay Baker, Discussion leader (Geography)
Doak C. Cox (Tsunamis)
David A. Griffith (Hurricane planning)
Michael J. Helpa (Federal emergency management)
Harry Kim (Local emergency management, Hawaii area)
Jon A. Kusler (Law)
John P. Lockwood (Volcanoes)
Claire B. Rubin (Disaster research, training, and information exchange)
Evan Vlachos (Sociology)

Appendix IV

SUMMARY OF DICUSSION: HAWAII WORKING GROUP

APPROACH AND PHILOSOPHY

The group took the term "multiple hazard" to mean that more than one natural hazard exists within a single administrative jurisdiction. Multiple hazard management then refers to using the same information, resources, plans, and strategies to address more than one hazard. The presumption was that efficiencies in resource use could be achieved by using some of the same system components to reduce losses from more than just one hazard. A building code designed to make structures resistant to tsunami damage, for example, might also include measures to reduce losses from hurricane storm surge. The group made a very explicit attempt to avoid talking about what it called single hazard issues--that is, issues pertinent to the management of any natural hazard but not especially relevant to the efficient management of two or more hazards simultaneously. (The term "simultaneously" refers to the management of the hazards, and not to their actual occurrence. The multiple hazard concept encompasses not only the simultaneous occurrence of two or more hazards in one place, but the concern that a given governmental entity--local, state, or national--may have with the occurrence of two or more hazards within the area of its jurisdiction.)

THE HAWAIIAN EXAMPLE

The state of Hawaii, and specifically the island and county of Hawaii, were used as examples of jurisdictions prone to several hazards. Members of the discussion group who came from Hawaii briefed the group on the extent of hazards facing the island(s) and on some of the steps taken by local, state, and federal government agencies to cope with each hazard. A summary of the briefing appears in Table IV-1. It should be noted that in the state of Hawaii most hazard management authority is exercised by county governments.

PURPOSE AND MOTIVATION BEHIND A MULTIPLE HAZARD APPROACH

The group questioned whether FEMA's concern with promoting the concept of multiple hazard management stems from a desire to enhance the acceptability of nuclear civil preparedness planning by extending the efficient-resource-use concept to include all hazards. Regardless of motivation, it was noted that federal and state governments might be more inclined than are local governments to embrace the notion of multiple hazard management. That inclination might result from the fact that the nation and the states--being spatially larger administrative areas--are

TABLE IV-1. Summary of Briefing on Natural Hazards Affecting Hawaii and Steps Taken by Local, State, and Federal Agencies

Hazard	Local Government	Federal Government	State Goverment
Tsunami	Zoning for flood insurance Hilo project Warning dissemination	Flood ins. standards (FEMA) Breakwater construction (Corps) Detection, warning (NOAA) Flood insurance maps (FEMA)	State radio system
Volcano	Warning dissemination Participation in decisions about diversion structures	Warning (prediction) (USGS) Barriers/bombing (Corps) Risk zone maps (USGS) Loan restrictions (FHA)	State radio system Cost sharing for structures
Earthquake	Building codes	Fault zone maps (USGS)	
Stream flooding	Warning dissemination Participation in decisions about structures Zoning for flood insurance	Warning (prediction) NWS Structures (Corps) Flood insurance standards (FEMA) Flood insurance maps (FEMA)	
Wind	Building codes (UBC)	Warnings (NWS)	
Waves	Warning dissemination Zoning for flood insurance Cost-share on structures	Warnings (NWS) Flood insurance standards, maps (FEMA) Structures, floodproofing (Corps)	State setbacks (40 ft)
Erosion		Structures (Corps)	Setback (40 ft)
Landslide	Soil, slope zoning	Mapping (USGS)	
Hurricane (see wind, waves)			
Drought			

more likely to face a wider range of hazards than are local communities. Clearly, the degree to which more than one hazard exists locally varies from place to place.

CURRENT PRACTICE OF MULTIPLE HAZARD MANAGEMENT

In localities where several hazards exist, the communities are to some degree already practicing multiple hazard management, whether by design or not. Probably the most common case in current practice involves warning dissemination. Almost every community uses the same communication equipment to receive and disseminate warning messages; in many places, for example, sirens are used to issue warnings of a variety of hazards. In general, short-term response operations--more than other mitigation strategies--utilize the same resources for several hazards. Zoning, building codes, and structural measures are infrequently intended to cope with more than a single hazard, and measures undertaken to mitigate one hazard may in fact aggravate other hazards. For example, construction of sea walls to protect property from waves and shoreline retreat has, in Hawaii, resulted in substantial beach loss. Whether that practice can or should be changed is a matter for consideration. Local and state governments appear to be far ahead of the federal government in deliberately employing their resources to deal with more than one hazard at a time.

HOW MULTIPLE HAZARD MANAGEMENT MIGHT BE PURSUED

The following is a summary of how the group felt FEMA (or any other interested agency) might further pursue the multiple hazard management concept.

1. Define the concept. Before attempting to improve upon present practice, FEMA should carefully decide just what the goals of the practice are, what it's supposed to accomplish, and why. Instead of being concerned with commonalities among hazards in one location, for example, FEMA might be more interested in measuring the overall hazardousness of different locations in order to guide decisions about allocation of resources.

2. Look for multiple hazard commonalities. The group stressed the concept of commonalities among hazards as the basis for multiple hazard management. The commonalities could be assessed with respect to many criteria:

- Hazard assessment: One could ask whether a hazard assessment performed for, say, tsunamis could be used to assess other hazards as well. Or one might ask whether in performing the tsunami hazard assessment one could save time and money by performing the assessment for certain other hazards concurrently.

o Vulnerability analysis: In inventorying structures by type of construction and calculating hazard-damage functions there could also be commonalities among some hazards. The commonalities might vary depending upon whether the vulnerability involved life or property and upon the measure of loss employed.

o Loss reduction measures: Possibly the most important commonality to assess is the extent to which the same measure can reduce losses from more than one hazard. The monitoring stage of forecasting serves as a basis for warning the public about meteorological hazards, and the same basic warning dissemination system serves many other purposes. The degree to which earthquake and storm surge construction codes can be integrated efficiently is less obvious. However, zoning, setbacks, and density constraints should have considerable multihazard commonality when several hazards coincide spatially.

o Agency responsibilities: It could be fruitful to assess the degree to which the same agencies are, could be, or should be responsible for different hazards. This is likely to vary according to the other commonality criteria already mentioned. For instance one might ask to what extent the National Weather Service is responsible for providing forecasts for various hazards or the extent to which the U.S. Geological Survey is, could be, or should be responsible for mapping various hazards.

3. Design a multiple hazard management strategy. The group found a cross-tabulation or matrix approach useful for summarizing the commonalities among hazards. Table IV-2 represents the way one might ascertain the degree of commonality among hazard assessment activities for 10 hazards in Hawaii. A very basic use of Table IV-2 might then be to note that if resources were scarce and no hazard mapping existed at all in

TABLE IV-2. Degree of Commonality Among Hazards in Hawaii with Respect to Hazard Assessment

	Tsunami	Volcano	Earthquake	Stream Flooding	Subsidence	Wind	Waves	Hurricane	Landslide
Tsunami		L	M	L	M	L	H	L/H	L
Volcano			L	L	L	L	L	L	L
Earthquake				L	H	L	L	L	H
Stream Flooding					L	L	L	M	M
Subsidence						L	L	L	L
Wind							H	H	L
Waves								H	L
Hurricane									L
Landslide									

Note: L = Low, M = Moderate, H = High Commonality

Hawaii, top priority might reasonably go to mapping tsunami areas, because that data-gathering effort would also provide valuable data on earthquakes, subsidence, waves, and hurricane surge.[1]

But the real payoff in a multiple hazard management scheme would seem to lie in a more deliberate "multiple use" policy. Multiple hazard management, as currently practiced, might be called "incrementalism." A community implements a warning system for volcanoes, and at a later date decides to develop a warning system for hurricanes. The community attempts to satisfy as many of the hurricane warning dissemination needs as possible by employing the system already in place for volcanoes.

Given an existing set of mitigation strategies for several hazards, assessment of the degree to which multiple hazard management is being practiced efficiently would require some sort of systems review to identify duplications, redundancies, gaps, and even counteracting provisions. It is unclear exactly how one would proceed in this process or exactly how one would proceed to construct an integrated, efficient, multiple hazard management scheme from scratch. Many members of the working group felt that they would fall back on something resembling incrementalism.

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[1]It is important to exercise care in this reasoning process. One member of the working group, in reviewing this aspect after the workshop, pointed out that assessment of the tsunami hazard as having comparatively high commonality with the assessments of other hazards was based on a superficial consideration of the number of "M's" and "H's" on the tsunami line of Table IV-2 without remembering precisely what these ratings signified. He suggested that mapping of tsunami-hazard areas would do little to further the mapping of earthquake, storm wave, and subsidence hazards. It has helped significantly in mapping coastal flood hazard areas associated with hurricanes, but not in mapping areas at hazard from the winds and stream floods associated with hurricanes. This is because the "hurricane hazard" is actually composed of four component hazards: (1) wind, (2) stream flooding, and coastal flooding which results from both (3) storm waves and (4) storm surge. Mapping the hurricane hazard could further the mapping of the wind hazard, the stream flood hazard, and the storm wave and storm surge hazards, but only if the four components were mapped separately.

It appears therefore that the "next step" is not so simply identified, but depends on using the results of Table IV-2 and similar tables that might be prepared for other aspects of hazard management and, most importantly, thinking back to the preparation of the tables, in order to clarify where there are geographic areas of more than one hazard, where there are genetic and hence temporal associations among hazards, where there are commonalities of management techniques, and where there are commonalities in actual or potential agency responsibilities.

4. Learn how to do multiple hazard management better. The working group offered the following suggestions:

o Look at a number of specific examples of multiple hazard planning in order to identify the processes used and to assess their effectiveness. These examples could serve as models for future efforts to foster multiple hazard planning at all levels of government.

o Design a deliberate, efficient, multiple hazard plan for a number of real places, unconstrained by existing plans and policies. This could lead to more creative approaches than can the incrementalism noted earlier.

o Describe a number of hazards in terms of their attributes (speed of onset, extent of impact, etc.) and design a flow chart for dealing with each attribute or set of relevant attributes. This approach, basing actions implicitly upon commonalities among the hazards' attributes, might lead to the most efficient system of responses.

SOME CONCLUSIONS

The group's discussion was wide ranging, but a number of points were made repeatedly by more than one person:

1. We do not know enough at present to give FEMA specific advice about how to offer state and local governments guidance and assistance on multiple hazard management.
2. FEMA should initially develop, in-house, a multiple hazard management program for utilization of its own resources.
3. To learn how to improve upon current practice, FEMA should fund case studies, assessments, and demonstrations like those described in the previous section.
4. Not every locality needs a multiple hazard approach as much as others, and FEMA should recognize this fact.
5. If FEMA is going to push the multiple hazard concept, it should get serious about it and back up the idea with money.
6. The kind of help that would be of most immediate use to local communities is technical assistance (information, people, and funding). A variety of hazards requires a variety of technical resources in order to identify and address commonalities.
7. If multiple hazard mitigation manuals for specific localities are to be prepared, they should be very specific and detailed. They should also clearly state the purpose, need, and value of the new approach.
8. A potential stumbling block for a multiple hazard approach is fractionalization of goals, obligations, attitudes, and capabilities among agencies and institutions. At local and state levels it is especially important that agencies other than the traditional "response and recovery" organizations be involved.

9. It may be more important, at this time, to persuade governmental entities at all levels to adopt the concept of multiple hazard management than to design specific multiple hazard management techniques.

10. If the idea is to be sold to local governments, methodologies need to be clear and simple.

11. Finally, there were questions regarding the role of multiple hazard management in the "integrated emergency management system" and its political reason for being.

Appendix V

SUMMARY OF DISCUSSION: SAN FRANCISCO BAY WORKING GROUP

APPROACH

The working group confined its attention to earthquakes, floods, and landslides. The group identified those mitigation actions or strategies that might be useful in addressing more than one of these three hazards.

The approach of the group was to list mitigation actions for each of the three hazards and then determine where commonalities or overlapping needs existed. In doing this, the group determined how and by whom each strategy or action would be accomplished. It also determined whether implementing the mitigation action or strategy was primarily a funding, technical, or political issue.

It was the consensus of the group that multiple hazard mitigation in the San Francisco Bay area should be coordinated on a regional basis. There is no regional government in the Bay area with general-purpose governmental authority, so there is no one governmental entity with the power to implement the various mitigation strategies. There is, however, the Association of Bay Area Governments (ABAG)--a voluntary organization made up of Bay area local governments and endowed with coordinating functions. The working group decided that it would approach the problem as if it were an advisory group to ABAG called the Multiple Hazard Mitigation Advisory Group (MHMAG).

Identifying the working group as MHMAG allowed the group to look at the entire spectrum of the hazard mitigation process. This included pre-event actions, planning, and preparation; response during an event; postevent cleanup and recovery; and long-range recovery. FEMA's focus is primarily on response during an event and on postevent cleanup and recovery, with much less focus or attention on pre-event actions, planning, and preparation. The working group felt that multiple hazard mitigation, to be most effective, should consider the entire spectrum. For example, land use management can be an effective means of preventing development in hazardous locations, building codes can be used to make structures more resistant to hazardous occurrences (e.g., floods and earthquakes), and hazard mapping can serve to define hazardous areas in a useful way.

FACTORS AFFECTING HAZARD MITIGATION STRATEGIES

Before listing mitigation strategies for each hazard, the working group considered a number of factors that can affect hazard mitigation actions. These factors are listed in Table V-1. Some of these factors are subtle and others more obvious. An understanding of these factors is helpful in gaining a perspective on practical concerns that affect hazard mitigation.

Two examples illustrate these factors.

1. A local government, concerned with its potential liability for poor code enforcement that might be a contributing factor to building collapse and possible loss of life, would be motivated to improve its code enforcement. Banking auditors concerned about their potential liability for failure of a bank's electronic money transfer system might require protection from an earthquake.

2. A developer building an office building with the intent of selling it will not have an incentive to consider costly mitigation measures, whereas a corporate entity constructing a manufacturing facility for its own use would most likely want to consider hazard protection measures. This difference in time perspective (between a short-term and a long-term view) affects the actions undertaken.

MITIGATION ACTIONS

Mitigation actions were listed for earthquakes (Table V-2), floods (Table V-3) and landslides (Table V-4). For each action the tables indicate the nature of the action, the governmental entity that would implement it, and the kind of issue--political, technical, or funding--that would be involved in implementing the action.

With regard to landslides (Table V-4) a distinction was made between landslides and debris flows. Landslides involve deep movement of earth, while debris flows of the type experienced in 1981 in the San Francisco Bay area involve only a surficial flow of earth. Landslides are easier to define and tend to occur in somewhat predictable fashion. Debris flows in the Bay area seem to occur entirely on a random basis, and it does not appear possible on the basis of today's knowledge to predict specifically where they might occur.

Specification of the implementation issue as a technical, political, or funding issue refers to implementation of the action, not the consequence of the action. For example, Table V-2 lists the action of requiring local jurisdictions to adopt land use measures appropriate for earthquake hazards. To carry out this action, the state legislature may have to adopt enabling legislation requiring local governments to adopt such land use measures. Thus, this action involves a political issue in terms of convincing the state legislature and in getting the local governments to comply. While successful implementation of land use measures will have an economic impact on property owners, the working group's purpose was to identify the nature of the issues that would have to be faced in implementing the mitigation action, rather than in dealing with its consequences.

The working group looked at each action from the viewpoint of an advisory group to ABAG. The same actions might be viewed differently by governmental bodies at the local, state, or federal levels. The working group felt strongly, however, that a mitigation process should be coordinated at the regional level.

TABLE V-1 Factors Affecting Hazard Mitigation Strategies

1. Potential liability
2. Auditor requirements (as in the case of financial institutions)
3. Compliance with law
4. Desire for open space
5. Insurance (achievement of lower rates by limiting exposure to hazards)
6. Misconceived perceptions of risks
7. Federal funding programs
8. Governmental administration of programs
9. Difference in time perspective (long term versus short term)
10. Tax laws
11. Interest shown by political leaders
12. Contribution of new knowledge
13. Previous hazard experience in community
14. Loan repayment and interest rate (payoff period versus exposure to hazards during repayment)
15. Type of ownership (leasing becoming more common)
16. Education of professionals involved in hazard mitigation (planners, engineers, emergency operations personnel)
17. Level of acceptable risk (e.g., no deaths from nuclear accidents are acceptable, whereas 50,000 deaths per year in highway accidents are acceptable)

TABLE V-2 Mitigation Actions for Earthquakes

Action	Agency or Level of Government	Type of Issue
Consolidated regional statement of hazard		
o Relate regional estimates of damage and casualties to estimates for local level. Consolidate what has already been done.	State geologist with support from U.S. Geological survey	Technical, funding
Upgrade capability for enforcing building codes		
o Define potential liability of poor code enforcement.	ABAG (regional)	Technical (legal sense), funding
o Provide education and training and improve pay of building inspectors.	State	Technical, funding
Upgrade, replace, or change use of buildings that are prone to hazards		
o Get more local governmental units to adopt specific rehabilititation standards.	ABAG (regional)	Political
o Encourage redevelopment of vulnerable areas through the use of federal tax credits for rehabilitating older buildings.	Regional or local governmental units can advertise advantages and filter information concerning the rehabilitation tax credits.	Funding
o Conduct basic inventory of buildings in hazardous areas.	Local jurisdictions will undertake; however, state legislature must require such an inventory and must provide support.	Political, funding

TABLE V-2 (cont'd)

Action	Agency or Level of Government	Type of Issue
o Explore recertification of buildings in hazardous areas.	ABAG (regional)	Political
Adjust land use to reflect hazard*		
o Compile maps and related information at an urban scale and from a land use point of view (1" = 500' or 1000').	Criteria developed at regional level; funding should be sought through federal, state, and local combination.	Technical, political, funding
o Require local jurisdictions to adopt land use measures to reflect earthquake hazard.	State legislature	Political
Upgrade preparedness and response capability for large events*		
o Develop local response plans at local level that address large events.	State requirement that response plans be developed at local level, supported by state funding.	Political, funding
o Integrate individual community response plans with other community plans and with regional, state, and federal plans.	Accomplished at state level with federal funding support.	Political
o Conduct training and exercise activities for response planning at the local level.	State-trained local units. Federal level assists in training local and state personnel and also provides funding support.	Funding

*Item applicable to other hazards as well.

TABLE V-2 (cont'd)

Action	Agency or Level of Government	Type of Issue
Lifeline protection: utility preparedness		
o Obtain evaluation of the ability of utilities to withstand and cope with earthquakes. Identify nature of problem, critical points, and planning action. (Utilities include power, water, gas, telephones, sewage, transportion, and dam safety.)	State initiative. Each utility service would be different.	Technical, political, funding
Planning and managing recovery: Emphasis on process rather than specific plans		
o Describe a process under which various scenarios can be developed. Indicate what funding is available from the state and federal government. Include scenarios of different or new reconstruction approaches.	Coordinate at regional level with funding support from federal grants and state and local levels.	Technical, funding
Liability		
o Identify areas of potential liability and risk. For example, what is liability of local public official if a building certified as "safe" fails during an aftershock, or if a hillside deemed safe according to a map later slides. Fear of taking a mitigative action may be related to fear of potential liability.	State	Technical

TABLE V-3 Mitigation Actions for Floods

Action	Agency or Level of Government	Type of Issue
Land use regulation*		
o Regulate at local level. This is being accomplished; emphasis should continue.	Local	Political
o Undertake multiple hazard mapping. Define where overlaps occur with flood hazard mapping. Determine if overlaps are independent or interactive. There is a need to composite multiple hazards on compatible mapping. Compatible scales are needed. Can earthquake maps be used as a base with flood and landslide hazard areas added? Work toward commonality of terms and standardization of maps.	Develop criteria at regional level; funding should be sought through federal, state sources.	Technical, political, funding
Develop warning plans*		
o Identify areas where warning and evacuation plans may be beneficial.	Regional. Appraisal crosses several local communities, includes riverine and coastal flooding.	Technical
Identify justifiable flood control projects		
o Inventory flood control facilities and needs. Include identification of safe and unsafe dams.	Regional	Technical, political
Flood control maintenance		
o Assess maintenance needs and existing maintenance level of flood control facilities, risk associated with lack of maintenance, and possibility of incurring liability through inadequate maintenance.	Regional	Technical

*Item applicable to other hazards as well.

TABLE V-4 Mitigation for Landslides and Debris Flows

Action	Agency or Level of Government	Type of Issue
Warning and evacuation procedures		
o Continue research that would lead to identification of debris flow hazard areas and potential warning devices.	Federal and state	Technical, funding
Land use mapping*		
See related items in Tables V-2 and V-3.		
Land use regulation*		
o Enact and enforce better land use regulation in defined slide areas at local level.	State through enabling legislation	Political
Develop better site control		
o Standardize enforcement at local level.	State requirement; local implementation	Political, funding
Define potential liability*		
See related item in Table V-2.		
Inventory and mapping*		
o Identify where landslides and debris flows have occurred. Information will become part of a regional data base, and will be applicable to all three hazards.	Regional with federal, state, and local funding support and assistance	Technical, funding

*Item applicable to other hazards as well.

COMMONALITIES AMONG MITIGATION STRATEGIES

The strategies with some basis of commonality are denoted by asterisks in Tables V-2, V-3, and V-4. Some strategies have common purposes but may not lend themselves to common action. For example, land use regulation involves the same principle whether it is for earthquakes or flooding, but it would take entirely independent actions to implement the strategy for each hazard. The land uses, building requirements, authorizing legislation, locations of the hazard, predictability of the hazard, and effect of the hazard on the public and on community facilities are all different. The degree to which these strategies can be viewed from a truly multihazard point of view is somewhat limited.

One area did appear to have a greater potential benefit from a multihazard approach than did the others, namely mapping. The working group felt that much could be gained if a regional digitized data base were to be established for the Bay area. The digitized data base would permit mapping for the region at an appropriate scale for land use decisions for each hazard. Information on the maps could include (but not be limited to) floodplain delineations, location of earthquake and landslide hazard areas, locations of prior occurrence of hazards, key transportation networks, hospital locations, locations of dams, etc.

Technology is developing to the point that such a data base is possible. It would even be feasible for a local government or a regional organization to develop the information base and then recoup development costs by charging for the information on a map-by-map basis. Such information would be an important input for the evaluation, planning, design, and construction of any facility in the area.

Table V-5 lists, in order of priority for implementation, the strategies set forth in Tables V-2, V-3, and V-4 and the hazards to which they apply.

The three columns on the right of Table V-5 indicate that several of the mitigation strategies are common to all three hazards. All but four strategies are common to at least two hazards. Again, it is misleading to assume that strategies common to more than one hazard can simply be developed once and then applied to another hazard or other hazards. It is the case, however, that similar thinking and approaches can be applied to more than one hazard.

SUGGESTIONS FOR FEMA OR OTHER FEDERAL AGENCIES

In Tables V-2, V-3, and V-4, for each strategy listed there is an indication of the governmental entity that would be involved in implementation. Where a federal involvement is indicated, there is a potential role for FEMA or another federal agency.

The working group also identified five specific suggestions for federal action (presumably by FEMA):

1. Upgrade disaster response through training programs and funding support.

TABLE V-5 Actions Relevant to Multiple Hazard Management and the Hazards to Which They Pertain, in Order of Priority

Action	Earthquake	Flood	Landslide
1. Mapping (collection of basic information and display)	X	X	X
2. Liability	X	X	X
3. Land use management	X	X	X
4. Warning (what is possible today)		X	X
5. Warning (what may be possible in future)	X	X	X
6. Statement of hazard definition	X	X	X
7. Upgrading enforcement of building codes	X		
8. Upgrading hazardous buildings and change use to be more compatible with hazard	X	X	
9. Upgrading response capability for large events	X	X	
10. Lifeline protection	X		
11a. Planning for and managing recovery: lifesaving response	X	X	X
11b. Planning for and managing recovery: recovery period	X	X	X
12. Implementation of flood control facilities		X	
13. Assessing actual and needed level of maintenance of flood control facilities		X	
14. Better site controls	X		X

2. Continue support for vulnerability assessment.

3. Modify the Disaster Assistance Act to increase federal involvement in mitigation and recovery strategies.

4. Develop a generalized model or process for planning and managing recovery.

5. Develop an approach to hazard management that would place an emphasis on predisaster planning and mitigation activities equal to that placed on response and near-term recovery.

CONCLUSIONS

The working group concluded that multiple hazard mitigation is already being practiced at the local level. For example, emergency preparedness plans and civil defense operations are geared to address several different kinds of hazards.

The working group also concluded that the most critical need is not adoption of an overall strategy based on a multihazard management approach, but correction of the imbalance that now exists between FEMA's primary interest and involvement in the response phase of hazard mitigation and its relative lack of activity in predisaster planning activities. It is at the predisaster stage that the groundwork can be laid for successful response and short- and long-term recovery efforts, and it is at this stage that a multiple hazard approach has the greatest potential value.

The mapping area in particular appears to have real potential for a multihazard approach. A digitized regional data base could contain information about several hazards that would have significant value to those in the public and private sector involved with any kind of physical improvements. Such an information base could also contain other data needed in the planning and development process, and could be of great value to the community.

Appendix VI

SUMMARY OF DISCUSSION: ST. LOUIS WORKING GROUP

INTRODUCTION

The St. Louis group's discussions centered on the need for a standardized data base, the continuation and improvement of ongoing federal programs, and a pilot demonstration study for the St. Louis metropolitan region.

GENERAL APPROACH

The group's approach was to think of the problems and algorithms one would have to analyze in creating a computer game called "Hazard Mitigation Expert." One would have to program the following kinds of things:

- o the probabilities of various hazards occurring
- o the probabilities of damages resulting when a hazard does occur
- o the extent to which the various strategies available to the game player would reduce damages
- o the payoff to the game player, which would depend on an assessment of the rewards and penalities of using each strategy

The group agreed at the outset that the appropriate payoff function would differ depending on whether the "expert" was a county, state, or federal administrator, and on various other social and political considerations. The group agreed that in addressing the goals of the workshop, it would be impossible to use a single payoff function--or to put it another way, to specifically define what the bottom line should be in making recommendations--and that therefore it would limit its recommendations to those that would increase the bottom line no matter how one chose to define it, or at least for a very broad spectrum of such definitions.

The group also agreed that while the goal was to assess multiple hazard mitigation strategies, it was best to begin on a hazard-by-hazard basis and then to seek out commonalities and interdependencies.

In looking at the problem from the perspective of designing a computer game, many different questions can be asked about hazard mitigation, such as

- o What is the damage associated with a particular hazard after it has taken place?

o What is the probability of a particular hazard occurring within a certain period at a particular location?

o What is the technical capability for reducing the probabilities of various levels of damage caused by natural hazards?

o What is the probability of effective implementation of these mitigation steps? (This is likely to depend on a number of legal and political conditions.)

o What is the probability that new or better mitigation procedures can be found, and at what cost?

o What is the community's or society's willingness to pay to reduce the probability of detrimental effects of natural hazards?

o What is the community's willingness to pay for more information about hazards and hazard mitigation?

The group decided to begin with the simplest question that could be asked, namely: Can the damages that will result from a given hazard at a specific location be estimated before the event occurs?

The group then examined in detail the data and methods that could be used to answer this question for the major natural hazards in the St. Louis area: flood; earthquake; tornado (or severe wind); and ice, snow, and hail.

The group divided potential strategies into those undertaken during four different periods:

o prior to the disaster

o during the warning period when the disaster is imminent

o during and immediately after the disaster

o during the extended period following the disaster

General types of strategies were analyzed for each hazard, and the commonalities were discussed and weighted by various measures.

ASSESSMENT OF THE POTENTIAL OF MULTIPLE HAZARD MITIGATION

The working group agreed that many mitigation strategies designed specifically for one hazard will affect the loss of life, property, and lifeline systems resulting from other hazards. For example, improved emergency response will reduce losses from all hazards. A more stringent building code to mitigate losses from severe wind will generally tend to reduce losses resulting from an earthquake. However, negative interrelations may also exist. A building code requirement that minimizes flood damage might increase the damage resulting from severe wind or earthquake. The importance of these interrelations is not known except in a vague, qualitative way.

The working group also agreed that individual hazard mitigation strategies have a number of common features involving coordination and cooperation among government agencies. The group felt that the potential efficiencies that a multiple hazard mitigation strategy might achieve are not clear.

The working group felt that within a multiple hazard mitigation approach, the effectiveness of a specific strategy[1] depends on the effectiveness of the other strategies in operation. Consequently, determining the advantages and disadvantages of modifying any one strategy depends on its interdependence with other strategies.

The group felt that a crucial ingredient that is missing today is a standardized, basic data base that would permit an initial analysis of the potential value of a multiple hazard approach in mitigating or reducing the net loss (however defined) from a range of natural hazards.

SUGGESTIONS

The working group agreed on the following suggestions that it felt would result in an improved "bottom line" for a very wide range of definitions of what the bottom line is.

Prior to the Disaster:

- Establish a standardized, basic, natural hazard data system covering the entire nation that would enable users (governmental agencies at all levels of government and other institutions) to do the following:
  - estimate the losses of property, lives, and lifeline systems that would result from specific hazards at various locations;
  - determine the annual ranges of probabilities of occurrence of specific hazards;
  - estimate the average annual public and private property losses and their variability over time and the public and private expenditures associated directly with each hazard (costs of evacuation, rescue, financial assistance, etc.);
  - estimate the losses and costs associated with each disaster under proposed new mitigation strategies.

- Use the basic data system indicated above to identify the relative importance of hazards in different regions as a basis for allocating resources.

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[1]The term "strategy" is used here to refer to a general mitigation measure, such as land use planning or evacuation, rather than to a comprehensive strategy that encompasses a number of such measures.

- Provide multiyear funding to hazard mitigation programs in order to increase efficiency.

During the Warning Period

- Continue to develop a capacity to provide advance warning of all disasters; this effort should be coordinated among all involved government agencies.

During and Immediately After the Hazard Occurs

- Continue to aid state and local governments in establishing the capacity to assess the general nature and extent of major disasters.
- Ensure that there are operational, professional coordinators with the authority to direct response to all hazards.

After the Event

- Continue to gather and disseminate data on structural and economic losses.

While the working group agreed that these suggestions would increase social welfare (under a broad range of definitions), it also realized that others may not agree. Further, it is not clear what the potential usefulness of the basic data system would be and what it would cost to create. Therefore, as a specific recommendation, the working group suggested that a demonstration study be undertaken for the St Louis metropolitan area. This project would assess

- general relationships between strategies and hazards,
- general relationships between strategies and governmental entities,
- specific relationships between strategies and hazards, and
- who pays and who benefits from specific strategies.

For illustrative purposes, the working group attempted a first approach to such an assessment in the context of the St. Louis area.

Table VI-1 illustrates the relation among eight general strategy categories and four natural hazards. The information required for such assessments is a general knowledge about hazards and would be applicable for any region.

Table VI-2 addresses the general relationship between strategies and governmental entities. The information needed for this is a detailed knowledge of agency interactions and interfaces.

The working group then examined more specific (but still not definitive) strategies (most of which addressed a single hazard) and guessed whether each such specific stragegy would reduce or increase the damages from other hazards. The + and - signs in Table VI-3 represent reductions and increases, respectively, in damages from the hazards listed. However, this qualitative assessment is not very useful. A quantitative data base such as that suggested above would be needed to change the + and - signs into dollar figures.

Table VI-4 is an attempt to assess who benefits and who pays for two specific strategies. The numbers are percentages of whatever the aggregate cost or benefit would be. Table VI-4 is obviously much more difficult to prepare and requires a substantially larger data base then that suggested above, although the data base suggested here is a necessary starting point.

TABLE VI-1 Relevance of Various Mitigation Strategies to Specific Hazards

Strategy	Flood	Earthquake	Wind	Hail/Snow
Prevention of event	Yes	No	No	No
Prediction/warning	Yes	No	Yes	Yes
Information collection	Yes	Yes	Yes	Yes
Building codes/land use	Yes	Yes	Yes	Yes
Insurance	Yes	Yes	Yes	Yes
Emergency services	Yes	Yes	Yes	Yes
Disaster relief	Yes	Yes	Yes	Yes

Information needed: General knowledge about hazards.

TABLE VI-2 Level of Government Involved in Specific Mitigation Strategies

Strategy	Local	Regional	State	Federal
Prevention	Yes	Yes	Yes	Yes
Prediction/warning	Yes	Yes	Yes	Yes
Information collection	Yes	Yes	Yes	Yes
Building codes/land Use	Yes	No	No	No
Insurance	No	No	No	Yes
Emergency services	Yes	No	Yes	Yes
Disaster relief	Yes	No	Yes	Yes

Information needed: Detailed knowledge of governmental interactions.

TABLE VI-3 Assessment of Whether Specific Mitigation Strategies Contribute to Reductions (+) or Increases (-) in Losses From Specific Hazards

Strategy	Flood	Earthquake	Wind	Snow/Ice
Emergency response	+	+	+	+
Flood land use	+	+	0	0
Earthquake land use	+	+	0	0
Flood building code	+	+ or -	+ or -	0
Earthquake building code	0 or -	+	+	0 or +
Wind building code	0 or +	+	+	0 or +

Information needed: Quantified data base to change ± to $.

TABLE VI-4 Illustration of a Preliminary Attempt to Apportion Cost and Benefits Associated with a Flood-Oriented Land Use Strategy, Depending on Whether it is Implemented Before or After a Flood.

Strategy	Cost/Benefit	Private	Local Government	State Government	Federal Government
Flood land use; implemented before a flood	Cost	99%	1%	-	-
	Benefit	5%	95%	-	-
Flood land use; implemented after a flood	Cost	60%	-	-	40%
	Benefit	5%	95%	-	-

Information needed: Detailed data base.